



OCT 22 2012

To All Interested Government Agencies and Public Groups:

Under the National Environmental Policy Act, an environmental review has been performed on the following action.

TITLE: Amendment 98 to the Fishery Management Plan for the Groundfish of the Bering Sea and Aleutian Islands Management Area (BSAI Groundfish FMP); Amendment 90 to the Fishery Management Plan for Groundfish of the Gulf of Alaska (GOA Groundfish FMP); Amendment 40 to the Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs (BSAI Crab FMP); Amendment 15 to the Fishery Management Plan for the Scallop Fishery off Alaska (Scallop FMP); Amendment 1 to the Fishery Management Plan for Fish Resources of the Arctic Management Area (Arctic FMP) Essential Fish Habitat (EFH) Omnibus Amendments [RIN 0648-XA500]

LOCATION: Exclusive economic zone off Alaska

SUMMARY: A review of Essential Fish Habitat (EFH) components in the North Pacific Fishery Management Council's (Council's) fishery management plans (FMPs) should be completed every 5 years, and the EFH provisions should be revised or amended, as warranted, based on the best available information. The 5-year review that concluded in April 2010 evaluated new information on EFH, assessed information gaps and research needs, and identified whether any revisions to EFH are needed or suggested. Based on the 5-year review, the Council determined that new habitat and life history information is available to revise many of the EFH descriptions and recommendations in the FMPs. Amendment 98 to the BSAI Groundfish FMP, Amendment 90 to the GOA Groundfish FMP, Amendment 40 to the BSAI Crab FMP, Amendment 15 to the Scallop FMP, and Amendment 1 to the Arctic FMP revise EFH provisions of these FMPs. The impact of the changes under these amendments is not substantively different from that analyzed in the 2005 EFH environmental impact statement. None of the changes require regulatory action, and the 2010 EFH 5-year review concluded that no change to the 2005 conclusions on the evaluation of fishing effects on EFH is warranted based on new information from the last 5 years.



RESPONSIBLE

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The environmental review process led us to conclude that this action will not have a significant impact on the environment. Therefore, an environmental impact statement was not prepared. A copy of the finding of no significant impact (FONSI), including the environmental assessment, is enclosed for your information.

Although NOAA is not soliciting comments on this completed EA/FONSI we will consider any comments submitted that would assist us in preparing future NEPA documents. Please submit any written comments to the Responsible Official named above.

Sincerely,


for Patricia A. Montanio
NOAA NEPA Coordinator

Enclosure

Final Environmental Assessment for:

Amendment 98 to the Fishery Management Plan for Groundfish of the Bering Sea and Aleutian Islands Management Area

Amendment 90 to the Fishery Management Plan for Groundfish of the Gulf of Alaska

Amendment 40 to the Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs

Amendment 15 to the Fishery Management Plan for the Scallop Fishery off Alaska

Amendment 1 to the Fishery Management Plan for Fish Resources of the Arctic Management Area

Essential Fish Habitat (EFH) Omnibus Amendments

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Abstract: A review of Essential Fish Habitat (EFH) components in the North Pacific Fishery Management Council's (Council's) fishery management plans (FMPs) should be completed every 5 years, and the EFH provisions should be revised or amended, as warranted, based on the best available information. The 5-year review that concluded in April 2010 evaluated new information on EFH, assessed information gaps and research needs, and identified whether any revisions to EFH are needed or suggested. Based on the 5-year review, the Council determined that new habitat and life history information is available to revise many of the EFH descriptions and recommendations in the FMPs. Amendment 98 to the Fishery Management Plan for Groundfish of the Bering Sea and Aleutian Islands Management Area, Amendment 90 to the Fishery Management Plan for Groundfish of the Gulf of Alaska, Amendment 40 to the Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs, Amendment 15 to the Fishery Management Plan for the Scallop Fishery off Alaska, and Amendment 1 to the Fishery Management Plan for Fish Resources of the Arctic Management Area revise EFH provisions of these FMPs. The impact of the changes under these amendments is not substantively different from that analyzed in the 2005 EFH environmental impact statement. None of the changes require regulatory action, and the 2010 EFH 5-year review concluded that no change to the 2005 conclusions on the evaluation of fishing effects on EFH is warranted based on new information from the last 5 years.

October 2012



*North Pacific Fishery Management Council
National Marine Fisheries Service, Alaska Region*

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1 Introduction and Purpose

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) includes provisions concerning the identification and conservation of Essential Fish Habitat (EFH). The MSA defines EFH as “those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity.” The National Marine Fisheries Service (NMFS) and regional Fishery Management Councils must describe and identify EFH in fishery management plans (FMP), minimize to the extent practicable the adverse effects of fishing on EFH, and identify other actions to encourage the conservation and enhancement of EFH. Federal agencies that authorize, fund, or undertake actions that may adversely affect EFH must consult with NMFS, and NMFS must provide conservation recommendations to federal and state agencies regarding actions that would adversely affect EFH. Regional Fishery Management Councils also have the authority to comment on federal or state agency actions that would adversely affect the habitat, including EFH, of managed species.

Each FMP contains the following EFH components:

1. EFH descriptions and identification;
2. Fishing activities that may adversely affect EFH;
3. Non-MSA fishing activities that may adversely affect EFH;
4. Non-fishing activities that may adversely affect EFH;
5. Cumulative impacts analysis;
6. EFH conservation and enhancement recommendations;
7. Prey species list and any locations;
8. Habitat Areas of Particular Concern (HAPC) identification;
9. Research and information needs; and
10. Requirement to review EFH every 5 years.

1.1 2010 EFH 5-year review

In 2009 and 2010, the most recent 5-year EFH review was conducted for the North Pacific Fishery Management Council (Council), and documented in the Final EFH 5-year Review for 2010 Summary Report (Council and NMFS 2010). Prior to the 2009-2010 EFH review, an EFH review was last conducted in 2005 with the Environmental Impact Statement (EIS) for EFH Habitat Identification and Conservation in Alaska (NMFS 2005). The Council anticipated the 2009-2010 update to EFH as all FMPs require EFH to be reviewed every 5 years. The report reviewed EFH provisions in five of the Council’s six FMPs (Table 1): the Fishery Management Plan for Groundfish of the Bering Sea and Aleutian Islands Management Area (BSAI Groundfish FMP), the Fishery Management Plan for Groundfish of the Gulf of Alaska (GOA Groundfish FMP), the Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs (BSAI Crab FMP), the Fishery Management Plan for the Scallop Fishery off Alaska (Scallop FMP), and the Fishery Management Plan for the Salmon Fisheries in the EEZ Off the Coast of Alaska (Salmon FMP). The Council’s sixth FMP, the Fishery Management Plan for Fish Resources of the Arctic Management Area (Arctic FMP), was approved by the Secretary of Commerce in August 2009 (Table 1). As a thorough assessment of EFH was included in the Arctic FMP, EFH descriptions for Arctic species were not addressed in the 5-year review report.

The review evaluated new information on EFH, assessed information gaps and research needs, and identified whether any revisions to EFH are needed or suggested. The EFH 5-year Review for 2010 Summary Report (Council and NMFS 2010) and the affected environment analysis from the 2005 EFH EIS (NMFS 2005) is incorporated by reference in this analysis).

Table 1 List of Council Fishery Management Plans, and status of EFH review

Fishery Management Plan	EFH Last Updated	Review Status
Groundfish of the Bering Sea and Aleutian Islands Management Area	2005	Council review in 2009-10 (including Plan Team)
Groundfish of the Gulf of Alaska	2005	Council review in 2009-10 (including Plan Team)
Bering Sea/ Aleutian Islands King and Tanner Crabs	2005	Council review in 2010 (including Plan Team)
Scallop Fishery off Alaska	2005	Council review in 2010 (including Plan Team)
Salmon Fisheries in the EEZ Off the Coast of Alaska	2005	Council review in 2010 No salmon plan team, so review was provided by NMFS salmon experts.
Fish Resources of the Arctic Management Area	FMP implemented in August 2009	Council review completed in 2009 with adoption of FMP

1.2 Purpose and Need Statement

At initial review, the Council adopted the following problem statement for this action:

The EFH Final Rule and each of the Council's FMPs state that a review of EFH components should be completed every 5 years and the EFH provisions should be revised or amended, as warranted, based on the best available information. The 5-year review of EFH was completed in April 2010, and synthesized in a Summary Report presented to the Council. Based on the review, the Council has determined that new habitat and life history information is available to revise many of the EFH descriptions and recommendations in the Council FMPs. Additionally, the EFH review process has proven to be an appropriate vehicle for identifying HAPC priorities, and the Council intends to consider whether periodic calls for HAPC proposals should be synchronized with future 5-year reviews.

The purpose of this action is to update the EFH provisions in five FMPs to reflect new information from the EFH 5-year review. Pursuant to section 303(a)(7) of the MSA, each FMP (1) describes and identifies EFH for the fishery, (2) minimizes to the extent practicable the adverse effects of fishing on EFH, and (3) identifies other actions to encourage the conservation and enhancement of EFH. The analysis contained in this document is based upon the best scientific information available and the guidelines articulated in the Final Rule to implement the EFH provisions of the MSA (see 50 CFR Part 600, Subpart J). This action is necessary to ensure the FMPs reflect the most up-to-date information on EFH.

1.3 Proposed Action

Based on the review and the summary report, the Council identified various elements of the EFH provisions that merit revision. Accordingly, the Council initiated an analysis to address recommendations arising from the 5-year review.

In April 2011, the Council recommended all FMP amendments: Amendment 98 to the BSAI Groundfish FMP, Amendment 90 to the GAO Groundfish FMP, Amendment 40 to the BSAI Crab FMP, Amendment 15 to the Scallop FMP, Amendment 11 to the Salmon FMP, and Amendment 1 to the Arctic FMP. These recommendations are summarized in Table 2. Table 2 also pairs each recommendation with the corresponding action included in this analysis. These recommendations and actions are minor changes to the EFH provisions and will not substantively change how fisheries are managed or how EFH consultations are conducted.

Subsequent to the April 2011 Council meeting, Amendment 11 to the Salmon FMP was combined with Amendments 10 and 12 to the Salmon FMP. Amendment 11 changes recommendations for non-fishing activities, HAPC timeline change, and EFH research objectives. The Notice of Availability for Amendments 10, 11, and 12 published in the Federal Register on April 2, 2012 (77 FR 19605). The comment period closed June 1, 2012. The Secretary of Commerce approved Amendments 10, 11, and 12 to the Salmon FMP on June 29, 2012 (77 FR 19605, April 2, 2012).

Table 2 Summary of the Council's recommended action resulting from the EFH 5-year review, April 2011

EFH component	Council FMP	Recommended change	Corresponding action in this analysis
EFH descriptions of individual species	BSAI Groundfish	Amendments for all 24 species or complexes whose habitat is described in the FMP, to revise some aspect of the EFH description, as described in the summary report.	Action 1
	GOA Groundfish	Amendments for all 24 species or complexes whose habitat is described in the FMP, to revise some aspect of the EFH description, as described in the summary report.	Action 2
	BSAI Crab	Amendments for all 5 species or complexes in the FMP, to revise general EFH and fishery information for each species, as described in the summary report (amendments to revise the evaluation of fishing effects conclusions are not initiated at this time, rather see discussion under evaluation of fishing effects).	Action 3
	Scallop	Amendment for the one species whose habitat is described in the FMP, to revise aspects of the EFH description, as described in the summary report.	Action 4
Fishing activities that may adversely affect EFH	All FMPs	A general re-evaluation of the effects of fishing activities on EFH, including re-running the model, should not be initiated at this time. Recent research results are consistent with the habitat sensitivity and recovery parameters and distributions of habitat types used in the prior analysis of fishing effects for the EFH EIS. Fishing intensity has decreased overall, gear regulations have been designated to reduce habitat damage, and area closures have limited the expansion of effort into areas of concern.	--
Non-fishing activities that may adversely affect EFH	All FMPs	Amendments to update EFH conservation recommendations for 14 of 27 non-fishing activities and the analysis of impacts of non-fishing activities.	Action 5
HAPC	All FMPs	Amendment to revise the timeline associated with the HAPC process to coincide with the EFH 5-year review. Note, the Council also set skate egg concentration sites as a habitat priority, and initiated a call for proposals for candidate HAPC sites. Any amendments resulting from the call for proposals will be, however, implemented through a separate process.	Action 6
Research and information needs	All FMPs	Amendments to revise research priority objectives in the FMP. The Council's research priority objectives from 2005 have largely been met, however many of the research questions are still valid and remain to be investigated. The Council preliminarily identified new objectives to guide EFH research over the next 5 years.	Action 7

1.4 Future EFH Actions

The Council also recognized two actions under the EFH descriptions of individual species and fishing activities that may adversely affect EFH that will be discussed in the future. These are detailed in Table 3. At initial review in February 2011, the Council chose to postpone amendments to EFH descriptions in the Salmon FMP. NMFS is currently developing a new methodology that will allow the Council to refine areas identified as EFH for marine life history stages of the Pacific salmon species. Once the

methodology has been peer reviewed, changes to EFH descriptions in the Salmon FMP will be initiated as a separate amendment. Consequently, the action relating to changes to the Salmon FMP has been removed from this omnibus amendment package.

Table 3 Future EFH actions

EFH component	Council FMP	Recommended change	Corresponding action in this analysis
EFH descriptions of individual species	Salmon	Amendments for all 5 species in the FMP, to revise some aspect of the EFH description, as described in the summary report, except that the recommendation to revise the conclusions of the effects of fishing on Chinook salmon would not be forwarded for analysis.	<i>(delayed until salmon EFH methodology is ready)</i>
Fishing activities that may adversely affect EFH	All Council FMPs	For crab species, the Council requested a discussion paper to look at how the effects of fishing are considered for crab stocks. After review of this paper in February 2012, the Council chose to postpone further discussion about crab habitat until additional research is conducted.	<i>(additional research and discussions)</i>

2 Description of Actions and Alternatives

This amendment package includes a series of actions for five FMPs; BSAI Groundfish, GOA Groundfish, BSAI King and Tanner Crab, Alaska Scallops, and the Arctic. Actions 1 through 4, below, would amend EFH provisions in four of the five FMPs that were addressed in the 5-year review (see Section 2.8 for discussion of intended changes to the Salmon FMP). Action 5 updates the effects of non-fishing activities in Alaska on EFH, and is applicable to all of the Council FMPs. Action 6 synchronizes the HAPC identification timeline with the EFH review, and is also applicable to all of the Council FMPs. While the EFH 5-year review addressed all of the Council's FMPs except the Arctic FMP, Actions 5 and 6 will require amendment of the Arctic FMP as well as the other FMPs. Under Action 7, the Council will adjust its EFH research objectives in the five Council FMPs that were addressed in the 5-year EFH review report.

More detail on the specific revisions proposed under Alternative 2 in Actions 1 through 7 is included in the sections that follow relating to the specific actions.

2.1 Action 1 – BSAI Groundfish

Alternative 1 – No Action; status quo

Alternative 2 – PREFERRED – Amend the EFH provisions for all twenty-four groundfish species or complexes

2.2 Action 2 – GOA Groundfish

Alternative 1 – No Action; status quo

Alternative 2 – PREFERRED – Amend the EFH provisions for all twenty-four groundfish species or complexes

2.3 Action 3 – BSAI King and Tanner Crab

Alternative 1 – No Action; status quo

Alternative 2 – PREFERRED – Amend the EFH provisions for all five crab species

2.4 Action 4 – Alaska Scallops

Alternative 1 – No Action; status quo

Alternative 2 – PREFERRED – Amend the EFH provisions for weathervane scallop

2.5 Action 5 – Non-fishing Activities – All FMPs

Alternative 1 – No Action; status quo

Alternative 2 – PREFERRED – Amend EFH conservation recommendations for non-fishing activities in all Council FMPs and analysis of impacts of non-fishing activities

2.6 Action 6 – HAPC Timeline – All FMPs

Alternative 1 – No Action; status quo

Alternative 2 – PREFERRED – Revise timeline for considering HAPCs from three to five years in all Council FMPs

2.7 Action 7 – EFH Research Priorities

Alternative 1 – No Action; status quo

Alternative 2 – PREFERRED – Revise research objectives for EFH in five Council FMPs

2.8 Relationship to other Council actions resulting from the 2010 EFH 5-year review

Salmon EFH descriptions

For Salmon FMP species, EFH is described in three parts: marine, nearshore, and freshwater. Marine and nearshore salmon EFH is generally described to include all marine waters from the mean higher tide line to the limits of the EEZ. However, a new methodology to refine the geographic scope of EFH for Pacific salmon in marine waters off Alaska has been developed by the Alaska Fisheries Science Center (AFSC). AFSC salmon experts have finalized their methodology, which will undergo peer review and be published as a NOAA Technical Memorandum. Once the NOAA Technical Memorandum is complete, the methodology can be used as a mechanism to update marine salmon EFH. The preliminary findings indicate that habitat preferences exist by salmon species and life stage, and that the methodology will be very useful to refine EFH for the different life stages of each Pacific salmon using oceanic variables (i.e., depth, temperature, salinity).

The omnibus amendment originally included an action to make technical or housekeeping changes to the EFH description language, pending the completion of the comprehensive refinement of EFH descriptions that would result from the application of the new methodology. At initial review in February 2011, the Council chose to postpone any amendments to EFH descriptions in the Salmon FMP until the new methodology is ready to be used. Once the methodology has been peer reviewed, the Council will initiate an amendment to change EFH descriptions in the Salmon FMP. Consequently, Amendment 11 the Salmon FMP is limited to updating non-fishing effects and revising the HAPC process to a 5-year cycle. Amendment 11 is not included in this action because it was combined with Amendments 10 and 12 to the Salmon FMP. The Secretary of Commerce approved Amendments 10, 11, and 12 to the Salmon FMP on June 29, 2012 (77 FR 19605, April 2, 2012). Changes to EFH descriptions for salmon may be considered in the future after the peer review of the new methodology for determining salmon EFH is completed.

Other discussion papers resulting from the 5-year EFH review

The Council requested two additional discussion papers during the April 2010 review of the final EFH 5-year Review for 2010 Summary Report. The summary report for the 5-year review contained a recommendation by the groundfish Plan Teams that the Council consider establishing measures to conserve EFH from fishing threats to sablefish recruitment. In April 2010, the Council considered the Teams' recommendation, and asked for further information with which to evaluate how it should be addressed. The Council was specifically interested in understanding whether the problems with sablefish recruitment are habitat-driven, or is poor recruitment attributable to other factors. At initial review of the omnibus amendment package, in February 2011, the Council reviewed a discussion paper on factors affecting sablefish recruitment in Alaska, which was prepared by the AFSC. The conclusions in the discussion paper indicate that adopting specific conservation measures for juvenile sablefish is premature given ongoing research about the relationship between habitat and recruitment. Consequently, the Council took no further action with regard to EFH conservation recommendations for sablefish.

The 5-year review also included recommendations by the BSAI Crab Plan Team that EFH for crab species should include the pelagic environment and transport mechanisms and their importance for spawning and breeding populations. A particular area of southwestern Bristol Bay, which is also an area of intensive trawl fishing, was newly identified as particularly important spawning grounds for Bristol

Bay red king crab. In April 2010, the Council requested a discussion paper to look at how the effects of fishing are considered for crab stocks, both to address the Plan Team's comments, and also to evaluate existing closures for crab habitat to see if habitat usage by crab species has changed since the mid-1990s when these closures were put into effect. Given the timing of the discussion paper, in February 2011, the Council determined that any action that might result from this discussion paper will be moved forward as a subsequent amendment to the omnibus package. The Council reviewed a draft of the discussion paper in February 2012. Based on the paper, the Council requested that the discussion on crab habitat resume once further research had taken place. It is anticipated that the nearshore crab survey conducted in summer 2012 will provide some additional input to the hypothesis that southwestern Bristol Bay habitat is particularly important in cold years, and may be in need of some protection. The Council also asked that the discussion paper be expanded to look at bycatch interactions with red king crab, to provide further analysis of the efficacy of existing red king crab closures, given theories about the change in distribution of the stock.

3 Methodology

3.1 Revisions to the EFH description for each species

The EFH description in the FMPs for each species includes several components, all of which were re-evaluated in the 2010 EFH 5-year review.

The EFH description by life history stage, in text and in maps, is included in the FMPs, as well as an indicator for how much habitat information is known about each life history stage. This is the legal description of EFH, based on which EFH consultations for fishing and non-fishing effects on EFH are held as directed by the MSA. It is on the basis of these descriptions that evaluations are made by the agency about whether an activity is likely to impact EFH.

The EFH descriptions were developed as part of the 2005 EFH EIS (NMFS 2005). In developing the text descriptions and maps used to describe EFH for individual species for the 2005 analysis, the analysts focused on two significant fishery geographic information data resources: survey (Resource Assessment and Conservation Engineering Division [RACE]) and observer (NORPAC). For adult and late juvenile life stages, each data set was analyzed for 95 percent of the total accumulated population for the species using GIS. For eggs and larvae, the EFH description is based on presence/absence data from surveys. EFH is identified as the areas where eggs and larvae are most commonly encountered in those surveys, which is the best available information regarding habitat use for those life stages. EFH shape files were developed based on these data sets.

For adult and late juvenile life stages of BSAI groundfish, GOA groundfish, BSAI crab, and scallop FMP species, fishery catch per unit of effort data from the NMFS Observer database (NORPAC, 1990 to 2001) and NMFS trawl survey data from RACE, 1987 to 2002, and, where appropriate, Alaska Department of Fish and Game survey data were analyzed to estimate the population distribution of each species. Where this information exists, the area described by these data is identified as EFH. The analyzed EFH data and areas were further reviewed by scientific stock assessment authors for accuracy. This review ensures that any outlying areas not considered were included, and errors in the data or described EFH area were removed.

Additionally, the FMPs include general information about the life history and distribution of the species/complex, the fishery, relevant trophic information, and habitat and biological associations. This information is primarily descriptive; it is, however, an important basis for identifying the geographic scope of EFH for each species. A literature section is also included in the FMPs, which cites references of where habitat information on the species/complex can be found. Currently in the groundfish FMPs, a section listing contact people for more information on the species is included, however it has been suggested as part of the proposed actions analyzed in this amendment package that this section be removed, as it is difficult to keep this contact information up to date in the FMP, and the information is available more readily in the annual stock assessment and fishery evaluation (SAFE) reports. Finally, the FMPs summarize conclusions from the evaluation of fishing effects on EFH for the species conducted during the 2005 EFH EIS.

In this amendment analysis, a table is provided summarizing which components of the provisions are being proposed for revision for each species in each FMP, and a series of bullets provides further detail. The complete EFH revisions are detailed in the Final Summary Report for the EFH 5-year Review for 2010 (NPFMC and NMFS 2010), and the amendment text for each FMP is included in Appendices 1 through 6 of this document. These appendices represent the changes that would be made to the FMPs under Alternative 2 in Actions 1 through 7.

3.2 Impacts assessment incorporated by reference from 2005 EFH EIS

The Council last amended five of its FMPs (BSAI Groundfish FMP, GOA Groundfish FMP, BSAI Crab FMP, Scallop FMP, and Salmon FMP) in 2005, to address EFH requirements. The Council and NMFS developed a comprehensive EFH EIS (NMFS 2005) evaluating alternatives and environmental consequences for three actions: (1) describing and identifying EFH for fisheries managed by the Council, (2) adopting an approach for the Council to identify HAPC within EFH, and (3) minimizing to the extent practicable the adverse effects of Council-managed fishing on EFH.

The Council used an extensive public process to develop the alternatives for the EIS, including numerous public meetings of the Council and its EFH Committee. With respect to the description and identification of EFH, it was identified that the action could have indirect negative effects for the industries and other entities that may face requirements (for federally managed fishing activities) or recommendations (for non-fishing activities) that are designed to protect fish habitats. Such negative effects could be short-term for the fishing industry; longer-term effects are less certain, especially for sectors that may benefit from enhanced habitat productivity resulting from EFH description and identification. The action identified that there would likely be indirect positive effects for the habitats and species that could be protected by measures resulting indirectly from EFH description and identification. Such measures would include either required measures to minimize adverse effects of fishing on EFH or recommended measures to minimize effects of non-fishing activities on EFH.

With respect to the effects of fishing on EFH, the analysis indicated that there are long-term effects of fishing on benthic habitat features off Alaska, and acknowledged that considerable scientific uncertainty remains regarding the consequences of such habitat changes for the sustained productivity of managed species. Nevertheless, based on the best available scientific information, the EIS concluded that the effects on EFH are minimal because the analysis found no indication that continued fishing activities at the current rate and intensity would alter the capacity of EFH to support healthy populations of managed species over the long term. The analysis concluded that no Council-managed fishing activities have more than minimal and temporary adverse effects on EFH, which is the regulatory standard requiring action to minimize adverse effects under the MSA. Importantly, the Council initiated a variety of practicable management actions and precautionary measures to conserve and protect EFH.

Fishing effects on EFH were reconsidered in the 2010 EFH 5-year review. The various factors put in the fishing effects model used for the 2005 EFH EIS were considered and compared against new information available in 2010. The impact of fishing, and changes in the overall location of fishing since 2005 were evaluated in aggregate, and also specifically considered by each of the stock assessment authors to determine whether there would be any change in impact for their assessed species. The 5-year EFH review concludes that recent research results are consistent with the habitat sensitivity and recovery parameters and distributions of habitat types used in the prior analysis of fishing effects for the 2005 EFH EIS. Fishing intensity has decreased overall, gear regulations have been designated to reduce habitat damage, and area closures have limited the expansion of effort into areas of concern. Consequently, the Council did not initiate a general re-evaluation of the effects of fishing activities on EFH, including re-running the model, based on the information synthesized in the EFH 5-year review summary report.

The affected environment, fishing impacts, and cumulative effects analyses from the 2005 EFH EIS (NMFS 2005) is incorporated by reference into this analysis. The amendments that would result should Alternative 2 be adopted in Actions 1 through 5 would result in relatively minor changes to the existing EFH descriptions and identifications, to incorporate more recent information, improve mapping, and identify new EFH descriptions for a few species that have been separated out from a complex since the existing descriptions and identifications were compiled. None of the proposed changes would require regulatory action, and the 2010 EFH 5-year review concluded that no change to the 2005 conclusions on

the evaluation of fishing effects on EFH was warranted based on new information from the last 5 years.¹ Consequently, the proposed actions contemplated in this amendment package differ very little from the actions that were comprehensively analyzed in the 2005 EFH EIS. This impact analysis is incorporated by reference, including the discussions of uncertainty that were fully disclosed and analyzed in that document.

In many cases, the proposed revisions to the EFH description are solely to update new information, and as such are largely technical or housekeeping changes. For those species for which an EFH text or map description has been proposed for a particular life history stage, the amendment would provide the best available information for these text and map descriptions, ensuring the most accurate information possible is available for EFH for these species. Providing more accurate EFH information could be beneficial to species as EFH is considered in the management of species. A change in the designation of EFH has no direct impact, as there are no management measures or regulations associated with the designation of EFH, nor are such conservation measures required. There may, however, be indirect impacts arising from the changes to the designation of EFH, as those text and map descriptions represent the legal description of EFH that are used by NMFS to provide EFH consultations for fishing and non-fishing effects on EFH as directed by the MSA.

The changes to the species' text and map descriptions are addressed in more detail under each specific action. In all cases, however, the refinement to the text and maps is minor, and any new area that is identified has already been designated as EFH for one of the other Alaska marine species. The total aggregated area of EFH description and identification for all managed species is unchanged as a result of this amendment. As such, federal agencies that conducted both fishing and non-fishing actions in that area are already required to consult with NMFS on EFH in that area.

The impact of the changes proposed under these amendments is not substantively different from that analyzed in the 2005 EFH EIS (NMFS 2005).

¹ Note, as described in Table 2, a discussion of the effects of fishing evaluation did arise with respect to the BSAI Crab FMP, and fishing in southwest Bristol Bay. This issue will be discussed further by the Council after additional crab habitat research.

4 Action 1 – BSAI Groundfish FMP amendments for all twenty-four species or complexes

4.1 Background – BSAI groundfish species

For the EFH 5-year review, stock assessment authors were asked to evaluate EFH information on their assessed species based on best available information. In addition, the review compared the EFH descriptions of species and species complexes that are currently identified in the BSAI Groundfish FMP (Table 4) with the species or species complexes that were assessed in the 2009 SAFE report. In a few cases, there were discrepancies. For example, shortraker and roughey rockfish were managed as a complex in 2005, but are now managed separately (in fact, roughey rockfish is managed as a complex with blackspotted rockfish). In these cases, the EFH descriptions were updated to reflect the current way the species are being assessed.

4.2 Description of Alternatives

Alternative 1 – No Action; status quo

Alternative 2 – PREFERRED – Amend the EFH provisions for all twenty-four groundfish species or complexes as outlined in Table 5.

Table 4 lists the species and species complexes for which EFH is currently identified in the BSAI Groundfish FMP, and identifies what species will have EFH descriptions under the revisions proposed in Alternative 2.

Table 4 Species or species complexes for which EFH is currently identified in the BSAI Groundfish FMP, compared to species or species complexes that will have EFH descriptions under Alternative 2

	Species or complexes for which EFH is identified in BSAI Groundfish FMP (Alternative 1)	Species or complexes for which EFH descriptions will be revised (Alternative 2)
Pollock	Pollock	Pollock
Pacific cod	Pacific cod	Pacific cod
Sablefish	Sablefish	Sablefish
Flatfish	Yellowfin sole	Yellowfin sole
	Greenland turbot	Greenland turbot
	Arrowtooth flounder	Arrowtooth flounder Kamchatka flounder
	Rock sole	Northern rock sole
	Flathead sole	Flathead sole
	Alaska plaice	Alaska plaice
	Rex sole	Rex sole
	Dover sole	Dover sole
Rockfish	Pacific ocean perch	Pacific ocean perch
	Northern rockfish	Northern rockfish
	Shortraker/ rougheye rockfish	Shortraker rockfish Blackspotted/ rougheye rockfish
	Yelloweye rockfish	Yelloweye rockfish
	Dusky rockfish	Dusky rockfish
	Thornyhead rockfish	Thornyhead rockfish
Atka mackerel	Atka mackerel	Atka mackerel
Squid	Squids	Squids
Other species	Octopuses	Octopuses
	Sharks	Sharks
	Sculpins	Sculpins
	Skates	Skates
Forage fish	Forage fish complex	forage fish complex

Table 5 provides an overall summary of the recommended changes to the EFH provisions under Alternative 2, for each species. “Yes” indicates that a substantive change to the text is being included for the identified section. To provide further detail on the summary table, the major changes recommended to the EFH text are detailed in bulleted form below the table.

Table 5 EFH review of BSAI Groundfish FMP species, with recommended changes to the existing EFH FMP text

KEY: yes = author has recommended an update to the existing FMP text, based on new information
e/c = author has recommended editorial changes or clarifications to the existing FMP text
“–” = no changes to the existing text have been recommended

Species	Recommended changes to the FMP text										
	EFH description			General information							2005 evaluation of fishing effects on EFH
	text	map	available level of information	tables of associations	life history, gen. distribution	trophic information	biological/ habitat associations	literature	contact person ²	description of fishery	
Pollock	e/c	–	–	yes	yes	–	–	yes	yes	yes	–
Pacific cod	e/c	–	–	–	yes	–	–	yes	yes	yes	–
Sablefish	yes	–	–	yes	yes	yes	–	yes	yes	yes	–
Yellowfin sole	–	–	–	–	–	–	–	yes	yes	–	e/c
Greenland turbot	–	–	–	–	e/c	–	–	yes	yes	–	–
Arrowtooth flounder	–	–	–	–	yes	–	–	yes	yes	–	e/c
Kamchatka flounder	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Northern rock sole	e/c	–	–	–	yes	–	–	yes	yes	–	e/c
Flathead sole	–	yes	–	yes	yes	–	yes	yes	yes	–	e/c
Alaska plaice	–	–	–	–	–	–	–	yes	yes	–	e/c
Rex sole	–	–	–	yes	yes	–	yes	yes	yes	–	(not in FMP)
Dover sole	–	–	–	–	–	–	–	–	yes	–	–
Pacific ocean perch	–	–	–	yes	yes	–	yes	yes	yes	yes	–
Northern rockfish	yes	–	yes	yes	yes	e/c	–	yes	yes	yes	–
Shortraker rockfish	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Blackspotted/rougeye rockfish	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Yelloweye rockfish	This EFH description will be deleted from the BSAI FMP.										
Dusky rockfish	–	–	–	–	e/c	e/c	–	–	yes	e/c	–
Thornyhead rockfish	–	–	–	–	e/c	e/c	–	–	yes	yes	–
Atka mackerel	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	e/c
Squids	–	–	–	–	–	–	–	–	yes	–	–
Octopuses	–	(not in FMP)	–	–	yes	yes	yes	yes	yes	yes	e/c
Sharks	–	(not in FMP)	–	yes	yes	yes	yes	–	yes	yes	–
Sculpins	–	–	–	–	yes	–	–	yes	yes	yes	–
Skates	yes	yes	yes	yes	–	–	–	yes	yes	–	yes
Forage fish complex	–	(not in FMP)	–	–	–	–	–	yes	yes	–	–

4.2.1 Recommended revisions for individual species

A description of the recommendations that are captured in the summary table (Table 5) is provided below for each individual species or species complex for which EFH is defined in the BSAI Groundfish FMP. The complete review for each species may be found in Appendix 1 to the Final EFH 5-year Review for 2010 Summary Report (NPFMC and NMFS 2010).

² It is recommended that the section identifying a contact person and phone number be removed for all stocks.

Pollock

- Clarifications but no substantive changes to EFH description
- Update to age at 50 percent maturity and general life history
- Updated with recent fishery information
- New literature references added
- Ongoing research: Bering Sea Integrated Ecosystem Research Program should provide more information for future EFH reviews

Pacific cod

- Editorial clarifications to the text in various places
- Updates to natural mortality, maturity, and maximum age information
- Update to description of the fishery
- Updated literature section
- Relevant ongoing studies identified: one EFH project and three North Pacific Research Board (NPRB) projects studying productivity, habitat utilization, and recruitment dynamics of Pacific cod; climate change and the match-mismatch hypothesis for Pacific cod larval survival; spatio-temporal spawning patterns of Pacific cod; and spawning and migration through a mark-recapture experiment.

Sablefish

- Information added to the EFH description for early juveniles, but no changes to the finding of no EFH description determined
- Additions to the BSAI general information sections to make consistent with the more comprehensive GOA sections
- Minor updates to the timing of the spawning season
- Updates to reflect recent fishery information
- Updated literature section
- Ongoing studies identified: Tagging juvenile sablefish in southeast Alaska with time/depth recording tags to track movements from shallow inshore waters to deeper areas on the slope. Revisited lightly trawled shelf habitat in Southeast Alaska to estimate recovery rates of benthic habitat organisms. Mounted substrate nearby corals and sponges to examine recolonization of benthic organisms in Southeast Alaska. Examining the distribution of juvenile sablefish in AFSC trawl surveys (1977 to present).

Yellowfin sole

- Literature section updated
- Fishing effects: change in trawling noted in recent period (increase in nearshore where spawning occurs and early juveniles reside, decrease in mid-shelf), although conclusion is same

Greenland turbot

- Editorial clarifications to the text
- Literature section updated

Arrowtooth flounder

- Update to fecundity information
- Literature section updated
- Fishing effects: change in trawling noted in recent period (increase in nearshore where early juveniles reside, decrease in mid-shelf), although conclusion is same

Kamchatka flounder

- New EFH description and maps as Kamchatka flounder has been split out from arrowtooth flounder for stock assessment

Northern rock sole

- Update to life history section and EFH description text to indicate northern rock sole (northern is over 95 percent of Bering Sea population)
- Literature section updated
- Fishing effects: change in trawling noted in recent period (increase in nearshore where early juveniles reside, decrease in mid-shelf), although conclusion is same

Flathead sole

- Map of distribution of larvae has been updated with the latest information from the EcoFOCI Ichthyoplankton Information System (IIS)
- Updates to age at 50 percent maturity, spawning behavior, size at metamorphosis
- Literature section updated
- Fishing effects: updated with SAFE reference, recent stock abundance trajectory

Alaska plaice

- Literature section updated
- Fishing effects: updated SAFE reference

Rex sole

- Updated age and length at 50 percent maturity, larval timing
- Literature section updated

Dover sole

- No update

Pacific ocean perch (POP)

- Associations table: updated depth association, spawning season
- Updates to natural mortality, maximum age
- Recent fishery information added
- Updated to note associations of juvenile POP with habitat structures
- Literature section updated

- Ongoing studies identified: EFH projects on juvenile POP habitat utilization, juvenile rockfish habitat utilization, juvenile slope rockfish habitat utilization, habitat specific production of POP in the Aleutian Islands, rockfish abundance, and diurnal habitat associations in isolated rocky habitat in the eastern Bering Sea.
- Note included on fishing effects: the POP fishery in the Aleutian Islands is more spread out throughout the year. It is not clear how this affects the spatial footprint of the fishery or how it would affect the impact of fishing upon the habitat.

Northern rockfish

- New information for late juvenile associations
- Associations table: updated depth associations, spawning season
- Updates to natural mortality, maximum age, upper size limit of juveniles
- Recent fishery information added
- Updated to note associations of juvenile POP with habitat structures
- Literature section updated
- Ongoing studies identified: EFH projects on juvenile rockfish habitat utilization, juvenile slope rockfish habitat utilization.

Shortraker rockfish

- New EFH descriptions as shortraker split out from rougheye; new maps provided, information level on larval life history stage downgraded.
- Associations table: revised depth and substrate associations, spawning season
- New life history information, trophic information, and habitat and biological associations sections rewritten.
- Recent fishery information added
- Literature section updated
- Ongoing studies: several studies on rockfish, but none focused on shortraker
- Fishing effects: The POP fishery in the Aleutian Islands is spread out more throughout the year, and this affects the manner in which shortraker are harvested as bycatch. It is not clear how this affects the spatial footprint of the fishery or how it would affect the impact of fishing upon the habitat.

Blackspotted/rougheye rockfish

- New EFH descriptions as shortraker split out from rougheye; new maps provided, information level on larval life history stage downgraded
- Associations table: revised depth and substrate associations, spawning season
- New life history information, trophic information, and habitat and biological associations sections rewritten
- Recent fishery information added
- Literature section updated
- Ongoing studies: several studies on rockfish, but none focused on blackspotted/rougheye
- Fishing effects: the POP fishery in the Aleutian Islands is spread out more throughout the year, and this affects the manner in which blackspotted/rougheye are harvested as bycatch. It is not clear how this affects the spatial footprint of the fishery or how it would affect the impact of fishing upon the habitat. If hard coral provides important habitat, damage to these corals may have negative impact on blackspotted/rougheye.

Yelloweye rockfish

- To be deleted from FMP; yelloweye rockfish is not a key species in the BSAI, there is no commercial targeting on this species, and the BSAI is not the center of its distribution

Dusky rockfish

- Clarification to indicate was once called light dusky rockfish
- Editorial clarifications to the text in various places

Thornyhead rockfish

- Editorial clarifications to the text in various places
- Recent fishery information added

Atka mackerel

- New information available on the distribution of eggs in the Aleutian Islands (limited, not general, distribution data)
- Updates to habitat, biological, and prey associations for various life history stages (depths, substrate, location in water column, community and temperature associations, reproductive traits)
- Update to age at 50 percent maturity, prey information
- Recent fishery information added
- Literature references added
- Minor change to evaluation of fishing effects text to indicate that stock no longer at peak spawning biomass, although biomass is still relatively high.

Squids

- No updates

Octopuses

- New general distribution maps available for individual species, but the scale of these maps is not sufficient for determination of EFH
- Updates to predator prey associations
- New life history information, trophic information, and habitat and biological associations sections rewritten
- Recent fishery information added
- Literature section updated
- Ongoing studies identified: doctoral research with *Enteroctopus dofleini* growth and development; NPRB project on field studies to document reproductive seasons of *E. dofleini* in Alaska and to develop octopus pot gear and tagging methods; ongoing observer program special project to collect individual weights and sex of octopus; in 2009, also tested vitality key for possible discard mortality; proposals for octopus discard mortality studies.

Sharks

- Updates to depth range, age at 50 percent maturity, maximum age, spawning season, and predator and prey species (in tables and sections).
- Recent fishery information added
- Ongoing studies identified: habitat use of spiny dogfish from satellite data

Sculpins

- Deleted red irish lord and butterfly as part of complex, added warty sculpins — life history updated
- Recent fishery information added
- Literature section updated

Skates

- New information available on location of skate egg concentration sites, affects level of information available on skate egg life history stage
- Update to depth association for eggs in table
- Recent fishery information added
- Updates to literature section
- Evaluation of the effects of fishing has not been done on skate egg concentration sites; fishing gear that touches the bottom has the potential to impact, but areas are small.
- Ongoing studies identified: NPRB project on habitat mapping and production estimate of skate egg concentration sites in the eastern Bering Sea; AFSC tagging of Alaska skates in the eastern Bering Sea to better understand their movement.

Forage fish

- Some progress on forage fish distribution and habitat, but not sufficient yet to formally describe EFH for forage fishes. One exception is that nearshore areas throughout the BSAI are almost certainly EFH for some forage species, but insufficient data as yet to support that.
- Literature section updated
- Ongoing studies identified: AFSC nearshore survey in northern Bristol Bay (capelin and rainbow smelt), but too limited in scope to provide comprehensive EFH information; University of Alaska Fairbanks researchers in Dillingham also working on nearshore projects; BSIERP contains some forage components.

4.3 Expected effects of Alternatives

4.3.1 Alternative 1 – No action; status quo

In 2005, the Council and NMFS developed a comprehensive EFH EIS (NMFS 2005) evaluating alternatives and environmental consequences for describing and identifying EFH for fisheries managed by the Council. The impacts analysis in this EIS is incorporated by reference. A more complete description of the EIS and its conclusions is included in Section 3.2 with respect to the description and identification of EFH. The EFH EIS (NMFS 2005) identified that the action (status quo) could have indirect negative effects for the industries and other entities that may face requirements (for federally managed fishing activities) or recommendations (for non-fishing activities) that are designed to protect fish habitats. The analysis identified that there would likely be indirect positive effects for the habitats and species that

could be protected by measures resulting indirectly from EFH description and identification. Such measures would include either measures to minimize adverse effects of fishing on EFH or recommendations to minimize effects of non-fishing activities on EFH.

4.3.2 Alternative 2 – Amend the BSAI Groundfish FMP for all twenty-four species or complexes

Alternative 2 would result in relatively minor changes to the existing EFH description and identification for BSAI groundfish stocks, to incorporate more recent information, improve mapping, and identify new EFH descriptions for a few species that have been separated out from a complex since the existing description and identification were compiled.

For sablefish, northern rockfish, flathead sole, Atka mackerel, and skate species, a revision to the EFH text or map description has been proposed for a particular life history stage. The geographic scope of the EFH designation for sablefish would remain unchanged. For northern rockfish, the depth identified for the adult life history stage has been refined. New information is available to refine EFH for larval flathead sole, as well as Atka mackerel and skate eggs. In all cases, the refinement of the designated EFH area falls within the overall aggregated area already designated as EFH for BSAI groundfish species.

Shortraker and rougheye rockfish were managed as a complex in 2005, when the EFH descriptions were last revised, but are now managed separately (rougheye rockfish is managed as a complex with blackspotted rockfish). Revised EFH descriptions have been prepared specifically for each species/complex. Also, the EFH descriptions for rock sole have been updated to reflect the stock split between northern and southern rock sole species (both part of the shallow water flatfish complex).

Under this alternative, the EFH description for yelloweye rockfish would be deleted from the BSAI Groundfish FMP. It is sporadically present in the BSAI, and at the edge of its range. The main center of distribution for this species is in the GOA.

For the remaining stocks, the proposed revisions update new information, or make editorial clarifications to existing text. These are technical or housekeeping changes, which have no impact. Additionally, for all stocks, the section identifying a contact person and phone number has been removed, as it is difficult to keep this contact information up to date in the FMP, and the information is available more readily in the annual SAFE reports.

None of the proposed changes would require regulatory action, and the 2010 EFH 5-year review concluded that no change to the 2005 conclusions on the evaluation of fishing effects on EFH was warranted based on new information from the last 5 years. The proposed refinement to the text and maps is minor, and any new area that is identified has already been designated as EFH for one of the other Alaska marine species. The total aggregated area of EFH description and identification for all managed species is unchanged as a result of these revisions. As such, federal actions (both fishing and non-fishing) in that area are already required to consult with NMFS on EFH in that area. While the proposed actions contemplated under Alternative 2 differ very little from the status quo, which was comprehensively analyzed in the 2005 EFH EIS (NMFS 2005), having updated information on EFH for each FMP species would improve management. As a result, no impacts have been identified under Alternative 2 and therefore it would have no significant impacts on the human environment.

5 Action 2 – GOA Groundfish FMP amendments for all twenty-four species or complexes

5.1 Background – GOA groundfish species

For the EFH 5-year review, stock assessment authors were asked to evaluate EFH information on their assessed species based on best available information. In addition, the review compared the EFH descriptions of species and species complexes that are currently identified in the GOA Groundfish FMP (Table 6) with the species or species complexes that were assessed in the 2009 SAFE report. In a few cases, there were discrepancies. For example, the habitat description currently in the FMP for rock sole is for southern rock sole, and, in fact, both northern and southern rock sole are the major species in the shallow water flatfish complex that is assessed in the SAFE report. In these cases, the EFH descriptions were updated to reflect the current way the species are being assessed.

5.2 Description of Alternatives

Alternative 1 – No Action; status quo

Alternative 2 – PREFERRED – Amend the EFH provisions for all twenty-four groundfish species or complexes as outlined in Table 7.

Table 6 lists the species and species complexes for which EFH is currently identified in the GOA Groundfish FMP, and identifies what species will have EFH descriptions under Alternative 2 revisions.

Table 6 Species or species complexes for which EFH is currently identified in the GOA Groundfish FMP, compared to species or species complexes that will have EFH descriptions under Alternative 2

	Species or complexes for which EFH is identified in GOA Groundfish FMP (Alternative 1)	Species or complexes for which EFH descriptions will be revised (Alternative 2)
Pollock	Pollock	Pollock
Pacific cod	Pacific cod	Pacific cod
Sablefish	Sablefish	Sablefish
Flatfish	Yellowfin sole	Yellowfin sole
	Rock sole	Northern rock sole Southern rock sole
	Alaska plaice	Alaska plaice
	Dover sole	Dover sole
	Greenland turbot	Greenland turbot
	Rex sole	Rex sole
Rockfish	Arrowtooth flounder	Arrowtooth flounder
	Flathead sole	Flathead sole
	Pacific ocean perch	Pacific ocean perch
	Northern rockfish	Northern rockfish
	Shortraker/ rougheye rockfish	Shortraker/ other slope rockfish Blackspotted and rougheye rockfish
	Dusky rockfish	Dusky rockfish
Atka mackerel	Yelloweye rockfish	Yelloweye rockfish
	Thornyhead rockfish	Thornyhead rockfish
Skates	Skates	Skates
Other species	Squids	Squids
	Octopuses	Octopuses
	Sharks	Sharks
	Sculpins	Sculpins
Forage fish	Forage fish complex	Forage fish complex

Table 7 provides an overall summary of the recommended changes to the EFH provisions under Alternative 2, for each species. “Yes” indicates that a substantive change to the text is being included for the identified section. To provide further detail on the summary table, the major changes recommended to the EFH text are detailed in bulleted form below the table.

Table 7 EFH review of GOA Groundfish FMP species, with recommended changes to the existing EFH FMP text

KEY: yes = update recommended to the existing FMP text, based on new information
e/c = editorial changes or clarifications recommended to the existing FMP text
“–” = no changes to the existing text have been recommended

Species	Recommended changes to the FMP text										
	EFH description			General information							2005 evaluation of fishing effects on EFH
	Text	map	available level of information	tables of associations	life history, gen. distribution	trophic information	biological/habitat associations	literature	contact person ³	description of fishery	
Pollock	e/c	–	–	–	e/c	–	–	yes	yes	yes	–
Pacific cod	–	–	–	–	yes	–	–	yes	yes	yes	–
Sablefish	yes	–	–	yes	e/c	yes	–	yes	yes	yes	e/c
Yellowfin sole	–	–	–	–	yes	–	yes	–	–	yes	–
Northern rock sole	e/c	–	–	–	yes	–	–	yes	–	yes	–
Southern rock sole	e/c	–	–	–	yes	e/c	yes	yes	–	yes	–
Alaska plaice	–	–	–	yes	yes	–	–	–	–	yes	–
Dover sole	–	yes	–	yes	yes	yes	yes	yes	yes	–	–
Greenland turbot	This EFH description to be deleted from the GOA Groundfish FMP.										
Rex sole	–	yes	–	yes	yes	yes	yes	yes	yes	–	–
Arrowtooth flounder	–	–	–	–	yes	–	–	yes	–	–	e/c
Flathead sole	–	yes	–	yes	yes	yes	yes	yes	yes	yes	–
Pacific ocean perch	–	–	–	yes	yes	–	yes	yes	yes	yes	–
Northern rockfish	yes	–	yes	yes	yes	yes	yes	yes	yes	yes	e/c
Shortraker rockfish	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Blackspotted/Rougheye rockfish	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	e/c
Dusky rockfish	–	–	–	e/c	e/c	–	–	yes	yes	yes	–
Yelloweye rockfish	yes	yes	yes	yes	yes	–	yes	yes	yes	e/c	(not in FMP)
Thornyhead rockfish	yes	–	yes	yes	yes	yes	yes	yes	yes	yes	–
Atka mackerel	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	e/c
Skates	–	–	–	–	yes	–	e/c	yes	yes	yes	–
Octopuses	–	(not in FMP)	–	yes	yes	yes	yes	yes	yes	yes	e/c
Sharks	–	(not in FMP)	–	yes	yes	yes	yes	yes	yes	yes	–
Sculpins	–	–	–	–	–	–	–	yes	yes	yes	–
Squids	–	–	–	–	–	–	–	–	yes	–	–
Forage fish complex	–	(not in FMP)	–	–	–	–	–	yes	yes	yes	–

5.2.1 Recommended revisions for individual species

A description of the recommendations that are captured in the summary table (Table 7) is provided below for each individual species or species complex for which EFH is defined in the GOA Groundfish FMP. The complete review for each species may be found in Appendix 2 to the Final EFH 5-year Review for 2010 Summary Report (NPFMC and NMFS 2010).

³ It is recommended that the section identifying a contact person and phone number be removed for all stocks.

Pollock

- Clarifications but no substantive changes to EFH description
- Update to age at 50 percent maturity and general life history
- Updated with recent fishery info
- New literature references added

Pacific cod

- Editorial clarifications to the text in various places
- Updates to natural mortality, maturity, and maximum age information
- Update to description of the fishery
- Updated literature section
- Relevant ongoing studies identified: one EFH project and three NPRB projects studying productivity, habitat utilization, and recruitment dynamics of Pacific cod; climate change and the match-mismatch hypothesis for Pacific cod larval survival; spatio-temporal spawning patterns of Pacific cod; and spawning and migration through a mark-recapture experiment

Sablefish

- Information added to the EFH description for early juveniles, but no changes to the finding of no EFH description determined
- Additions to the BSAI general information sections to make consistent with the more comprehensive GOA sections
- Minor updates to the timing of the spawning season
- Updates to reflect recent fishery information
- Updated literature section
- Ongoing studies identified: Tagging juvenile sablefish in southeast Alaska with time/depth recording tags to track movements from shallow inshore waters to deeper areas on the slope. Revisited lightly trawled shelf habitat in Southeast Alaska to estimate recovery rates of benthic habitat organisms. Mounted substrate nearby corals and sponges to examine recolonization of benthic organisms in Southeast Alaska. Examining the distribution of juvenile sablefish in AFSC trawl surveys (1977 to present).

Yellowfin sole

- Updated general distribution, depth preferences, and fishery information

Rock sole (northern and southern)

- EFH information currently written for rock sole generically; revision separates into two distinct EFH descriptions, to distinguish northern and southern rock sole
- EFH text descriptions referring to the combined rock sole species is still relevant for substrate preference by life history stage, also diet information
- Updated life history information including distribution, spawning depth, age at 50 percent maturity
- Updated fishery description to reflect GOA catch locations
- Spawning information added for southern rock sole
- Literature references updated
- Editorial changes to the EFH text descriptions to distinguish northern and southern species

Alaska plaice

- Updated predator information, distribution, and fishery information

Dover sole

- Map of distribution of larvae has been updated with the latest information from the EcoFOCI Ichthyoplankton Information System (IIS).
- Updates to biological and predator-prey associations for Dover sole life history stages (female age at 50 percent and 100 percent maturity, spawning season, predators, prey) in tables and sections
- Literature references updated

Greenland turbot

- To be deleted from FMP. Greenland turbot is not a key species in the GOA and is not a direct target. Its main center of distribution is the Bering Sea. It is sporadically present in the GOA, which is at the edge of its range.

Rex sole

- Map of distribution of larvae has been updated with the latest information from the EcoFOCI Ichthyoplankton Information System (IIS).
- Updates to prey association table and revised trophic information section
- Update to life history and general distribution information (spawning season, larval duration, female maturity, natural mortality rate)
- Literature references updated

Arrowtooth flounder

- Updates to natural mortality
- Literature references updated (also updated in fishing effects section)

Flathead sole

- Map of distribution of larvae has been updated with the latest information from the EcoFOCI Ichthyoplankton Information System (IIS).
- Updates to habitat, biological, and predator-prey associations for flathead sole life history stages (substrate, female age at 50 percent maturity, spawning season, predators, prey) in tables and sections.
- Description of fishery updated
- Literature references updated
- Acknowledgment that more information on early juvenile distribution exists in the GOA than in the BSAI, but insufficient to change level of information for this life stage from "insufficient" to "sufficient"

Pacific ocean perch (POP)

- Updates to depth, substrate, age at female 100 percent maturity, predator and prey species in tables and sections
- Recent fishery information added

- Literature references added
- Fishing effects: no change required; the Central GOA Rockfish Program has the potential effect of spreading effort in time and space and the increase in pelagic trawling will likely decrease effects of fishing.
- Ongoing studies identified: EFH habitat studies being conducted at Little Port Walter Field station on POP juveniles; several submarine dive studies that will be published in the future related to POP habitat and catchability

Northern rockfish

- Clarifications to EFH descriptions, and refinement of depths for adult life history stage
- Updates to spawning season, predator in tables
- Update to life history information, including size at 50 percent maturity, maximum age; trophic information; and larval and juvenile associations
- Recent fishery information added
- Literature references added
- Fishing effects: editorial changes to reflect that the spatial distribution of the fishery has changed since the original analysis. When the 2005 EFH EIS for GOA northern rockfish was prepared, fishery catches were described as being particularly concentrated in one relatively small area, the “Snakehead” south of Kodiak Island. More recent catch data show this area no longer produces large catches and that localized depletion likely occurred here as a result of the heavy fishing effort in the 1990s. Fishing is now more dispersed over other fishing grounds, which is probably beneficial to the habitat of these fish. In addition, the Central GOA Rockfish Program, which includes northern rockfish, has the potential effect of spreading effort in space and time and also will likely decrease the effects of fishing.

Shortraker rockfish

- New EFH descriptions as shortraker rockfish split out from rougheye rockfish; new map; information level on larval life history stage downgraded as, in comparison with rougheye rockfish, much less is known about juvenile shortraker rockfish
- Associations table: rewritten for depth, water column, substrate associations, spawning season.
- New life history information, trophic information, and habitat and biological associations sections rewritten.
- Recent fishery information added
- Literature references added
- Fishing effects: the Rockfish Pilot Program appears to have spread fishery effort in space and time, and this will likely decrease the effects of fishing on the bottom. The Central GOA Rockfish Program is anticipated to have the same effect. Section edited to excise rougheye rockfish.

Rougheye/blackspotted rockfish

- New EFH descriptions as shortraker removed and two distinct species of rougheye rockfish identified; new adult map needed; information level on larval life history stage downgraded as, in comparison with rougheye rockfish, much less is known about juvenile shortraker rockfish
- Associations table: rewritten for depth, water column, substrate associations, age at 50 percent maturity, spawning season, predator, and prey
- New life history information, trophic information, and habitat and biological associations sections rewritten

- Recent fishery information added
- Literature references added
- Ongoing studies: larval rougheye rockfish identification; 2009 NMFS trawl survey collected data on rougheye and blackspotted rockfish to evaluate new identification techniques and potential population distribution differences.
- Fishing effects: the Central GOA Rockfish Program has the potential effect of spreading fishery effort in space and time, and the increase in pelagic trawling will likely decrease the effects of fishing. Section edited to excise shortraker rockfish and add blackspotted rockfish.

Dusky rockfish

- Update to life history information, including size at 50 percent maturity, maximum age; tropic information; and larval and juvenile associations
- Editorial clarifications in table to remove “light” before dusky; implementation date of dark rockfish removal corrected
- Recent fishery information added
- Literature references added
- Fishing effects: the Central GOA Rockfish Pilot Program has the potential effect of spreading fishery effort in space and time, and the increase in pelagic trawling will likely decrease the effects of fishing.

Yelloweye rockfish

- EFH description for early juveniles added, and information level updated
- Update to larval map recommended to indicate presence of larval rockfish in Statistical Areas 640 and 650
- Updates to depth, substrate, structure, community associations, age at 50 percent maturity, maximum age, egg development, prey in tables and sections
- Editorial clarifications to fishery text
- Literature references added
- Ongoing studies identified: Alaska Department of Fish and Game research for collecting density information for the demersal shelf rockfish stock assessment; NMFS studies on rockfish larvae.

Thornyhead rockfish

- EFH description for early juveniles added, and information level updated
- Update to substrate, age at 50 percent maturity, fertilization, spawning season, predator, and prey in tables and sections
- Recent fishery information added
- Literature references added

Atka mackerel

- New information included on the distribution of eggs in the GOA (limited, not general, distribution data).
- Updates to habitat, biological, and prey associations for various life history stages (depths, substrate, location in water column, community and temperature associations, reproductive traits)
- Update to age at 50 percent maturity, prey information
- Recent fishery information added
- Literature references added

- Minor change to evaluation of fishing effects text to indicate that stock no longer at peak spawning biomass, although biomass is still relatively high

Skates

- Added depth distribution information for skate species in life history section
- Recent fishery information added
- Updated SAFE reference

Octopuses

- New general distribution maps available for individual species, but the scale of these maps is not sufficient for determination of EFH
- Updates to predator prey associations
- New life history information, trophic information, and habitat and biological associations sections rewritten
- Recent fishery information added
- Literature section updated
- Ongoing studies identified: doctoral research with *E. dofleini* growth and development; NPRB project on field studies to document reproductive seasons of *E dofleini* in Alaska and to develop octopus pot gear and tagging methods; ongoing observer program special project to collect individual weights and sex of octopus; in 2009, also tested vitality key for possible discard mortality; proposals for octopus discard mortality studies.

Sharks

- Updates to depth range, age at 50 percent maturity, maximum age, spawning season, and predator and prey species (in tables and sections).
- Recent fishery information added
- Ongoing studies identified: habitat use of spiny dogfish from satellite data

Sculpins

- Recent fishery information added
- Literature section updated

Squids

- No updates

Forage fish

- Some progress on forage fish distribution and habitat (more than in the BSAI), but not sufficient yet to formally describe EFH for forage fishes. Nearshore areas in general are likely to be EFH for some forage species for at least part of the year.
- Recent fishery information for eulachon added
- Literature section updated
- Ongoing studies identified: There is a lot of interest in GOA forage fishes. The NPRB is currently creating a GOA integrated ecosystem research project, and forage species will be a

primary focus of this work. The project is slated to run from 2010 through 2014 and will probably yield some useful results for the next 5-year review.

5.3 Expected effects of Alternatives

5.3.1 Alternative 1 – No action; status quo

In 2005, the Council and NMFS developed a comprehensive EFH EIS (NMFS 2005) evaluating alternatives and environmental consequences for describing and identifying EFH for fisheries managed by the Council. The impacts analysis in this EIS is incorporated by reference. A more complete description of the EIS and its conclusions is included in Section 3.2 with respect to the description and identification of EFH. The EFH EIS (NMFS 2005) identified that the action (status quo) could have indirect negative effects for the industries and other entities that may face requirements (for federally managed fishing activities) or recommendations (for non-fishing activities) that are designed to protect fish habitats. The analysis identified that there would likely be indirect positive effects for the habitats and species that could be protected by measures resulting indirectly from EFH description and identification. Such measures would include either measures to minimize adverse effects of fishing on EFH or recommendations to minimize effects of non-fishing activities on EFH.

5.3.2 Alternative 2 – Amend the GOA Groundfish FMP for all twenty-four species or complexes

Alternative 2 would result in relatively minor changes to the existing EFH description and identification for GOA groundfish stocks, to incorporate more recent information, improve mapping, and identify new EFH descriptions for a few species that have been separated out from a complex since the existing description and identification were compiled.

For sablefish, flathead sole, rex sole, Dover sole, northern rockfish, yelloweye rockfish, thornyhead rockfish, and Atka mackerel species, a revision to the EFH text or map description has been proposed for a particular life history stage. The geographic scope of the EFH designation for sablefish would remain unchanged. For northern rockfish, the depth identified for the adult life history stage has been refined. New information is available to define EFH for early juvenile yelloweye and thornyhead rockfish, larval flathead sole, rex and Dover sole, as well as Atka mackerel eggs. In all cases, the refinement of the designated EFH area falls within the overall aggregated area already designated as EFH for GOA groundfish species.

Shortraker and rougheye rockfish were managed as a complex in 2005, when the EFH descriptions were last revised, but are now managed separately (rougheye rockfish is managed as a complex with blackspotted rockfish). Revised EFH descriptions have been prepared specifically for each species/complex. Also, the EFH descriptions for rock sole have been updated to reflect the stock split between northern and southern rock sole species (both part of the shallow water flatfish complex).

Under this alternative, the EFH description for Greenland turbot would be deleted from the FMP. It is sporadically present in the GOA and at the edge of its range. The main center of distribution for this species is in the BSAI.

For the remaining stocks, the proposed revisions update new information or make editorial clarifications to existing text. These are technical or housekeeping changes that have no impact. Additionally, for all stocks, the section identifying a contact person and phone number has been removed, as it is difficult to keep this contact information up to date in the FMP, and the information is available more readily in the annual SAFE reports.

None of the proposed changes would require regulatory action, and the 2010 EFH 5-year review concluded that no change to the 2005 conclusions on the evaluation of fishing effects on EFH was warranted based on new information from the last 5 years. The proposed refinement to the text and maps is minor, and any new area that is identified has already been designated as EFH for one of the other Alaska marine species. The total aggregated area of EFH description and identification for all managed species is unchanged as a result of these revisions. As such, federal actions (both fishing and non-fishing) in that area are already required to consult with NMFS on EFH in that area. While the proposed actions contemplated under Alternative 2 differ very little from the status quo, which was comprehensively analyzed in the 2005 EFH EIS (NMFS 2005), having updated information on EFH for each FMP species would improve management. As a result, no impacts have been identified under Alternative 2 and therefore it would have no significant impacts on the human environment.

6 Action 3 – BSAI King and Tanner Crab FMP

6.1 Background – BSAI king and Tanner crab species

Since the 2005 EFH EIS, FMP Amendment 24 removed certain crab species from the BSAI Crab FMP. The managed species currently identified in the BSAI Crab FMP, and which were reviewed as part of this process, are the following:

- red king crab,
- blue king crab,
- golden king crab,
- Tanner crab, and
- Snow crab.

6.2 Description of Alternatives

Alternative 1 – No Action; status quo

Alternative 2 – PREFERRED – Amend the EFH provisions for all five crab species, and remove EFH provisions for other species no longer in the FMP as outlined in Table 8.

EFH text relating to scarlet king crab, grooved Tanner crab, and triangle Tanner crab is no longer necessary in the FMP, because these species were removed under Amendment 24. The removal of this EFH text is a housekeeping amendment to the FMP, and is included under Alternative 2.

Table 8 provides an overall summary of the recommended changes to the EFH provisions under Alternative 2, for the managed individual species. “Yes” indicates that a substantive change to the text is being included for the identified section. To provide further detail on the summary table, the major changes recommended to the EFH text are detailed in bulleted form below the table.

Table 8 EFH review of BSAI Crab FMP species, with recommended changes to the existing EFH FMP text

KEY: yes = updates recommended to the existing FMP text, based on new information
e/c = editorial changes or clarifications recommended to the existing FMP text

Species	Recommended changes to the FMP text									2005 evaluation of fishing effects on EFH
	EFH description			General information						
	text	map	available level of information	tables of associations	life history, gen. distribution	trophic information	biological/ habitat associations	literature	description of fishery	
Red king crab	-	-	-	yes	yes	yes	-	-	yes	-
Blue king crab	-	-	-	yes	e/c	yes	e/c	-	e/c	yes
Golden king crab	-	-	-	yes	yes	yes	yes	yes	yes	-
Tanner crab	-	-	-	yes	yes	yes	yes	yes	yes	yes
Snow crab	-	-	-	yes	yes	yes	yes	yes	yes	yes

“-“ = no changes to the existing text have been recommended

6.2.1 Recommended revisions for individual species

A description of the recommendations that are captured in the summary table are provided below for each individual species for which EFH is defined in the BSAI Crab FMP. The complete review for each species may be found in Appendix 3 to the Final EFH 5-year Review for 2010 Summary Report (NPFMC and NMFS 2010).

Red king crab

- Updates to prey associations, natural mortality, recent fishery information
- A discussion of the effects of fishing on spawning and breeding in southern Bristol Bay, specifically, has been deferred to a separate discussion paper.

Blue king crab

- Updates to age at maturity, editorial clarifications
- Recommendation to change determination of effect of fishing on growth to maturity to “unknown”

Golden king crab

- Updates to size at sexual maturity, reproductive cycle, depth associations by life history stage
- Recent fishery information updated
- Literature references added

Tanner crab

- Editorial clarifications to evaluation of fishing effects summary
- Updates to size and age at maturity, natural mortality, fecundity, reproduction, and predator and prey associations
- Substantial clarifications and additions to life history, general distribution, and fishery description
- Literature references added
- Recommendation to change determination of effect of fishing on growth to maturity to “unknown”

Snow crab

- Updates to prey associations, natural mortality, molting and mating cycle, recent fishery information
- Literature reference added
- Recommendation to change determination of effect of fishing on growth to maturity to “unknown”

6.3 Expected effects of Alternatives

6.3.1 Alternative 1 – No action; status quo

In 2005, the Council and NMFS developed a comprehensive EFH EIS (NMFS 2005) evaluating alternatives and environmental consequences for describing and identifying EFH for fisheries managed by the Council. The impacts analysis in this EIS is incorporated by reference. A more complete description of the EIS and its conclusions is included in Section 3.2 with respect to the description and identification

of EFH. The EFH EIS (NMFS 2005) identified that the action (status quo) could have indirect negative effects for the industries and other entities that may face requirements (for federally managed fishing activities) or recommendations (for non-fishing activities) that are designed to protect fish habitats. The analysis identified that there would likely be indirect positive effects for the habitats and species that could be protected by measures resulting indirectly from EFH description and identification. Such measures would include either measures to minimize adverse effects of fishing on EFH or recommendations to minimize effects of non-fishing activities on EFH.

6.3.2 Alternative 2 – Amend the EFH provisions for all five crab species or complexes, and remove EFH provisions for other species no longer in the FMP

Alternative 2 would result in relatively minor changes to the existing EFH description and identification for BSAI crab stocks, to incorporate more recent information. A discussion of the effects of fishing evaluation did arise during the 2010 5-year review of EFH, with respect to the BSAI Crab FMP, and groundfish fishing in southwest Bristol Bay. The Council requested that more information be compiled on this issue, which is being further evaluated by the Council in a separate discussion paper that looks at how the effects of fishing are considered for crab stocks. Should any revision be proposed as a result of this discussion paper, it will be advanced in as a separate amendment analysis.

None of the proposed changes would require regulatory action, and the 2010 EFH 5-year review concluded that no change to the 2005 conclusions on the evaluation of fishing effects on EFH was warranted based on new information from the last 5 years. Entities taking action (both fishing and non-fishing) in that area are already required to consult with NMFS on EFH in the areas identified. For all crab stocks, the proposed revisions in Alternative 2 update new information, or make editorial clarifications to existing text. These are technical or housekeeping changes, therefore no impacts have been identified and there would be no significant impacts to the human environment.

Alternative 2 also includes another housekeeping action, to remove the EFH descriptions of species that are no longer managed under the FMP. Again, as this is a housekeeping change with no identified impacts, therefore it would have no significant impacts to the human environment.

7 Action 4 – Alaska Scallops FMP amendment for weathervane scallop

7.1 Background – Alaska Scallop species description

All scallop stocks off the coast of Alaska are covered under the Scallop FMP. Only weathervane scallops (*Patinopecten caurinus*) are currently commercially harvested in Alaska, and it is the only scallop species for which EFH is described. Rock scallops (*Crassadoma gigantean*), pink scallops (*Chlamys rubida*), and spiny scallops (*Chlamys hastata*, *Chlamys behringiana*, and *Chlamys albida*) are classified as ecosystem component species.

7.2 Description of alternatives

Alternative 1 – No Action; status quo

Alternative 2 – PREFERRED – Amend the EFH provisions for weathervane scallop as outlined in Table 9.

Table 9 provides an overall summary of the recommended changes to the EFH provisions under Alternative 2, for weathervane scallop. “Yes” indicates that a substantive change to the text is being included for the identified section. To provide further detail on the summary table, the major changes recommended to the EFH text are detailed in bulleted form below the table.

Table 9 EFH review of Weathervane Scallop, with recommended changes to the existing EFH FMP text

KEY: yes = updates recommended to the existing FMP text, based on new information
e/c = editorial changes or clarifications recommended to the existing FMP text
“–” = no changes to the existing text have been recommended

Species	Recommended changes to the FMP text									
	EFH description			General information						2005 evaluation of fishing effects on EFH
	text	map	available level of information	tables of associations	life history, gen. distribution	trophic information	biological/ habitat associations	literature	description of fishery	
Weathervane Scallop	yes	yes	–	e/c	e/c	–	e/c	yes	–	–

7.2.1 Recommended revisions for individual species

A description of the recommendations that are captured in the summary table is provided below for weathervane scallop. The complete review for this species may be found in Appendix 4 to the Final EFH 5-year Review for 2010 Summary Report (NPFMC and NMFS 2010):

- Maps of weathervane scallop EFH distribution have been updated to include bays and inshore areas that are important scallop habitat, based on NMFS and Alaska Department of Fish and Game trawl survey data. These include, but may not be limited to, bays on the east side of Kodiak Island and south of the Alaska Peninsula between Chignik and Unimak Pass, also

Kachemak Bay, and bays in Prince William Sound such as Orca Bay. The EFH distribution should also be reviewed against areas where scallops are no longer fished commercially, but may still constitute important scallop habitat (although any such changes should be based on reliable and fairly recent data).

- The scallop EFH text description has been updated to include inner shelf waters (less than 50 m) where scallops are generally distributed.

7.3 Expected effects of Alternatives

7.3.1 Alternative 1 – No action taken; remain at status quo

In 2005, the Council and NMFS developed a comprehensive EFH EIS (NMFS 2005) evaluating alternatives and environmental consequences for describing and identifying EFH for fisheries managed by the Council. The impacts analysis in this EIS is incorporated by reference. A more complete description of the EIS and its conclusions is included in Section 3.2 with respect to the description and identification of EFH. The EFH EIS (NMFS 2005) identified that the action (status quo) could have indirect negative effects for the industries and other entities that may face requirements (for federally managed fishing activities) or recommendations (for non-fishing activities) that are designed to protect fish habitats. The analysis identified that there would likely be indirect positive effects for the habitats and species that could be protected by measures resulting indirectly from EFH description and identification. Such measures would include either measures to minimize adverse effects of fishing on EFH or recommendations to minimize effects of non-fishing activities on EFH.

7.3.2 Alternative 2 – Amend the EFH provisions for weathervane scallop

Alternative 2 would result in relatively minor changes to the existing EFH description and identification for weathervane scallop, to incorporate more recent information and improve the text description and mapping. Revisions to the mapping of weathervane scallop would update the EFH description to include nearshore bays and inshore areas where important scallop beds may exist. These areas are very small and discrete.

None of the proposed changes would require regulatory action, and the 2010 EFH 5-year review concluded that no change to the 2005 conclusions on the evaluation of fishing effects on EFH was warranted based on new information from the last 5 years.⁴ The proposed refinement to the text and maps is minor, and any new area that is identified has already been designated as EFH for one of the other Alaska marine species (such as Alaska stocks of Pacific salmon). The total aggregated area of EFH description and identification for all managed species is unchanged as a result of these revisions. As such, federal actions (both fishing and non-fishing) in that area are already required to consult with NMFS on EFH in that area. While the proposed actions contemplated under Alternative 2 differ very little from the status quo, which was comprehensively analyzed in the 2005 EFH EIS (NMFS 2005) having updated information on EFH for each FMP species would improve management. As a result, no impacts have been identified under Alternative 2 and therefore it would have no significant impacts on the human environment.

⁴ Note, as described in Table 2, a discussion of the effects of fishing evaluation did arise with respect to the BSAI Crab FMP and fishing in southwest Bristol Bay. This issue will be discussed further by the Council after additional crab habitat research.

8 Action 5 – EFH conservation recommendations for non-fishing activities

8.1 Background

Non-fishing activities that may adversely affect EFH are diverse and have the potential to reduce the quantity and/or quality of EFH. Such activities may include dredging, filling, discharges, and actions that contribute to non-point source pollution. The EFH regulations at 50 CFR 600.815(a)(4) specify that “FMPs must identify activities other than fishing that may adversely affect EFH.” The regulations also specify that FMPs must identify actions to encourage the conservation and enhancement of EFH, including recommended options to avoid, minimize, or compensate for the adverse effects identified...especially in habitat areas of particular concern (50 CFR part 600, Subpart K). In 2005, Appendix G of the 2005 EFH EIS fulfilled the requirement to describe non-fishing activities that may have adverse effects on EFH and identify actions to encourage the conservation and enhancement of EFH.

In 2010, NMFS Habitat Conservation Division staff reviewed the original non-fishing activities evaluation (Appendix G of the 2005 EFH EIS and as abbreviated in the FMPs) and based on more recent scientific literature and the best available information specific to Alaska, updated the analysis of each activity’s potential to result in adverse impacts on EFH and recommended conservation measures to avoid, minimize, or compensate for adverse effects on EFH, as needed. The updated review provides an introductory description of each activity, identifies potential adverse impacts, and revises existing general conservation measures by deleting some that were found to be not current and suggesting clarifications as appropriate. The potential for effects from larger, less readily managed processes associated with human activity also exists, such as climate change and ocean acidification. These larger, ecosystem level effects are discussed in the updated document where applicable within each activity type.

Non-fishing activities are already subject to a variety of regulations and restrictions under federal, state, and local laws that would help minimize and avoid adverse effects of non-fishing activities on EFH. Therefore, the recommendations are general in nature and may overlap with certain existing standards for specific development activities. They are meant to highlight options to avoid, minimize, or compensate for adverse impacts and promote the conservation and enhancement of EFH. All of the suggested measures are not necessarily applicable to any one project or activity and are not binding on any action agency or permit applicant. Subject-specific recommendations are advisory and serve as proactive conservation measures that would help minimize and avoid adverse effects of these non-fishing activities on EFH. Site-specific EFH conservation recommendations will be prepared per activity and as necessary during EFH consultation (see CFR 50 Part 600 Subpart K).

The following is an example of existing and new EFH recommendations for flood and shoreline protection in coastal estuarine areas (*= *new EFH conservation recommendations*):

Recommendations from 2005 EFH FEIS Appendix G

- Do not dike or drain tidal marshlands or estuaries.
- Wherever possible, use soft approaches (such as beach nourishment, vegetative plantings, and placement of large woody debris to shoreline modifications).
- Include efforts to preserve and enhance EFH by providing new gravel for spawning areas, removing barriers to natural fish passage, and using weirs, grade control structures, and low-flow channels to provide the proper depth and velocity for fish.

- Offset unavoidable impacts to in-stream fish habitat by providing rootwads, deflector logs, boulders, and rock weirs and by planting shaded riverine aquatic cover vegetation.
- Use an adaptive management plan with ecological indicators to oversee monitoring and to ensure that mitigation objectives are met. Take corrective action as needed.

Updated recommendations from new analysis

- * *Avoid or minimize the loss of coastal wetlands as much as possible, including encouraging coastal wetland habitat preservation.*
- * *Ensure that the hydrodynamics and sedimentation patterns are properly modeled and that the design avoids erosion to adjacent properties when “hard” shoreline stabilization is deemed necessary.*
- * *Avoid installing new water control structures in tidal marshes and freshwater streams. If the installation of new structures cannot be avoided, ensure that they are designed to allow optimal fish passage and natural water circulation.*
- * *Ensure water control structures are monitored for potential alteration of water temperature, dissolved oxygen concentration, and other parameters.*
- * *Use seasonal restrictions to avoid impacts to habitat during species critical life history stages (e.g., spawning, egg, and larval development periods). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.*
- * *Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats by considering them in the review process for flood control and shoreline protection projects.*

8.2 Description of Alternatives – New EFH Conservation Recommendations

Alternative 1 – No Action; status quo

Alternative 2 – PREFERRED – Amend EFH conservation recommendations for non-fishing activities in all FMPs and the analysis of impacts of non-fishing activities

For each of the non-fishing activities, staff reviewed each activity’s potential to result in adverse impacts on EFH. Conservation measures are recommended to avoid, minimize, or compensate for adverse effects on EFH, if needed. The complete review may be found in Appendix 7 to this document. Table 10 identifies new EFH conservation recommendations that resulted from the review. Alternative 2 would add these conservation recommendations to each of the FMPs.

Table 10 New EFH Recommendations for Non-fishing Activities

Activity	New EFH Conservation Recommendations (bullets) <i>Other recommended changes to non-fishing FMP text (italics)</i>
Silviculture / Timber Harvest	<p><i>Existing recommendations have been updated to reflect agreement on the adequacy of Forest-Wide Standards and Guidance in protecting EFH.</i></p> <p><i>Minor editorial comments.</i></p> <p><i>New subject references and information provided.</i></p>
Pesticide Application	<ul style="list-style-type: none"> • Carefully review labels and ensure that application is consistent with the product's directions. Follow local, supplemental instructions such as state-use bulletins where they are available. • Incorporate integrated pest management and best management practices as part of the authorization or permitting process to ensure the reduction of pesticide contamination in EFH (Scott et al. 1999). If pesticides must be applied consider several factors including: why application is necessary (such as to eradicate an invasive plant species), area, terrain, weather, droplet size, pesticide characteristics, and other conditions to avoid or reduce effects to EFH. • Avoid the use of pesticides within 500 lineal feet and/or 1,000 aerial feet of anadromous fish bearing streams. • For forestry vegetation management projects, NMFS recommends to follow the Alaska Department of Environmental Conservation measures that establish a 35-foot pesticide-free buffer area from any surface or marine water body and that pesticides not be applied within 200 feet of a public water source (http://www.dec.state.ak.us/regulations/pdfs/18%20AAC%2090.pdf). • Consider immediate weather events, as rainfall events may increase pesticide runoff into adjacent water bodies or ground conditions may inhibit intended application. This includes application when soil moisture content is at its field capacity; where soils are saturated as not to allow pesticide penetration, as applicable. • Do not apply pesticides when wind speeds exceed 10 mph, as measured with an anemometer immediately prior to application. • When applying pesticide products, begin nearest to the aquatic habitat boundary and proceed away from the aquatic habitat; do not apply towards a water body. <p><i>Re-write of recommendations to include knowledge of pesticide use near anadromous fish streams.</i></p> <p><i>Other minor editorial comments.</i></p> <p><i>New subject references and information provided.</i></p>
Urban / Suburban Development	<ul style="list-style-type: none"> • Where vegetated swales are not feasible, install oil/water separators to treat runoff from impervious surfaces in areas adjacent to marine or anadromous waters. Ensure that oil/water separators are regularly maintained such that they do not become clogged and function properly on a continuing basis. • Where feasible, remove impervious surfaces such as abandoned parking lots and buildings from hyporheic, riparian, and shoreline areas; re-establish water regime, wetlands, and native vegetation. <p><i>Minor editorial comments.</i></p> <p><i>New subject references and information provided.</i></p>
Road Building and Maintenance	<ul style="list-style-type: none"> • After creating disturbance to the riparian area, re-vegetate with native vegetation to avoid colonization by non-native plant species. • Avoid storage or disposal of snow directly into waters. Snow laden with salt and ice melt chemical should not be placed in anadromous fish streams. Snow-melt disposal areas should be silt-fenced and include a collection basin. • Use stream simulation techniques to design watered crossing structures (bridges or culverts); maintain flow, slope, and natural alignment. <p><i>Additional information regarding the impacts of non-point source pollution from transportation infrastructure and the effects of bio accumulation and magnification on EFH as well as new subject references provided.</i></p>

Activity	New EFH Conservation Recommendations (bullets) <i>Other recommended changes to non-fishing FMP text (italics)</i>
Mining	<ul style="list-style-type: none"> • To the extent practicable, avoid mineral mining in waters, water sources and watersheds, riparian areas, hyporheic zones, and floodplains providing habitat for federally managed species. • Incorporate stochastic water models and include predictions to illustrate uncertainty. <p><i>Additional information regarding the impacts of mining on EFH and new subject references provided.</i></p>
Sand and Gravel Mining	<ul style="list-style-type: none"> • To the extent practicable, avoid sand/gravel mining in waters, water sources and watersheds, riparian areas, hyporheic zones, and floodplains providing habitat for federally managed species. • Implement seasonal restrictions to avoid impacts to habitat during species critical life history stages (e.g., spawning season, egg, and larval development period). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements. <p><i>New subject matter references</i></p>
Organic Debris	<ul style="list-style-type: none"> • Advise gardeners to only harvest dislodged, dead kelp and leave live, growing kelp (whether dislodged or not). (See Alaska Department of Fish and Game brochure, "Harvesting Kelp and other Aquatic Plants in Southcentral Alaska, www.sf.adfg.state.ak.us). <p><i>New subject matter references</i></p>
Organic Debris	<ul style="list-style-type: none"> • Advocate for local, state and national legislation that rewards proper disposal of debris (e.g., implementation of a deposit on all plastic bottles). • Educate the public on the impact of marine debris and provide guidance on how to reduce or eliminate the problem. • Require all existing and new commercial construction projects near the coast (e.g., marinas and ferry terminals, recreational facilities, boat building and repair facilities) to develop and implement refuse disposal plans. <p><i>Additional information regarding marine debris and new legislation, and new subject matter references</i></p>
Dam Operation	<ul style="list-style-type: none"> • Operate dams to create flow conditions that provide for passage, water quality, proper timing of life history stages, and properly functioning channel conditions to avoid strandings and redd dewatering. • Provide mitigation (including monitoring and evaluation) for unavoidable adverse effects on EFH. • Develop and implement monitoring protocols for fish passage. <p><i>Minor rewrites and editorial comments</i> <i>New subject matter references</i></p>

Activity	New EFH Conservation Recommendations (bullets) <i>Other recommended changes to non-fishing FMP text (italics)</i>
Commercial and Domestic Water Use	<ul style="list-style-type: none"> • Design water diversion and impoundment projects to create flow conditions that provide for adequate fish passage, particularly during critical life history stages. Avoid low water levels that strand juveniles and dewater redds. Incorporate juvenile and adult fish passage facilities on all water diversion projects (e.g., fish bypass systems). Install screens at water diversions on fish-bearing streams, as needed. • Maintain water quality necessary to support fish populations by monitoring and adjusting water temperature, sediment loads, and pollution levels. Water temperatures should not vary or alter native fish populations. • Maintain appropriate flow velocity and water levels to support continued stream functions. • Where practicable, mitigate for unavoidable impacts to fish and their habitat. Mitigation can include water conservation measures that reduce the volume of water diverted or impounded. <p><i>Re-write of recommendations.</i> <i>Minor editorial comments.</i> <i>New subject references and information provided.</i></p>
Dredging	<ul style="list-style-type: none"> • Avoid new dredging in sensitive habitat areas to the maximum extent practicable. Activities that would likely require dredging (e.g., placement of piers, docks, marinas) should instead be located in deep water or designed to alleviate the need for maintenance dredging. • Reduce the area and volume of material to be dredged to the maximum extent practicable. • Avoid dredging and placement of equipment used in conjunction with dredging operations in special aquatic sites and other high value habitat areas, (e.g., kelp beds, eelgrass beds, salt marshes). • Implement seasonal restrictions to avoid impacts to habitat during species critical life history stages (e.g., spawning season, egg, and larval development period). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements. • Utilize best management practices (BMPs) to limit and control the amount and extent of turbidity and sedimentation. Standard BMPs may include constructing silt fences, coffer dams, and operational modification (e.g., hydraulic dredge rather than mechanical dredge). • For new dredging projects, undertake multi-season, pre- and post-dredging biological surveys to assess the cumulative impacts to EFH and allow for implementation of adaptive management techniques. • Prior to dredging, test sediments to be dredged for contaminants as per U.S. Environmental Protection Agency (EPA) and U.S. Army Corps of Engineers (USACE) requirements. • Provide appropriate compensation for significant impacts (short-term, long-term, and cumulative) to benthic environments resulting from dredging. • Identify excess sedimentation in the watershed that prompts excessive maintenance dredging activities, and implement appropriate management actions, if possible, to curtail those causes. <p><i>Re-write of recommendations to provide clarity and recognize existing requirements.</i> <i>New subject references and information provided.</i></p>

Activity	New EFH Conservation Recommendations (bullets) <i>Other recommended changes to non-fishing FMP text (italics)</i>
Disposal of Dredged Material	<ul style="list-style-type: none"> • Avoid disposing dredged material in wetlands, submerged aquatic vegetation and other special aquatic sites whenever possible. Study all options for disposal of dredged materials, including upland disposal sites, and select disposal sites that minimize adverse effects to EFH. • Test sediment compatibility for open-water disposal per EPA and USACE requirements for inshore and offshore, unconfined disposal. • Ensure that disposal sites are properly managed (e.g., disposal site marking buoys, inspectors, the use of sediment capping and dredge sequencing) and monitored (e.g., chemical and toxicity testing, benthic recovery) to minimize impacts associated with dredge material. • Where long-term maintenance dredging is anticipated, acquire and maintain disposal sites for the entire project life. <p><i>Re-write of recommendations to provide clarity and recognize existing requirements. New subject references and information provided.</i></p>
Discharge of Fill Material	<ul style="list-style-type: none"> • Fill should be sloped to maintain shallow water photic zone productivity; allow for unrestricted fish migration; and provide refugia for juvenile fish. • In marine areas of kelp and other aquatic vegetation, fill (including artificial structure fill reefs) should be designed to maximize kelp colonization and provide areas for juvenile fish to find shelter from higher currents and exposure to predators. <p><i>New subject references and information provided.</i></p>
Vessel Operations / Transportation / Navigation	<ul style="list-style-type: none"> • To facilitate movement of fish around breakwaters, breach gaps and construct shallow shelves to serve as “fish benches,” as appropriate. Often benches are expanded shelf features used in common toe-slope stabilization transitions within the breakwater design. Benches need to provide for unrestricted fish movement throughout all tidal stages. <p><i>Minor editorial comments. New subject references and information provided.</i></p>
Introduction of Exotic Species	<ul style="list-style-type: none"> • Undertake a thorough scientific review and risk assessment before any non-native species are introduced. <p><i>Editorial comments. New subject references and information provided.</i></p>
Pile Driving	<p><i>Existing recommendations are adequate. Minor editorial comments. New subject references and information provided.</i></p>
Pile Removal	<p><i>Existing recommendations are adequate. Minor editorial comments. New subject references and information provided.</i></p>
Overwater Structures	<p><i>Existing recommendations are adequate. Minor editorial comments. New subject references and information provided.</i></p>

Activity	New EFH Conservation Recommendations (bullets) <i>Other recommended changes to non-fishing FMP text (italics)</i>
Flood Control / Shoreline Protection	<ul style="list-style-type: none"> • Avoid or minimize the loss of coastal wetlands as much as possible, including encouraging coastal wetland habitat preservation. • Ensure that the hydrodynamics and sedimentation patterns are properly modeled and that the design avoids erosion to adjacent properties when “hard” shoreline stabilization is deemed necessary. • Avoid installing new water control structures in tidal marshes and freshwater streams. If the installation of new structures cannot be avoided, ensure that they are designed to allow optimal fish passage and natural water circulation. • Ensure water control structures are monitored for potential alteration of water temperature, dissolved oxygen concentration, and other parameters. • Use seasonal restrictions to avoid impacts to habitat during species critical life history stages (e.g., spawning, egg, and larval development periods). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements. • Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats by considering them in the review process for flood control and shoreline protection projects. <p><i>Re-write of recommendations to provide clarity and recognize existing requirements. New subject references and information provided.</i></p>
Log Transfer Facilities / In-water Log Storage	<ul style="list-style-type: none"> • The physical, chemical, and biological impacts of Log Transfer Facility operations can be substantially reduced by adherence to appropriate siting and operational constraints. In 1985, the Alaska Timber Task Force (ATTF) developed guidelines to “delineate the physical requirements necessary to construct a log transfer and associated facilities, and in context with requirements of applicable law and regulations, methods to avoid or control potential impacts from these facilities on water quality, aquatic and other resources.” Since 1985, the ATTF guidelines have been applied to new LTFs through the requirements of the National Pollutant Discharge Elimination System permits and other state and federal programs (USEPA 1996). Adherence to the ATTF operational and siting guidelines and BMPs in the NPDES General Permit will reduce (1) the amount of bark and wood debris that enters the marine and coastal environment, (2) the potential for displacement or harm to aquatic species, and (3) the accumulation of bark and wood debris on the ocean floor. <p><i>Re-write of recommendations to provide clarity and recognize existing requirements. New subject references and information provided.</i></p>
Utility Line / Cables / Pipeline Installation	<p><i>Existing recommendations are adequate.</i> <i>Minor editorial comments.</i> <i>New subject references and information provided.</i></p>
Mariculture* <i>*Section title changed for clarity.</i>	<ul style="list-style-type: none"> • Ensure that mariculture facilities spat and related items transported from other areas are free of nonindigenous species. For control of Didemnum tunicates, remove nets, floats, and other structures from salt water periodically and allow them to dry thoroughly, and/or soak them in fresh water. <p><i>Existing section title changed for clarity.</i> <i>Minor editorial comments.</i> <i>New subject references and information provided.</i></p>
Point Source Discharge	<p><i>Existing recommendations are adequate.</i> <i>Minor editorial comments.</i> <i>New subject references and information provided.</i></p>

Activity	New EFH Conservation Recommendations (bullets) <i>Other recommended changes to non-fishing FMP text (italics)</i>
Fish Processing Waste – Shoreside and Vessel Operation	<ul style="list-style-type: none"> • Encourage the use of secondary or wastewater treatment systems where possible. • Monitor biological and chemical changes to the site of seafood processing waste discharges. <p><i>Clarification of recommendations to recognize existing requirements. New subject references and information provided.</i></p>
Water Intake Structures / Discharge Plumes	<p><i>Existing recommendations are adequate. Minor editorial comments. New subject references and information provided.</i></p>
Oil and Gas Exploration / Development / Production	<ul style="list-style-type: none"> • Evaluate potential impacts that may result to EFH from activities carried out during the decommissioning phase of oil and gas facilities. Minimize such impacts to the extent practicable. • Vessel operations and shipping activities should be familiar with Alaska Geographic Response Strategies (GRS) which detail environmentally sensitive areas of Alaska's coastline. Currently, GRSs exist for the many different regions and areas including Southeast Alaska, South Central Alaska, Kodiak Island, Prince William Sound, Cook Inlet, Bristol Bay, Northwest Arctic, North Slope, and the Aleutian Islands (see http://www.dec.state.ak.us/spar/perp/grs/home.htm). <p><i>Clarification of recommendations to recognize existing requirements. New subject references and information provided.</i></p>
Habitat Restoration and Enhancement	<p><i>Existing recommendations are adequate. Minor editorial comments. New subject references and information provided.</i></p>

8.3 Expected effects of Alternatives

8.3.1 Alternative 1 – No action; status quo

In 2005, the Council and NMFS developed a comprehensive EFH EIS (NMFS 2005) evaluating alternatives and environmental consequences for describing and identifying EFH for all the fisheries managed by the Council except the Arctic FMP (EFH in the Arctic FMP was analyzed in the environmental assessment (EA) adopting the FMP, NMFS 2009). The impacts analysis in the 2005 EFH EIS is incorporated by reference. A more complete description of the EIS and its conclusions is included in Section 3.2 with respect to the description and identification of EFH. The EFH EIS (NMFS 2005) identified that the action (status quo) could have indirect negative effects for the non-fishing industries and other entities that may face recommendations that are designed to protect fish habitats. The analysis identified that there would likely be indirect positive effects for the habitats and species that could be protected by measures to minimize effects of non-fishing activities on EFH resulting indirectly from EFH description and identification.

8.3.2 Alternative 2 – Amend EFH conservation recommendations for non-fishing activities in all Council FMPs

Under Alternative 2, the recommendations for entities conducting non-fishing activities in areas that are considered EFH have been updated. Entities taking action (both fishing and non-fishing) in areas designated as EFH are already required to consult with NMFS on EFH in areas identified as EFH. There are no regulations that will result from this alternative; the recommendations are guidelines only and do not have the force of law. The proposed action contemplated under Alternative 2 differs very little from the status quo, which was comprehensively analyzed in the 2005 EFH EIS (NMFS 2005) and the EA

implementing the Arctic FMP (NMFS 2009). Since the proposed action updates the information used from non-fishing activity consultations under the status quo, as identified in the 2005 EFH EIS, there would likely be indirect positive effects for the habitats and species that could be protected by measures to minimize effects of non-fishing activities on EFH resulting indirectly from EFH description and identification. These updates are not expected to make large changes to the consultation process and therefore only slight beneficial effects are expected.

8.4 Outreach efforts for informing stakeholders of changes to the EFH conservation recommendations for non-fishing activities

NMFS Habitat Conservation Division routinely informs stakeholders and the public of EFH consultation requirements through specific EFH consultation training sessions, posting of NMFS official comment letters, and by making information readily accessible on the NMFS website at www.alaskafisheries.noaa.gov.

EFH training occurs every couple of years or as specifically requested. Specifically, NMFS invites federal, state, tribal, academic, and any interested consulting firms to attend EFH workshops. Discussion addresses how the MSA, and associated EFH provisions, are applied to federal agencies, including NMFS, and their actions that may adversely affect EFH. A summary of fisheries management explains NMFS' role to manage healthy, sustainable fish stocks using a rigorous, public management process through the Council. The training further details what is required of federal action agencies should they determine their activity may adversely affect EFH resources.

NMFS posts correspondence for actions where NMFS has offered comment to conserve EFH. NMFS' official comment letters give the public and natural resource developers working with EFH ideas as to what NMFS might specifically offer as EFH conservation recommendations. Posting occurs at: <http://www.alaskafisheries.noaa.gov/index/habitat/correspondence.asp>.

NMFS makes EFH information readily available online at: <http://www.alaskafisheries.noaa.gov/habitat/efh.htm>. The website provides: Frequently Asked Questions, EFH Regulations, EFH Descriptions and Identification, Analyses, and EFH Species Habitat Assessment Reports.

Additionally, with respect to the proposed changes anticipated in this amendment, NMFS has contacted several of the resource development groups that provided comment on the non-fishing EFH conservation recommendations in the past (i.e., during the process culminating in the 2005 EFH EIS), to inform them that changes to the recommendations are being proposed. The organizations that have been contacted are the Resource Development Council, Alaska Miners Association, Alaska Oil and Gas Association, and Alaska Forest Association. Comments from these and other stakeholders have been considered by the Council and NMFS during the development of this amendment.

9 Action 6 – Amendment to revise the HAPC process timeline to coincide with the EFH five-year review

9.1 Background

HAPCs are areas within EFH that may require additional protection from adverse effects. The Council has a formalized process identified in its FMPs for selecting HAPCs. Under this process, the Council periodically considers whether to set priority habitat type. If so, the Council initiates a call for proposals for HAPC candidate areas that meet the specific priority habitat type. Members of the public, organizations, and federal and other agencies may submit HAPC proposals. Sites proposed under this process are reviewed, and the Council may choose to select HAPC proposals for analysis and implementation. As identified in the Council's FMPs, HAPC proposals may be solicited every 3 years or on a schedule established by the Council.

9.1.1 Council policy statement on the HAPC process

In conjunction with this action and also the ongoing HAPC proposal process on skate egg concentration sites, the Council has identified that there is some ambiguity in the Council's HAPC process with respect to whether Council HAPC priorities are considered to be valid in perpetuity, or whether they are specific to a particular HAPC cycle, and in effect, expire at the conclusion of a particular call for proposals and subsequent Council action. At the February 2011 Council meeting, the Council considered this ambiguity, and made a policy statement with respect to how the Council's HAPC process should be interpreted. The Council has indicated that a HAPC priority exists exclusively for the duration of a Council HAPC proposal cycle. This means that HAPC site proposals for a previously-designated HAPC priority may not be submitted on a continuing basis. No HAPC proposals responding to a given HAPC priority need be accepted after the conclusion of the HAPC proposal cycle, unless (a) the Council re-designates that particular HAPC priority, and initiates another HAPC proposal cycle; or (b) NMFS brings forward compelling information to suggest that the Council should re-designate the HAPC priority.

During the development of the Council's HAPC process (as outlined in the 2005 EFH EIS), it was understood that there would be two primary avenues for alerting the Council to habitat priorities that might need consideration as HAPCs. The first is the Council's periodic consideration of habitat priorities, at which time staff, the Plan Teams, or members of the public may bring up habitat issues for Council consideration. Under the current program, this periodic review occurs every 3 years, however the proposed amendment would change this review period to 5 years so that the gathering of information for the 5-year EFH review can provide the basis of the Council's HAPC consideration.

At the same time, it was understood that NMFS would be reviewing habitat information on a continuous basis. When warranted, NMFS is able to bring proposed habitat concerns, or suggested HAPC priorities, to the Council, and the Council may act upon them. The HAPC process language in the FMP, which would remain unchanged under the proposed amendment, allows the Council to initiate a HAPC process and solicit HAPC proposals "on a schedule established by the Council."

9.2 Description of Alternatives

Alternative 1 – No Action; status quo

Alternative 2 – PREFERRED – Revise timeline for considering HAPCs from three to five years in all six Council FMPs

Under Alternative 2, the default timeline for considering HAPC priorities and calling for HAPC proposals would be extended from 3 to 5 years, although the Council retains the flexibility to initiate a HAPC process at any time of its choosing. The change to the default timeline was initially recommended by the Council's SSC and Ecosystem Committee in order to synchronize the HAPC process with the regulatory 5-year EFH review. During the course of the EFH review, habitat issues are fully vetted by the Council, the Council's Plan Teams, and stock assessment authors, and habitat scientists. The SSC suggested, and the Council agreed, that this is an appropriate process that may be used to identify HAPC priorities.

The recommendation to change the HAPC timeframe was discussed in the EFH 5-year review, which addressed five of the Council's FMPs. The change in timing, however, is also applicable to the Council's sixth and newest FMP, the Arctic FMP. Consequently, the Council has indicated that this action will also apply to the Arctic FMP.

9.3 Expected effects of Alternatives

In 2005, the Council and NMFS developed a comprehensive EFH EIS (NMFS 2005) evaluating alternatives and environmental consequences for identifying a process for identifying HAPC. The process adopted in the FMPs provides a default 3-year timeline for considering whether to initiate HAPC proposals, although the Council may always identify a HAPC priority and call for proposals at any time of their choosing.

Under Alternative 2, the default timeline for considering whether to initiate the HAPC process would be extended to 5 years. Under this alternative, the Council would benefit from results of the EFH 5-year review in considering whether to identify HAPC priorities. The Council would still retain the flexibility to identify HAPC priorities mid-cycle, if appropriate. There is no requirement that the HAPC process be considered on a prescribed timeline; therefore the change in proposed timing is solely a matter of Council discretion, and public policy for the Council in signaling to the public the default timeline for considering HAPC sites. The updating of the timeframe in the FMPs is a housekeeping action; as a result, no impacts have been identified under Alternative 2 and therefore it would have no significant impacts on the human environment.

10 Action 7 – Revise FMP Research Objectives

10.1 Background – EFH research approach

One of the required components of the EFH provisions of each FMP is to include research and information needs. The Council's five FMPs (all except the Arctic FMP) include EFH research objectives, questions, activities, and a time frame, which were developed during the 2005 EFH EIS.

The following is currently included as the research approach in the Council's FMPs:

Objectives

Reduce impacts. (1) Limit bottom trawling in the Aleutian Islands to areas historically fished and prevent expansion into new areas. (2) Limit bottom contact gear in specified coral garden habitat areas. (3) Restrict higher impact trawl fisheries from a portion of the GOA slope. (4) Increase monitoring for enforcement. (5) Establish a scientific research program.

Benthic habitat recovery. Allow recovery of habitat in a large area with relatively low historic effort.

Research Questions

Reduce impacts. Does the closure effectively restrict higher-impact trawl fisheries from a portion of the GOA slope? Is there increased use of alternative gears in the GOA closed areas? Does total bottom trawl effort in adjacent open areas increase as a result of effort displaced from closed areas? Do bottom trawls affect these benthic habitats more than the alternative gear types? What are the research priorities? Are fragile habitats in the Aleutian Islands affected by any fisheries that are not covered by the new EFH closures? Are sponge and coral essential components of the habitat supporting FMP species?

Benthic habitat recovery. Did the habitat within closed areas recover or remain unfished because of these closures? Do recovered habitats support more abundant and healthier FMP species? If FMP species are more abundant in the EFH protection areas, is there any benefit in yield for areas that are still fished without EFH protection?

Research Activities

Reduce impacts. Fishing effort data from observers and remote sensing would be used to study changes in bottom trawl and other fishing gear activity in the closed (and open) areas. First, the recent gear-specific fishing pattern must be characterized to establish a baseline for comparison with observed changes in effort after closures occur. An effective analysis of change requires comprehensive effort data with high spatial resolution, including accurate information about the tow path or setting location, as well as complete gear specifications. Effects of displaced fishing effort would have to be considered. The relative effects of bottom trawl and alternative gear/footrope designs and, thus, the efficacy of the measure should be investigated experimentally in a relatively undisturbed area that is representative of the closed areas. The basis of comparison would be changes in the structure and function of benthic communities and populations, as well as important physical features of the seabed, after comparable harvests of target species are taken with each gear type. Ultimately, there should be detectable increases in FMP species that are directly attributable to the reduced impacts on sponge and coral habitat.

Benthic habitat recovery. Monitor the structure and function of benthic communities and populations in the newly closed areas, as well as important physical features of the seabed, for changes that may indicate recovery of benthic habitat. Whether these changes constitute recovery from fishing or just natural variability/shifts requires comparison with an area that is undisturbed by

fishing and otherwise comparable. A reference site would have to remain undisturbed by fishing during the entire course of the recovery experiment. Such a reference site may or may not exist, and the essential elements of comparability for identifying this area are presently unknown. Without proper reference sites, it may still be possible to deduce recovery dynamics based on changes observed in comparable newly closed areas with different histories of fishing disturbance.

Research Time Frame

Changes in fishing effort and gear types should be readily detectable. Biological recovery monitoring may require an extended period if undisturbed habitats of this type typically include large or long-lived organisms and/or high species diversity. Recovery of smaller, shorter-lived components should be apparent much sooner.

The research objectives that are defined under this approach have largely been met by the Council in the time period since the 2005 EFH EIS was developed. A discussion of the Council's actions with respect to EFH is included in the 2010 EFH 5-year review Summary Report.

In addition, as part of the EFH 5-year review, each stock assessment author provided a stock-specific evaluation of EFH research needs. Although it is not proposed that this list of information should be included in the FMPs, it is being used by the Council in the development of the overall annual research priorities. The Council also recommends both the overall research approach and the stock-specific research needs be used in EFH research planning.

10.2 Description of Alternatives

Alternative 1 – No Action; status quo

Alternative 2 – PREFERRED – Revise research objectives and research activities for EFH in five Council FMPs

At initial review in February 2011, the Council's Scientific and Statistical Committee (SSC) suggested minor edits to the way the revisions to the research approach were formulated. The following text was provided by the SSC, with a restated research objective, and the research activities section edited and expanded to include additional activities identified during the 5-year EFH review.

Under Alternative 2, the research objectives currently in the FMPs (see above) would be replaced with the following overarching objective:

Establish a scientific research and monitoring program to understand the degree to which impacts have been reduced within habitat closure areas, and to understand how benthic habitat recovery of key species is occurring.

Additionally, the section on research activities would be replaced with the following:

- Fishing effort data from observers and remote sensing would be used to study changes in bottom trawl and other fishing gear activity in the closed (and open) areas. Effects of displaced fishing effort would have to be considered. The basis of comparison would be changes in the structure and function of benthic communities and populations, as well as important physical features of the seabed, after comparable harvests of target species are taken with each gear type.
- Monitor the structure and function of benthic communities and populations in the newly closed areas, as well as important physical features of the seabed, for changes that may indicate recovery of benthic habitat. Whether these changes constitute recovery from fishing or just natural

variability/shifts requires comparison with an area that is undisturbed by fishing and otherwise comparable.

- Validate the LEI model and improve estimates of recovery rates, particularly for the more sensitive habitats, including coral and sponge habitats in the Aleutian Islands region, possibly addressed through comparisons of benthic communities in trawled and untrawled areas.
- Obtain high resolution mapping of benthic habitats, particularly in the on-shelf regions of the Aleutian Islands.
- Time series of maturity at age should be collected to facilitate the assessment of whether habitat conditions are suitable for growth to maturity.
- In the case of red king crab spawning habitat in southern Bristol Bay, research the current impacts of trawling on habitat in spawning areas and the relationship of female crab distribution with respect to bottom temperature.

The remainder of the research approach (research questions and research time frame) remains valid and will be kept unchanged in the FMPs.

10.3 Expected effects of Alternatives

In 2005, the Council and NMFS developed a comprehensive EFH EIS (NMFS 2005) that identified a research approach for EFH. The research approach is identified in the section above. The research objectives included under that research approach have largely been met over last 5 years.

Under Alternative 2, the Council has proposed new objectives and activities for EFH research, which would replace or revise the objectives and activities currently listed in all of the Council's FMPs except the Arctic FMP (research objectives specifically for the Arctic were developed when that FMP was adopted in 2009). The updating of these objectives is a housekeeping action. No immediate impacts have been identified under Alternative 2, however, longer term beneficial impacts to habitat may result from these research activities. Therefore this action is not likely to result in significant impacts on the human environment.

11 Conclusions

The EFH Omnibus Amendment would implement amendments of EFH provisions: Amendment 98 to the BSAI Groundfish FMP; Amendment 90 to the GOA Groundfish FMP; Amendment 40 to the BSAI Crab FMP; Amendment 15 to the Scallop FMP; and Amendment 1 to the Arctic FMP. Changes to the Salmon FMP will be implemented with Amendment 12 to the Salmon FMP, as EFH descriptions for salmon are not available at this time. This action is necessary to update these FMPs with the best scientific information for the EFH components. The EFH Final Rule and each of the Council's FMPs state that a review of EFH components should be completed every 5 years. The most recent review was completed in April 2010 and synthesized in a Summary Report.

NOAA Administrative Order 216-6 (NAO 216-6) (May 20, 1999) contains criteria for determining the significance of the impacts of a proposed action. In addition, the Council on Environmental Quality regulations at 40 CFR 1508.27 state that the significance of an action should be analyzed both in terms of "context" and "intensity." Significance was determined by considering the contexts (geographic, temporal, and societal) in which the action would occur, and the intensity of the effects of the action. The evaluation of intensity included consideration of the magnitude of the impact, the degree of certainty in the evaluation, the cumulative impact when the action is related to other actions, the degree of controversy, and consistency with other laws.

Context: For this action the setting is the Bering Sea and Aleutian Islands management area, the Gulf of Alaska, and the Arctic Ocean. Any effects of this action are limited to these areas.

Intensity: Listings of considerations to determine intensity of the impacts are in 40 CFR 1508.28(b) and in the NAO 216-6, Section 6. Each consideration is addressed below in order as it appears in the NMFS Instruction 30-124-1 dated July 22, 2005, Guidelines for Preparation of a FONSI. The preferred alternatives are the focus of the responses to the questions.

1) Can the proposed action reasonably be expected to jeopardize the sustainability of any target species that may be affected by the action?

Response: No. The proposed action will have no impact on the sustainability of the target species. Target species are those species managed under the BSAI Groundfish FMP; GOA Groundfish FMP; BSAI Crab FMP; Scallop FMP; and the Arctic FMP. As mentioned in Sections 4.3.2, 5.3.2, 6.3.2, and 7.3.2 of the EA, the preferred alternatives would result in relatively minor changes to the existing EFH descriptions for the target stocks, and the impact of the changes is not substantively different from that analyzed in the 2005 EFH EIS. Updated information on EFH for each FMP species would improve management.

2) Can the proposed action reasonably be expected to jeopardize the sustainability of any non-target species?

Response: No. The proposed action will have no impact on the sustainability of the non-target species that are caught in the fisheries of the above-referenced FMPs. The proposed action amends EFH information and will not affect the management of these species. The proposed revisions to EFH text and maps are minor and the impact of the changes proposed under these amendments is not substantively different from that analyzed in the 2005 EFH EIS.

3) Can the proposed action reasonably be expected to cause substantial damage to the ocean and coastal habitats and/or essential fish habitat as defined under the Magnuson-Stevens Act and identified in FMPs?

Response: No. The proposed action will have no damaging effect on ocean and coastal habitats and/or essential fish habitat. The proposed revisions to EFH text and maps are minor and the impact of the changes proposed under these amendments is not substantively different from that analyzed in the 2005 EFH EIS. The inclusion of more up-to-date and accurate EFH information might have a slightly beneficial impact on ocean and coastal habitats and/or essential fish habitat compared to status quo by better informing fisheries management.

4) Can the proposed action be reasonably expected to have a substantial adverse impact on public health or safety?

Response: No, the proposed action will have no impact on public health and safety. The proposed revisions to EFH text and maps are minor. The impact of the changes proposed under these amendments is not substantively different from that analyzed in the 2005 EFH EIS, and no changes are expected in fisheries activities that would lead to public health impacts or safety impacts.

5) Can the proposed action reasonably be expected to adversely affect endangered or threatened species, marine mammals, or critical habitat of these species?

Response: No, the proposed action will not affect endangered or threatened species, marine mammals, or critical habitat of these species. The proposed revisions to EFH text and maps are minor and the impact of the changes proposed under these amendments is not substantively different from that analyzed in the 2005 EFH EIS. The inclusion of more up-to-date and accurate EFH information might have a slight beneficial impact on endangered or threatened species, marine mammals, or critical habitat compared to status quo by better informing fisheries management for managed fish species that may also be used by ESA-listed species or marine mammals.

6) Can the proposed action be expected to have a substantial impact on biodiversity and/or ecosystem function within the affected area (e.g., benthic productivity, predator-prey relationships, etc.)?

Response: No, the proposed action is not expected to impact biodiversity and/or ecosystem function within the affected areas. The proposed revisions to EFH text and maps are minor, and the impact of the changes proposed under these amendments is not substantively different from that analyzed in the 2005 EFH EIS. Any adjustments to fisheries management based on the minor changes to the EFH descriptions are not expected to have ecosystem level impacts or impacts on biodiversity.

7) Are significant social or economic impacts interrelated with natural or physical environmental effects?

Response: No, there are no significant social or economic impacts interrelated with natural or physical environmental effects. The proposed revisions to EFH text and maps are minor, and the impact of the changes proposed under these amendments is not substantively different from that analyzed in the 2005 EFH EIS. No social or economic impacts are expected with the EFH description changes, as only minor shifts in fisheries management may occur and no overall changes in economic or social aspects of the fisheries are expected.

8) Are the effects on the quality of the human environment likely to be highly controversial?

Response: No, the effects on the quality of the human environment are not likely to be controversial. The proposed revisions to EFH text and maps are minor and the impact of the changes proposed under these

amendments is not substantively different from that analyzed in the 2005 EFH EIS. The effects of describing EFH are not controversial as any changes to fisheries management due to the minor changes in the EFH descriptions are well understood and described in the 2005 EFH EIS; there is no new information that would lead to different effects conclusions.

9) Can the proposed action reasonably be expected to result in substantial impacts to unique areas, such as historic or cultural resources, park land, prime farmlands, wetlands, wild and scenic rivers or ecologically critical areas?

Response: No, the proposed action is not expected to result in impacts to unique areas. EFH may include ecologically sensitive areas, but this action is only a description of EFH to use in consideration of fisheries management measures and EFH consultation. No substantial impacts on these areas are expected because the proposed revisions to EFH text and maps are minor, and the impact of the changes proposed under these amendments is not substantively different from that analyzed in the 2005 EFH EIS.

10) Are the effects on the human environment likely to be highly uncertain or involve unique or unknown risks?

Response: No, the effects on the human environment are not likely to be uncertain or involve unique or unknown risks. The proposed revisions to EFH text and maps are minor, and the impact of the changes proposed under these amendments is not substantively different from that analyzed in the 2005 EFH EIS. Impacts of describing EFH are well known as shown in the 2005 EFH EIS.

11) Is the proposed action related to other actions with individually insignificant, but cumulatively significant impacts?

Response: No, the proposed action is not related to other actions with individually insignificant, but cumulative significant impacts. The proposed revisions to EFH text and maps are minor, and the impact of the changes proposed under these amendments is not substantively different from that analyzed in the 2005 EFH EIS. No additional past, present, or reasonably foreseeable future actions beyond those described in the cumulative effects analysis in the 2005 EFH EIS have been identified that would combine with the minor beneficial effects of improved EFH descriptions to result in significant cumulative effects.

12) Is the proposed action likely to adversely affect districts, sites, highways, structures, or objects listed in or eligible for listing in the National Register of Historic Places or may cause loss or destruction of significant scientific, cultural or historical resources?

Response: No, the proposed action will not adversely affect districts, sites, highways, structures, or objects listed in or eligible for listing in the National Register of Historic Places or cause loss or destruction of significant scientific, cultural, or historical resources. This action occurs in the exclusive economic zone off Alaska, which does not contain these types of sites. This action revises EFH text and maps and will result in the minor beneficial effect of improved fisheries management through more accurate EFH descriptions.

13) Can the proposed action reasonably be expected to result in the introduction or spread of a nonindigenous species?

Response: No, the proposed action is not reasonably expected to result in the introduction or spread of a nonindigenous species as this action has no effect on the location or participation of fishing vessels in the fisheries that could result in the introduction of invasive species.

14) Is the proposed action likely to establish a precedent for future actions with significant effects or represents a decision in principle about a future consideration?

Response: No, the proposed action is not likely to establish a precedent for future actions with significant effects or represent a decision in principle about a future consideration. The schedule for revisions to EFH descriptions are mandated by the Magnuson-Stevens Act and the FMPs for Alaska fisheries, as analyzed in the 2005 EFH EIS and implemented in 2006. The proposed revisions to EFH text and maps are minor, and the impact of the changes proposed under these amendments is not substantively different from that analyzed in the 2005 EFH EIS.

15) Can the proposed action reasonably be expected to threaten a violation of federal, state, or local law or requirements imposed for the protection of the environment?

Response: No, the proposed action is not expected to threaten a violation of federal, state, or local law or requirements imposed for the protection of the environment. The proposed revisions to EFH text and maps are minor, and the impact of the changes proposed under these amendments is not substantively different from that analyzed in the 2005 EFH EIS. The action is consistent with requirements of the Magnuson-Stevens Act established for the identification and conservation of EFH and does not conflict with any other laws for the protection of the environment.

16) Can the proposed action reasonably be expected to result in cumulative adverse effects that could have a substantial effect on the target species or non-target species?

Response: No, the proposed action is not expected to result in cumulative adverse effects that could have a substantial effect on the target species or non-target species. The proposed revisions to EFH text and maps are minor, and the impact of the changes proposed under these amendments is not substantively different from that analyzed in the 2005 EFH EIS. No additional past, present, or reasonably foreseeable future actions beyond those described in the 2005 EFH EIS have been identified that would combine with the minor beneficial effects of improved EFH descriptions to result in significant cumulative effects on target or non-target species.

12 Preparation of Document

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13 References

- [Council] North Pacific Fishery Management Council. 2009. Fishery Management Plan for Fish Resources of the Arctic Management Area. 605 West 4th Ave, Suite 306, Anchorage, AK 99501-2252.
- [Council] North Pacific Fishery Management Council and NMFS. 2010. Essential Fish Habitat (EFH) 5-year Review for 2010 Summary Report: Final. April 2010.
<http://www.alaskafisheries.noaa.gov/habitat/efh/review.htm>.
- NMFS. 2005. Final Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska. March 2005. NMFS, P.O. Box 21668, Juneau, AK 99801.
<http://alaskafisheries.noaa.gov/habitat/seis/efheis.htm>
- Scott G.I., M.H. Fulton, D.W. Moore, E.F. Wirth, G.T. Chandler, P.B. Key, J.W. Daugomah, E.D. Strozier, J. Devane, J.R. Clark, M.A. Lewis, D.B. Finley, W. Ellenberg, and K.J. Karnaky. 1999. "Assessment of risk reduction strategies for the management of agricultural nonpoint source pesticide runoff in estuarine ecosystems." *Toxicology and Industrial Health*. 15:200-213.
- USEPA, Region 10. 1996. Authorization to discharge under the National Pollutant Discharge Elimination System (NPDES) for Section 402 modifications of Section 404 permits for log Transfer Facilities which received a Section 404 permit prior to October 22, 1985. NPDES Permit Number AK-G70-1000. EPA Response to Comments from September 1996 Public Notice <http://info.dec.state.ak.us/DECPermit/water31rtc.pdf>.

Appendices

Appendix 1	BSAI Groundfish FMP Amendment Text
Appendix 2	GOA Groundfish FMP Amendment Text
Appendix 3	BSAI Crab FMP Amendment Text
Appendix 4	Scallop FMP Amendment Text
Appendix 5	Arctic FMP Amendment Text
Appendix 6	Impacts to EFH from Non-fishing Activities

Appendix 1 BSAI Groundfish FMP Amendment 98- amendment text for updating EFH description and non-fishing impacts to EFH, changing HAPC timeline, and updating EFH research objectives (EFH Omnibus Amendment)

Make the following changes to Section 4, Section 6, Appendix A, Appendix D, Appendix E, Appendix F, and Appendix H of the Fishery Management Plan for Groundfish of the Bering Sea/Aleutian Islands Management Area. When edits to existing sections are proposed, words indicated with ~~strikeout~~ (e.g., ~~strikeout~~) should be deleted from the FMP, and words that are underlined (e.g., underlined) should be inserted into the FMP. Instructions are italicized and highlighted. Note, instructions reference three supplemental files: Appendix D, Appendix E, and Appendix F.2.

1. In Section 3.10.2, Schedule for Review, revise the second paragraph under the subheading “Essential Fish Habitat Components” as follows:

Additionally, the Council may ~~use the FMP amendment cycle every three years to~~ solicit proposals for habitat areas of particular concern (HAPC) and/or conservation and enhancement measures to minimize the potential adverse effects of fishing. Those proposals that the Council endorses would be implemented through FMP amendments. HAPC proposals may be solicited every 5 years, coinciding with the EFH 5-year review, or may be initiated at any time by the Council.

2. In Section 4.2.2, make the following edits to the existing text:

4.2.2 Essential Fish Habitat Definitions

EFH is defined in the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act) as “those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity.” EFH for groundfish species is determined to be the general distribution of a species described by life stage. General distribution is a subset of a species’ total population distribution, and is identified as the distribution of 95 percent of the species population, for a particular life stage, if life history data are available for the species. Where information is insufficient and a suitable proxy cannot be inferred, EFH is not described. General distribution is used to describe EFH for all stock conditions whether or not higher levels of information exist, because the available higher level data are not sufficiently comprehensive to account for changes in stock distribution (and thus habitat use) over time.

EFH is described for FMP-managed species by life stage as general distribution using ~~new~~ guidance from the EFH Final Rule (50 CFR 600.815), such as including the updated EFH Level of Information definitions. New analytical tools are used and recent scientific information is incorporated for each life history stage from updated scientific habitat assessment reports (see Appendix F to ~~the~~ NMFS 2005, and NPFMC and NMFS 2010). EFH descriptions include both text (Section 4.2.2.2) and maps (Section 4.2.2.3 and Appendix E), if information is available for a species’ particular life stage. These descriptions are risk averse, supported by scientific rationale, and accounts for changing oceanographic conditions, regime shifts, and the seasonality of migrating fish stocks.

EFH descriptions are interpretations of the best scientific information. In support of this information, a thorough review of FMP species is contained in the Environmental Impact Statement for Essential Fish Habitat Identification and Conservation (NMFS 2005) (EFH EIS) ~~is contained~~ in Section 3.2.1, Biology, Habitat Usage, and Status of Magnuson-Stevens Act Managed Species and detailed by life history stage in Appendix F: EFH Habitat Assessment Reports. This EIS was supplemented in 2010 by a 5-year

review, which re-evaluated EFH descriptions and fishing and non-fishing impacts on EFH in light of new information (NPFMC and NMFS 2010).

3. In Section 4.2.2.1, replace Table 4-9 and the associated table notes with the following revised table and table notes:

Table 4-9 Levels of essential fish habitat information currently available for BSAI groundfish, by life history stage.

Species	Eggs	Larvae	Early Juveniles	Late Juveniles	Adults
Pollock	1	1	x	1	1
Pacific cod	x	1	x	1	1
Sablefish	x	1	x	1	1
Yellowfin sole	x	x	x	1	1
Greenland turbot	1	1	x	1	1
Arrowtooth flounder	x	x	x	1	1
Kamchatka flounder	x	x	x	1	1
Northern rock sole	x	1	x	1	1
Alaska plaice	1	x	x	1	1
Rex sole	x	x	x	1	1
Dover sole	x	x	x	1	1
Flathead sole	1	1	x	1	1
Pacific ocean perch	x	1	x	1	1
Northern rockfish	x	1	x	1	1
Shortraker rockfish	x	x	x	x	1
Blackspotted/ roughey rockfish	x	x	x	x	1
Dusky rockfish	x	1	x	x	1
Thornyhead rockfish	x	1	x	1	1
Atka mackerel	1	1	x	x	1
Squids	x	x	x	1	1
Sculpins	x	x	x	1	1
Skates	1	x	x	x	1
Sharks	x	x	x	x	x
Octopuses	x	x	x	x	x
Forage fish complex	x	x	x	x	x

Juveniles were subdivided into early and late juvenile stages based on survey selectivity curves.

Note: "1" indicates general distribution data are available for some or all portions of the geographic range of the species; "x" indicates insufficient information is available to describe EFH.

4. In Section 4.2.2.2.1, make the following edits to the early juvenile, late juvenile, and adult descriptions for pollock:

Early Juveniles: No EFH ~~d~~Description ~~d~~Determined. Information is insufficient information is available due to these ages (primarily age 2) being unavailable to bottom-trawl survey gear and partially available to echo-integrated mid-water trawl surveys.

Late Juveniles: EFH for late juvenile walleye pollock is the general distribution area for this life stage, located in the lower and middle portion of the water column along the inner (0 to 50 m), middle (50 to 100 m), and outer (100 to 200 m) shelf throughout the BSAI, as depicted in Figure E-3. ~~No known preference for s~~Substrate preferences, if they exist, are unknown.

Adults: EFH for adult walleye pollock is the general distribution area for this life stage, located in the lower and middle portion of the water column along the entire shelf (~10 to 200 m) and slope (200 to 1,000 m) throughout the BSAI, as depicted in Figure E-3. ~~No~~

~~known preference for substrates exist.~~ Substrate preferences, if they exist, are unknown.

5. In Section 4.2.2.2.2, make the following edits to the egg description for Pacific cod:

Eggs: ~~No EFH dDescription dDetermined. Scientific information notes the rare occurrence of Pacific cod eggs in the BSAI. Pacific cod eggs, which are demersal, are rarely encountered during surveys in the BSAI.~~

6. In Section 4.2.2.2.3, replace references to “Figure E-20” and “Figure E-21” with “Figure E-6” and “Figure E-7”, respectively. Make the following edits to the early juvenile description for sablefish:

Early Juveniles: ~~No EFH dDescription dDetermined. Insufficient information is available. Generally, have been observed in inshore water, bays, and passes, and on shallow shelf pelagic and demersal habitat. Information is limited.~~

7. In Section 4.2.2.2.4, Yellowfin Sole, replace reference to “Figure E-6” with “Figure E-8”.

8. In Section 4.2.2.2.5, Greenland Turbot, replace references to “Figure E-7”, “Figure E-8”, and “Figure E-9” with “Figure E-9”, “Figure E-10”, and “Figure E-11”, respectively.

9. In Section 4.2.2.2.6, Arrowtooth Flounder, replace reference to “Figure E-10” with “Figure E-12”.

10. In Section 4.2.2.2.7, change the title from “Rock Sole” to “Northern Rock Sole”. Replace reference to “Figure E-11” with “Figure E-14”. Replace reference to “Figure E-12” with “Figure E-15”.

11. In Section 4.2.2.2.8, Alaska Plaice, replace reference to “Figure E-13” with “Figure E-16”. Replace reference to “Figure E-14” with “Figure E-17”.

12. In Section 4.2.2.2.9, Rex Sole, replace reference to “Figure E-15” with “Figure E-18”.

13. In Section 4.2.2.2.10, Dover Sole, replace reference to “Figure E-16” with “Figure E-19”.

14. In Section 4.2.2.2.11, Flathead Sole, replace references to “Figure E-17”, “Figure E-18”, and “Figure E-19” with “Figure E-20”, “Figure E-21”, and “Figure E-22”, respectively.

15. In Section 4.2.2.2.12, Pacific Ocean Perch, replace reference to “Figure E-22” with “Figure E-23”. Replace reference to “Figure E-23” with “Figure E-24”.

16. In Section 4.2.2.2.13, replace reference to “Figure E-22” with “Figure E-23”. Make the following edits to the late juvenile and adult descriptions for northern rockfish:

Late Juveniles: ~~No EFH Description Determined. Insufficient information is available.~~ EFH for late juveniles is the general distribution area for this life stage, located in the middle and lower portions of the water column along the outer slope (100 to 200 m) throughout the BSAI, wherever there are substrates of cobble and rock.

Adults: ~~EFH for adult northern rockfish is the general distribution area for this life stage, located in the middle and lower portions of the water column along the outer slope (100 to 200 m) and upper slope (200 to 500 m) throughout the BSAI wherever there are substrates of cobble and rock, as depicted in Figure E-25.~~

17. In Section 4.2.2.2.14, retitle the section as “Shortraker Rockfish”, delete existing descriptions and replace with the following :

- Eggs:** Eggs develop internally, so this category is not applicable.
- Larvae:** No EFH description determined. Insufficient information is available.
- Early Juveniles:** No EFH description determined. Insufficient information is available.
- Late Juveniles:** No EFH description determined. Insufficient information is available.
- Adults:** EFH for adult shortraker rockfish is the general distribution area for this life stage, located in the lower portion of the water column along the outer shelf (100 to 200 m) and upper slope (200 to 500 m) regions throughout the BSAI wherever there are substrates consisting of mud, sand, sandy mud, muddy sand, rock, cobble, and gravel, as depicted in Figure E-26.

18. In Section 4.2.2.2.15, retitle the section as “Blackspotted and Rougheye Rockfish”, delete existing descriptions for yelloweye rockfish, and replace with the following :

- Eggs:** Eggs develop internally, so this category is not applicable.
- Larvae:** No EFH description determined. Insufficient information is available.
- Early Juveniles:** No EFH description determined. Insufficient information is available.
- Late Juveniles:** No EFH description determined. Insufficient information is available.
- Adults:** EFH for adult blackspotted/rougheye rockfish is the general distribution area for this life stage, located in the lower portion of the water column along the outer shelf (100 to 200 m) and upper slope (200 to 500 m) regions throughout the BSAI wherever there are substrates consisting of mud, sand, sandy mud, muddy sand, rock, cobble, and gravel, as depicted in Figure E-27.

19. In Section 4.2.2.2.16, Dusky Rockfish, replace reference to “Figure E-22” with “Figure E-23”.

20. In Section 4.2.2.2.17, Thornyhead Rockfish, replace reference to “Figure E-22” with “Figure E-23”. Replace reference to “Figure E-26” with “Figure E-29”.

21. In Section 4.2.2.2.18, replace reference to “Figure E-29” with “Figure E-31”. Replace reference to “Figure E-30” with “Figure E-32”. Make the following edits to the egg description for atka mackerel:

- Eggs:** ~~No EFH Description Determined. Insufficient information is available.~~ Several nesting sites in the Aleutian Islands have been identified and the habitat described, as depicted in Figure E-30.

22. In Section 4.2.2.2.20, Sculpins, replace reference to “Figure E-32” with “Figure E-34”.

23. In Section 4.2.2.2.21, replace reference to “Figure E-31” with “Figure E-36”. Make the following edits to the egg description for skates:

- Eggs:** ~~No EFH Description Determined. Insufficient information is available.~~ EFH for skate egg cases is defined as the seafloor below the shelf-slope interface in the eastern Bering Sea, in depths from 140 to 360 m, as depicted in Figure E-35.

24. Insert a new section after Section 4.2.2.2.6 “Arrowtooth flounder”, titled Section 4.2.2.2.7 “Kamchatka flounder”, and renumber all subsequent subsections in 4.2.2.2 accordingly. Insert the following text descriptions for the new Section 4.2.2.2.7:

- Eggs:** No EFH description determined. Insufficient information is available.
- Larvae:** No EFH description determined. Limited information exists. Late stage Kamchatka flounder have been caught at depths of 400 m in the Bering Sea.
- Early Juveniles:** No EFH description determined. Insufficient information is available; settlement patterns are unknown.
- Late Juveniles:** EFH for late juvenile Kamchatka flounder is the general distribution area for this life stage, located in the lower portion of the water column along the middle (50 to 100 m), and outer (100 to 200 m) shelf and upper slope (200 to 500 m) throughout the BSAI wherever there are softer substrates consisting of gravel, sand, and mud, as depicted in Figure E-13.
- Adults:** EFH for adult Kamchatka flounder is the general distribution area for this life stage, located in the lower portion of the water column along the middle (50 to 100 m), and outer (100 to 200 m) shelf and slope waters down to 600 m throughout the BSAI wherever there are softer substrates consisting of gravel, sand, and mud, as depicted in Figure E-13.

25. In Section 4.2.2.3, make the following edit to the existing text:

Figures E-1 through E-3336 in Appendix E show EFH distribution for the BSAI groundfish species.

26. In Section 4.2.3, delete the last sentence of the first paragraph, and the second paragraph with associated bullets, as follows:

~~50 CFR 600.815(a)(8) provides guidance to the Councils in identifying HAPCs.~~

~~FMPs should identify specific types or areas of habitat within EFH as habitat areas of particular concern based on one or more of the following considerations:~~

- ~~(i) The importance of the ecological function provided by the habitat.~~
- ~~(ii) The extent to which the habitat is sensitive to human induced environmental degradation.~~
- ~~(iii) Whether, and to what extent, development activities are, or will be, stressing the habitat type.~~
- ~~(iv) The rarity of the habitat type.~~

27. In Section 4.2.3.1, revise the existing final two paragraphs, as follows:

The Council will initiate the HAPC process by setting priorities and issuing a request for HAPC proposals. Any member of the public may submit a HAPC proposal. HAPC proposals may be solicited every 3 years or on a schedule established by the Council 5 years, to coincide with the EFH 5-year review, or may be initiated at any time by the Council. The Council will establish a process to review the proposals. The Council may periodically review existing HAPCs for efficacy and considerations based on new scientific research.

~~Criteria to evaluate the HAPC proposals will be reviewed by the Council and the Scientific and Statistical Committee prior to the request for proposals. The Council will establish a process to review the proposals and may establish HAPCs and conservation measures (NPFMC 2005).~~

28. In Section 6.1.3.2, insert the following new paragraph at the end of the section:

In 2009–2010, the Council undertook a 5-year review of EFH for the Council’s managed species, which was documented in the Final EFH 5-year Review Summary Report published in April 2010 (NPFMC and NMFS 2010). The review evaluated new information on EFH, including EFH descriptions and identification, and fishing and non-fishing activities that may adversely affect EFH. The review also assessed information gaps and research needs, and identified whether any revisions to EFH are needed or suggested. The Council identified various elements of the EFH descriptions meriting revision, and approved omnibus amendments 98/90/40/15/11 to the BSAI Groundfish FMP, the GOA Groundfish FMP, the BSAI King and Tanner Crab FMP, the Scallop FMP, and the Salmon FMP, respectively, in 2011.

29. In Section 6.3, insert the following reference for NPFMC and NMFS 2010 alphabetically, and delete reference for NPFMC 2005 (in strikeout).

NPFMC and NMFS. 2010. Essential Fish Habitat (EFH) 5-year Review for 2010 Summary Report: Final. April 2010. <http://www.alaskafisheries.noaa.gov/habitat/efh/review.htm>

~~NPFMC. 2005. Environmental Assessment/Regulatory Impact Review/Regulatory Flexibility Analysis for Amendments 65/65/12/7/8 to the BSAI Groundfish FMP (#65), GOA Groundfish FMP (#65), BSAI Crab FMP (#12), Scallop FMP (#7) and the Salmon FMP (# 8) and regulatory amendments to provide Habitat Areas of Particular Concern. March 2005. NPFMC 605 West 4th St. Ste. 306, Anchorage, AK 99501-2252. 248pp.~~

30. In Appendix A, insert the following description of this amendment in sequential order, and include the effective date of the approved amendment.

Amendment 98, implemented on _____ (insert effective date)_____, revised Amendment 78:

1. Revise EFH description and identification by species, and update life history, distribution, and habitat association information, based on the 2010 EFH 5-year review.
2. Update description of EFH impacts from non-fishing activities, and EFH conservation recommendations for non-fishing activities.
3. Revise the timeline associated with the HAPC process to a 5-year timeline.
4. Update EFH research priority objectives.

31. In Appendix D, delete existing text and tables, and replace with revised life history text and tables in attached file. Update date in footer.

32. In Appendix E, delete existing text and figures, and replace with revised maps of essential fish habitat text and Figures E-1 to E-36 in attached file. Update date in footer.

33. In Appendix F, Section F.1.5.4, Atka Mackerel, revise the final paragraph as follows :

Stock assessment data do not show a negative trend in spawning biomass and recruitment or evidence of chronic low abundance and recruitment. There is no evidence that the cumulative effects of fishing activities on habitat have impaired the stock’s ability to produce MSY since 1977. Spawning biomass is at a relatively high~~peak~~ level. The stock has produced several years of above average recruitment since 1977, and recent recruitment has been strong.

34. In Appendix F, Section F.1.5.5, Yellowfin Sole, revise the two existing paragraphs as follows :

Summary of Effects—The nearshore areas, where spawning occurs and where early juveniles reside, are mostly unaffected by past and current fishery activities, although there has been an increase in nearshore trawling in some areas during 2002–2007 relative to the 1998–2002 period (and a moderate decrease in mid-shelf areas). Adult and late juvenile yellowfin sole concentrations primarily overlap with the EBS sand (61 percent and sand/mud 39 percent) habitats on the inner- and mid-shelf areas (Table B.3-3 of the EFH EIS). Projected equilibrium reductions in epifauna and infaunal prey in those overlaps were less than 1 percent for sand and 3 percent for sand/mud. The reduction in living structure is estimated at a range of 5 (sand) to 18 (sand/mud) percent for the summer distribution (relevant because 10 percent of the yellowfin sole diet consists of tunicates). Given this level of disturbance, it is unlikely that late-juvenile and adult feeding would be negatively impacted. The diet and length-weight analysis presented in the preceding sections supports this assertion. The trawl survey CPUE analysis also did not provide evidence of spatial shifts on the population level in response to areas of high fishing impacts.

The yellowfin sole stock is currently at a high level of abundance (Wilderbuer ~~and Nichol 2004~~ et al. 2010a) and has been consistently above the B_{MSY} and MSST for the past 20 years. No declines in weight and/or length at age have been documented in this stock for year classes observed over the past 22 years. Such declines might be expected if the quality of the benthic feeding habitat was degraded or essential habitat were reduced. Therefore, the combined evidence from diet analysis, individual fish length-weight analysis, examination of recruitment, stock biomass, and CPUE trends indicate that the effects of the reductions in habitat features from fishing are either minimal or temporary for BS yellowfin sole.

35. In Appendix F, Section F.1.5.7, Arrowtooth Flounder, revise the two existing paragraphs as follows :

Summary of Effects—The nearshore areas inhabited by arrowtooth flounder early juveniles are mostly unaffected by current fishery activities, although there has been an increase in nearshore trawling in some areas during 2002–2007 relative to the 1998–2002 period (and a moderate decrease in the mid-shelf areas). Adult and late juvenile concentrations primarily overlap the EBS sand/mud habitat (34 percent) and the GOA deep shelf habitat (35 percent) (Table B.3-3 of the EFH EIS). Overall, epifaunal prey reduction in those overlaps is predicted to be 3 percent for EBS sand/mud and 1 percent for GOA deep shelf habitats. Given this level of disturbance, and the large percentage of the diet of arrowtooth flounder not including epifauna prey, it is unlikely that the adult feeding would be negatively impacted. The arrowtooth flounder stock is currently at a high level of abundance due to sustained above-average recruitment in the 1980s and 1990s (Turnock ~~et al. 2002~~ and Wilderbuer 2009). No change in weight and length at age has been observed in this stock from bottom trawl surveys conducted from 1984 through 2003.

The BS arrowtooth flounder stock is currently at a high level of abundance due to sustained above-average recruitment in the 1980s (Wilderbuer ~~and Sample 2004~~ et al. 2010b). The productivity of the stock is currently believed to correspond to favorable atmospheric forces in which larvae are advected to nearshore nursery areas (Wilderbuer et al. 2002). The GOA stock has increased steadily since the 1970s and is at a very high level. Therefore, the combined evidence from individual fish length-weight analysis, length at age analysis, examination of recruitment, stock biomass, and CPUE trends indicate that the effects of the reductions in habitat features from fishing are minimal or temporary for BSAI and GOA arrowtooth flounder.

36. In Appendix F, Section F.1.5.8, change the title from “Rock Sole (BSAI)” to “Northern Rock Sole (BSAI)”, and revise the two existing paragraphs as follows :

Summary of Effects—The nearshore areas inhabited by rock sole early juveniles are mostly unaffected by current fishery activities, although there has been an increase in nearshore trawling in some areas during 2002–2007 relative to the 1998–2002 period (and a moderate decrease in the mid-shelf areas). Adult and

late juvenile rock sole in the BSAI are primarily concentrated in sand/mud (41 percent) and sand (37 percent) habitats and are affected by levels of infaunal prey (Table B.3-3 of the EFH EIS). Predicted reductions of infaunal prey in those concentration overlaps are 3 percent (sand/mud) and less than 1 percent (sand). Given this level of disturbance, it is unlikely that adult feeding would be negatively impacted. The diet and length-weight analysis presented in the preceding sections supports this assertion. The trawl survey CPUE analysis did not provide evidence of spatial shifts on the population level in response to areas of high fishing impacts.

The rock sole stock is currently at a high level of abundance due to sustained above-average recruitment in the 1980s (Wilderbuer and ~~Nichol 2010~~Walters 2004). The productivity of the stock is currently believed to correspond to favorable atmospheric forces in which larvae are advected to nearshore nursery areas (Wilderbuer et al. 2002). A decline in weight and length at age has been documented in this stock for year classes between 1979 and 1987 (Walters and Wilderbuer 2000), but was hypothesized to be a density dependent response to a rapid increase in an expanding population. Individual rock sole may have been displaced beyond favorable feeding habitat, rather than by a reduction in the quality of habitat. Therefore, the combined evidence from diet analysis, individual fish length-weight analysis, examination of recruitment, stock biomass, and CPUE trends indicate that the effects of the reductions in habitat features from fishing are minimal or temporary for BS rock sole.

37. In Appendix F, Section F.1.5.9, Flathead Sole, revise the final paragraph as follows :

The flathead sole stock is currently at a high level of abundance due to sustained above-average recruitment in the 1980s, although abundance has been declining very gradually since achieving a maximum in 1992–1993 (Stockhausen et al. 2010~~Spencer et al. 2002)~~. The productivity of the stock is currently believed to correspond to favorable atmospheric forcing whereby larvae are advected to nearshore nursery areas (Wilderbuer et al. 2002). A decline in Neither weight at age nor~~and length at age appear to have declined in this has not been documented in this~~ stock during the ~~27~~22-year time horizon of the trawl surveys (Stockhausen et al. 2010~~Spencer et al. 2002)~~. Therefore, the combined evidence from diet analysis, individual fish length-weight analysis, examination of recruitment, stock biomass, and CPUE trends indicate that effects of the reductions in habitat features from fishing are either minimal or temporary for BS flathead sole.

38. In Appendix F, Section F.1.5.10, Alaska Plaice, revise the final paragraph as follows :

The Alaska plaice stock is currently at a high level of abundance (Wilderbuer et al. 2010~~c~~~~Spencer et al. 2004)~~ and well above the MSST. There have been no observations of a decline in length or weight at age for this stock over the 22 years of trawl survey sampling. Therefore, the combined evidence from diet analysis, individual fish length-weight analysis, examination of recruitment, stock biomass, and CPUE trends indicate that effects of the reductions in habitat features from fishing are either minimal or temporary for BS Alaska plaice.

39. In Appendix F, Section F.1.5.12, change the title from “Shortraker and Rougheye Rockfish (BSAI)” to “Shortraker Rockfish (BSAI)”, and revise the two existing paragraphs as follows :

~~Rougheye (Sebastes aleutianus) and s~~Shortraker (*Sebastes borealis*) rockfish are distributed from southern California, north to GOA and the EBS, and west to the Aleutian and Kuril Islands and the Okhotsk Sea (Love et al. 2002). In Alaskan waters, concentrations of abundance occur in the GOA and the AI, with smaller concentrations along the EBS slope. The mean depth at which shortraker ~~and rougheye~~ rockfish appear in recent AI summer trawl surveys is approximately 400 ~~and 375~~ m, respectively.

<u>Issue</u>	<u>Evaluation</u>
Spawning/breeding	MT (Minimal, temporary, or no effect)
Growth to maturity	U (Unknown effect)
Feeding	MT (Minimal, temporary, or no effect)

Summary of Effects—The effects of fishing on the habitat of BSAI rougheye and shortraker rockfish are rated as either unknown or minimal and temporary. There is little information to suggest that these habitat reductions would affect spawning/breeding or feeding in a manner that is more than minimal or temporary, although much is unknown about these processes for BSAI shortraker and rougheye rockfish.

Regarding growth to maturity, the available literature indicates that juvenile red rockfish use living (corals) and non-living (rocky areas) habitat features, with one specific use being the ability to find refuge from predators. Although several of these studies did not specifically observe shortraker ~~or rougheye~~ rockfish, it is reasonable to assume that their juvenile habitat use would follow a similar pattern. Trawling would be expected to have negative impacts for these life stages, although the extent to which the productivity of BSAI rougheye and shortraker stocks are related to these habitat features is not well known. The expected percent reduction in living and non-living habitat features does not exceed 7 percent in the AI deep and AI shallow habitats, suggesting that fishing impacts on these features are not likely to substantially affect BSAI ~~rougheye and shortraker~~ rockfish. However, larger percent reductions for hard corals are estimated, and studies on habitat associations have indicated that larger rougheye rockfish are associated with hard corals such as *Primnoa*, possibly due to the concentration of prey items in these habitats or for providing refuge for juveniles (Kreiger and Wing 2002). If hard coral provides an important habitat for shortraker rockfish, damage to these corals may have a negative impact upon shortraker rockfish. The extent to which habitat impacts occur at smaller scales and the importance of these impacts to the overall BSAI population are unknown.

40. In Appendix F, Section F.1.5.15, Squid and Other Species, revise the first paragraph as follows :

While there was considerable new information to evaluate habitat effects for the major target groundfish species in Alaska, there were some species where information was either too sparse to evaluate, or simply did not exist. For other species, especially nontarget species such as skates, sculpins, sharks, squids, and octopuses~~i~~, growth information has not been collected historically, and species-specific catch per unit effort information may be unreliable. Information on nontarget species is improving, but it is currently insufficient to evaluate habitat specific impacts. For these reasons, the original evaluations for the following species groups presented in the DEIS still represent the best available information, despite extensive inquiry to improve upon it.

41. In Appendix F, Section F.1.5.15.5, change the title from “BSAI octopi (5 or more species)” to “BSAI octopuses (7 or more species)”, and revise the existing paragraph as follows:

Summary of Effects—Essential habitat requirements for species in this category are unknown. No studies have been conducted in the EBS or AI to determine whether fishing activities have an effect on the habitat of octopus~~i~~. Octopus~~i~~ occupy all types of benthic habitats, extending from very shallow subtidal areas to deep slope habitats; thus, any adverse effects to this habitat may influence the health of octopus populations. Knowledge of octopus~~i~~ distributions are insufficient to allow comparison with fishing effects.

42. In Appendix F, Section F.1.5.15.2, Skates, revise the existing paragraph as follows :

Summary of Effects—Effects on essential habitat requirements for species in this category are unknown. No studies have been conducted in the EBS or AI to determine whether fishing activities have an effect

on the habitat of skates. Skates are benthic dwellers. The Alaska skate dominates the skate complex biomass in the EBS and is distributed mainly on the upper continental shelf. The diversity of the group increases with depth along the outer continental shelf and slope, with several new species likely to be described in the near future. Therefore, any adverse effects to the shallow shelf habitat may influence the health of the Alaska skate populations, while any adverse effects to outer continental shelf and slope habitats may influence the health of multiple species of skates. Any fishing gear that touches the bottom has the potential to impact skate egg case concentration sites (where egg cases are deposited), but these are small areas and as of 2009, only a handful have been identified. No studies have been performed on the effects of fishing on these areas.

43. Insert a new section after Section F.1.5.12 “Shortraker Rockfish”, titled Section F.1.5.13 “Blackspotted and Rougheye Rockfish”, and renumber all subsequent subsections in F.1.5 accordingly. Insert the following text descriptions for the new Section F.1.5.13:

Blackspotted/rougheye rockfish are distributed from southern California, north to the GOA and the EBS, and west to the Aleutian and Kuril Islands and the Okhotsk Sea (Love et al. 2002). In Alaskan waters, concentrations of abundance occur in the GOA and the AI, with smaller concentrations along the EBS slope. The mean depth at which blackspotted/rougheye rockfish appear in recent AI summer trawl surveys is approximately 375 m.

<u>Issue</u>	<u>Evaluation</u>
Spawning/breeding	MT (Minimal, temporary, or no effect)
Growth to maturity	U (Unknown effect)
Feeding	MT (Minimal, temporary, or no effect)

Summary of Effects - The effects of fishing on the habitat of BSAI blackspotted/rougheye rockfish are rated as either unknown or minimal and temporary. There is little information to suggest that these habitat reductions would affect spawning/breeding or feeding in a manner that is more than minimal or temporary, although much is unknown about these processes for BSAI blackspotted/rougheye rockfish.

Regarding growth to maturity, the available literature indicates that juvenile red rockfish use living (corals) and non-living (rocky areas) habitat features, with one specific use being the ability to find refuge from predators. Although several of these studies did not specifically observe blackspotted or rougheye rockfish, it is reasonable to assume that their juvenile habitat use would follow a similar pattern. Trawling would be expected to have negative impacts for these life stages, although the extent to which the productivity of BSAI blackspotted/rougheye rockfish is related to these habitat features is not well known. The expected percent reduction in living and non-living habitat features does not exceed 7 percent in the AI deep and AI shallow habitats, suggesting that fishing impacts on these features are not likely to substantially affect BSAI blackspotted/rougheye rockfish. However, larger percent reductions for hard corals are estimated, and studies on habitat associations have indicated that large rockfish are associated with hard corals such as *Primnoa*, possibly due to the concentration of prey items in these habitats or for providing refuge for juveniles (Kreiger and Wing 2002). If hard coral provides an important habitat for blackspotted/rougheye rockfish, the damage to these corals may have a negative impact upon blackspotted/rougheye rockfish. The extent to which habitat impacts occur at smaller scales and the importance of these impacts to the overall BSAI population are unknown.

44. In Appendix F, Section F.1.6.1, add a new paragraph to the end of the section, as follows:

The evaluation of fishing effects on EFH for BSAI groundfish species was reconsidered as part of the Council’s EFH 5-year Review for 2010, and is documented in the Final Summary Report for that review (NPFMC and NMFS 2010). The review evaluated new information since the development of the EFH EIS, for individual species and their habitat needs, as well as the distribution of fishing intensity, spatial

habitat classifications, classification of habitat features, habitat- and feature-specific recovery rates, and gear- and habitat-specific sensitivity of habitat features. Based on the review, the Council concluded that recent research results are consistent with the habitat sensitivity and recovery parameters and distributions of habitat types used in the analysis of fishing effects documented in the EFH EIS. The review noted that fishing intensity has decreased overall, gear regulations have been designated to reduce habitat damage, and area closures have limited the expansion of effort into areas of concern.

45. In Appendix F, Section F.1.6.2, under the heading References, add the following references in alphabetical order, and delete references that are marked below in ~~strikeout~~:

- Krieger, K.J., and B.L. Wing. 2002. Megafauna associations with deepwater corals (*Primnoa* spp.) in the GOA. *Hydrobiologia* 471: 83-90.
- NPFMC and NMFS. 2010. Essential Fish Habitat (EFH) 5-year Review for 2010 Summary Report: Final. April 2010. <http://www.alaskafisheries.noaa.gov/habitat/efh/review.htm>.
- Stockhausen, W.T., D.G. Nichol, R. Lauth, and M. Wilkins. 2010. Flathead sole. *In* Stock Assessment and Fishery Evaluation Report for Groundfish Resources of the Bering Sea/Aleutian Islands Regions. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, Alaska 99501. Pp. 869-968.
- Turnock, B.J. and T.K. Wilderbuer. 2009. Arrowtooth flounder. *In* Appendix B Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501. Pp. 627-680.
- Wilderbuer, T.K. and D.G. Nichol. 2010. Northern Rock sole. *In* Stock Assessment and Fishery Evaluation Report for Groundfish Resources of the Bering Sea/Aleutian Islands Regions. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, Alaska 99501. Pp. 781-868.
- Wilderbuer, T.K., D. Nichol, and K. Aydin. 2010b. Arrowtooth flounder. *In* Stock Assessment and Fishery Evaluation Report for Groundfish Resources of the Bering Sea/Aleutian Islands Regions. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, Alaska 99501. Pp. 697-762.
- Wilderbuer, T.K., D.G. Nichol, and J. Ianelli. 2010a. Yellowfin sole. *In* Stock Assessment and Fishery Evaluation Report for Groundfish Resources of the Bering Sea/Aleutian Islands Regions. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, Alaska 99501. Pp. 565-644.
- Wilderbuer, T.K., D.G. Nichol, and P.D. Spencer. 2010c. Alaska Plaice. *In* Stock Assessment and Fishery Evaluation Report for Groundfish Resources of the Bering Sea/Aleutian Islands Regions. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, Alaska 99501. Pp. 969-1020.
- ~~Spencer, P.D., G.E. Walters, and T.K. Wilderbuer. 2002. Flathead sole. *In* Appendix A Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the BSAI Region. P 361-408. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.~~
- ~~Spencer, P., T.K. Wilderbuer, and T.M. Sample. 2004. Alaska plaice. *In* Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the BSAI Region as Projected for 2005. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage Alaska 99510.~~
- ~~Turnock, B.J., T.K. Wilderbuer, and E.S. Brown. 2002. Arrowtooth flounder. *In* Appendix B Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the GOA Region. P~~

~~199-228. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.~~

~~Wilderbuer, T.K. and D. Nichol. 2004. Yellowfin sole. In Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the BSAI Region as Projected for 2005. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage Alaska 99510.~~

~~Wilderbuer, T.K. and T.M. Sample. 2004. Arrowtooth flounder. In Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the BSAI Region as Projected for 2005. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage Alaska 99510.~~

~~Wilderbuer, T.K. and G.E. Walters. 2004. Northern rock sole. In Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the BSAI Region as Projected for 2005. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage Alaska 99510.~~

46. In Appendix F, delete existing text in Section F.2 Non-fishing Impacts, and replace with the revised Section F.2 in the attached file.

47. In Appendix H, Section H.4, delete existing text under the heading “Objectives” and replace with the following:

Establish a scientific research and monitoring program to understand the degree to which impacts have been reduced within habitat closure areas, and to understand how benthic habitat recovery of key species is occurring.

48. In Appendix H, Section H.4, delete existing text under the heading “Research Activities” and replace with the following:

- Fishing effort data from observers and remote sensing would be used to study changes in bottom trawl and other fishing gear activity in the closed (and open) areas. Effects of displaced fishing effort would have to be considered. The basis of comparison would be changes in the structure and function of benthic communities and populations, as well as important physical features of the seabed, after comparable harvests of target species are taken with each gear type.
- Monitor the structure and function of benthic communities and populations in the newly closed areas, as well as important physical features of the seabed, for changes that may indicate recovery of benthic habitat. Whether these changes constitute recovery from fishing or just natural variability/shifts requires comparison with an area that is undisturbed by fishing and otherwise comparable.
- Validate the LEI model and improve estimates of recovery rates, particularly for the more sensitive habitats, including coral and sponge habitats in the Aleutian Islands region; possibly address through comparisons of benthic communities in trawled and untrawled areas.
- Obtain high resolution mapping of benthic habitats, particularly in the on-shelf regions of the Aleutian Islands.
- Time series of maturity at age should be collected to facilitate the assessment of whether habitat conditions are suitable for growth to maturity.
- In the case of red king crab spawning habitat in southern Bristol Bay, research the current impacts of trawling on habitat in spawning areas and the relationship of female crab distribution with respect to bottom temperature.

49. Update the Table of Contents for the main document.

50. Update the Table of Contents for the appendices.

51. In alphabetical order, add “LEI” to the list of acronyms used in the FMP (page ES-ix), with the definition “long-term effect index”.

Life History Features and Habitat Requirements of Fishery Management Plan Species

This appendix describes habitat requirements and life histories of the groundfish species managed by this fishery management plan. Each species or species group is described individually; however, summary tables that denote habitat associations (Table D-1), biological associations (Table D-2), and predator and prey associations (Table D-3) are also provided.

In each individual section, a species-specific table summarizes habitat. The following abbreviations are used in these habitat tables to specify location, position in the water column, bottom type, and other oceanographic features.

Location

BAY	= nearshore bays, with depth if appropriate (e.g., fjords)
BCH	= beach (intertidal)
BSN	= basin (>3,000 m)
FW	= freshwater
ICS	= inner continental shelf (1–50 m)
IP	= island passes (areas of high current), with depth if appropriate
LSP	= lower slope (1,000–3,000 m)
MCS	= middle continental shelf (50–100 m)
OCS	= outer continental shelf (100–200 m)
USP	= upper slope (200–1,000 m)

Water column

D	= demersal (found on bottom)
N	= neustonic (found near surface)
P	= pelagic (found off bottom, not necessarily associated with a particular bottom type)
SD/SP	= semi-demersal or semi-pelagic, if slightly greater or less than 50% on or off bottom

General

BSAI	= Bering Sea/Aleutian Islands
EBS	= eastern Bering Sea
EFH	= essential fish habitat
GOA	= Gulf of Alaska
NA	= not applicable
U	= unknown

Bottom Type

C	= coral
CB	= cobble
G	= gravel
K	= kelp
M	= mud
MS	= muddy sand
R	= rock
S	= sand
SM	= sandy mud
CB	= cobble
G	= gravel
C	= coral
K	= kelp

Oceanographic Features

CL	= thermocline or pycnocline
E	= edges
F	= fronts
G	= gyres
UP	= upwelling

Table 0.1 Summary of habitat associations for BSAI groundfish.

[illegible]

Table 0.1 (continued) Summary of habitat associations for BSAI groundfish.

[illegible]

Table 0.1 (continued) Summary of habitat associations for BSAI groundfish.

[illegible]

Table 0.2 Summary of biological associations for BSAI groundfish.

BSAI Groundfish	Life Stage	Reproductive Traits																											
		Age at Maturity				Fertilization/Egg Development						Spawning Behavior						Spawning Season											
		Female		Male		External	Internal	Oviparous	Ovoviparous	Aplacental	Viviparous	Batch Spawner	Broadcast Spawner	Egg Case Deposition	Nest Builder	Egg/Young Guarder	Egg/Young Bearer	January	February	March	April	May	June	July	August	September	October	November	December
50%	100%	50%	100%																										
Walleye Pollock	M	3-4		3-4		x						x							x	x	x	x							
Pacific Cod	M	5		5		x						x						x	x	x	x	x							
Sablefish	M	57-61cm				x						x						x	x	x									
Yellowfin Sole	M	10.5				x						x										x	x	x					
Greenland Turbot	M	5-10				x												x	x	x							x	x	x
Arrowtooth Flounder	M	5		4		x												x	x	x	x							x	x
Kamchatka Flounder	M	10		10		x												x	x	x								x	x
Northern Rock Sole	M	9				x						x						x	x	x									
Flathead Sole	M	9.7				x						x						x	x	x	x								
Alaska Plaice	M	6-7				x														x	x	x							
Rex Sole	M	35cm				x													x	x	x	x	x	x					
Dover Sole	M	33cm				x												x	x	x	x	x	x	x	x				
Pacific Ocean Perch	M	10.5					x				x	x							x	x	x	x							
Northern Rockfish	M	13					x				x	x																	
Shortraker Rockfish	M						x				x	x							x	x	x	x	x	x	x				
Blackspotted/Rougheye Rockfish	M						x				x	x						x	x	x	x								
Thornyhead Rockfish	M	12										x							x				x						
Dusky Rockfish	M	11					x				x	x																	
Atka Mackerel	M	3.6		3.6		x						x			x	x							x	x	x	x	x		
Squid	M						x					x																	
Octopus	M						x					x			x	x													
Sharks	M	35		21			x	x		x	x			x			x	x	x	x						x	x	x	x
Sculpins	M					x										x													
Skates	M						x	x						x															
Eulachon	M	3	5	3	5	x		x				x									x	x	x						
Capelin	M	2	4	2	4	x		x				x									x	x	x	x					
Sand Lance	M	1	2	1	2	x		x				x						x	x									x	x

[illegible]

Table 0.3 (continued) Summary of predator and prey associations for BSAI groundfish.

[illegible]

Table 0.3 (continued) Summary of predator and prey associations for BSAI groundfish

[illegible]

D.1 Walleye pollock (*Theragra calcogramma*)

The eastern Bering Sea and Aleutian Islands pollock stocks are managed under the Fishery Management Plan for Groundfish of the Bering Sea and Aleutian Islands Management Area (FMP). Pollock occur throughout the area covered by the FMP and straddle into the Canadian and Russian exclusive economic zone (EEZ), international waters of the central Bering Sea, and into the Chukchi Sea.

D.1.1 Life History and General Distribution

Pollock is the most abundant species within the eastern Bering Sea comprising 75 to 80 percent of the catch and 60 percent of the biomass. In the Gulf of Alaska, pollock is the second most abundant groundfish stock comprising 25 to 50 percent of the catch and 20 percent of the biomass.

Four stocks of pollock are recognized for management purposes: Gulf of Alaska, eastern Bering Sea, Aleutian Islands, and Aleutian Basin. For the contiguous sub-regions (i.e., areas adjacent to their management delineation), there appears to be some relationship among the eastern Bering Sea, Aleutian Islands, and Aleutian Basin stocks. Some strong year classes appear in all three places suggesting that pollock may expand from one area into the others or that discrete spawning areas benefit (in terms of recruitment) from similar environmental conditions. There appears to be stock separation between the Gulf of Alaska stocks and stocks to the north.

The most abundant stock of pollock is the eastern Bering Sea stock which is primarily distributed over the eastern Bering Sea outer continental shelf between approximately 70 m and 200 m. Information on pollock distribution in the eastern Bering Sea comes from commercial fishing locations, annual bottom trawl surveys and regular (every two or three years) echo-integration mid-water trawl surveys.

The Aleutian Islands stock extends through the Aleutian Islands from 170° W. to the end of the Aleutian Islands (Attu Island), with the greatest abundance in the eastern Aleutian Islands (170° W. to Segum Pass). Most of the information on pollock distribution in the Aleutian Islands comes from regular (every two or three years) bottom trawl surveys. These surveys indicate that pollock are primarily located on the Bering Sea side of the Aleutian Islands, and have a spotty distribution throughout the Aleutian Islands chain, particularly during the summer months when the survey is conducted. Thus, the bottom trawl data may be a poor indicator of pollock distribution because a significant portion of the pollock biomass is likely to be unavailable to bottom trawls. Also, many areas of the Aleutian Islands shelf are untrawlable due to the rough bottom.

The Aleutian Basin stock appears to be distributed throughout the Aleutian Basin which encompasses the U.S. EEZ, Russian EEZ, and international waters in the central Bering Sea. This stock appears throughout the Aleutian Basin apparently for feeding, but concentrates near the continental shelf for spawning. The principal spawning location is thought to be near Bogoslof Island in the eastern Aleutian Islands, but data from pollock fisheries in the first quarter of the year indicate that there are other concentrations of deepwater spawning concentrations in the central and western Aleutian Islands. The Aleutian Basin spawning stock appears to be derived from migrants from the eastern Bering Sea shelf stock, and possibly some western Bering Sea pollock. Recruitment to the stock occurs generally around age 5 with younger fish being rare in the Aleutian Basin. Most of the pollock in the Aleutian Basin appear to originate from strong year classes also observed in the Aleutian Islands and eastern Bering Sea shelf region.

The Gulf of Alaska stock extends from southeast Alaska to the Aleutian Islands (170° W.), with the greatest abundance in the western and central regulatory areas (147° W. to 170° W.). Most of the information on pollock distribution in the Gulf of Alaska comes from annual winter echo-integration mid-water trawl surveys and regular (every two or three years) bottom trawl surveys. These surveys indicate that pollock are distributed throughout the shelf regions of the Gulf of Alaska at depths less than 300 m. The bottom trawl data may not provide an accurate view of pollock distribution because a significant portion of the pollock

biomass may be pelagic and unavailable to bottom trawls. The principal spawning location is in Shelikof Strait, but other spawning concentrations in the Shumagin Islands, the east side of Kodiak Island, and near Prince William Sound also contribute to the stock.

Peak pollock spawning occurs on the southeastern Bering Sea and eastern Aleutian Islands along the outer continental shelf around mid-March. North of the Pribilof Islands spawning occurs later (April and May) in smaller spawning aggregations. The deep spawning pollock of the Aleutian Basin appear to spawn slightly earlier, late February and early March. In the Gulf of Alaska, peak spawning occurs in late March in Shelikof Strait. Peak spawning in the Shumagin area appears to be 2 to 3 weeks earlier than in Shelikof Strait.

Spawning occurs in the pelagic zone and eggs develop throughout the water column (70 to 80 m in the Bering Sea shelf, 150 to 200 m in Shelikof Strait). Development is dependent on water temperature. In the Bering Sea, eggs take about 17 to 20 days to develop at 4 °C in the Bogoslof area and 25.5 days at 2 °C on the shelf. In the Gulf of Alaska, development takes approximately 2 weeks at ambient temperature (5 °C). Larvae are also distributed in the upper water column. In the Bering Sea the larval period lasts approximately 60 days. The larvae eat progressively larger naupliar stages of copepods as they grow and then small euphausiids as they approach transformation to juveniles (approximately 25 mm standard length). In the Gulf of Alaska, larvae are distributed in the upper 40 m of the water column and their diet is similar to Bering Sea larvae. Fisheries-Oceanography Coordinated Investigations survey data indicate larval pollock may utilize the stratified warmer upper waters of the mid-shelf to avoid predation by adult pollock which reside in the colder bottom water.

At age 1 pollock are found throughout the eastern Bering Sea both in the water column and on the bottom depending on temperature. Age 1 pollock from strong year-classes appear to be found in great numbers on the inner shelf, and further north on the shelf than weak year classes which appear to be more concentrated on the outer continental shelf. From age 2 to 3 pollock are primarily pelagic and then are most abundant on the outer and mid-shelf northwest of the Pribilof Islands. As pollock reach maturity (age 4) in the Bering Sea, they appear to move from the northwest to the southeast shelf to recruit to the adult spawning population. Strong year-classes of pollock persist in the population in significant numbers until about age 12, and very few pollock survive beyond age 16. The oldest recorded pollock was age 31.

Growth varies by area with the largest pollock occurring on the southeastern shelf. On the northwest shelf the growth rate is slower. A newly maturing pollock is around 40 cm.

The upper size limit for juvenile pollock in the eastern Bering Sea and Gulf of Alaska is about 38 to 42 cm. This is the size of 50 percent maturity. There is some evidence that this has changed over time.

D.1.2 Fishery

The eastern Bering Sea pollock fishery has, since 1990 been divided into two fishing periods: an “A season” occurring from January through March, and a “B season” occurring from June through October. The A season concentrates fishing effort on prespawning pollock in the southeastern Bering Sea. During the B season fishing is more dispersed with concentrations in the southeastern Bering Sea and extending north generally along the 200 m isobaths. During the B season the offshore fleet (catcher/processors and motherships) are required to fish north of 56° N. latitude while the area to the south is reserved for catcher vessels delivering to shoreside processing plants on Unalaska and Akutan.

Since 1992, the Gulf of Alaska pollock total allowable catch (TAC) has been apportioned spatially and temporally to reduce impacts on Steller sea lions. Although the details of the apportionment scheme have evolved over time, the general objective is to allocate the TAC to management areas based on the distribution of surveyed biomass, and to establish three or four seasons between mid-January and autumn during which some fraction of the TAC can be taken. The Steller Sea Lion Protection Measures implemented in 2001 establish four seasons in the Central and Western Gulf of Alaska beginning January

20, March 10, August 25, and October 1, with 25 percent of the total TAC allocated to each season. Allocations to management areas 610, 620, and 630 are based on the seasonal biomass distribution as estimated by groundfish surveys. In addition, a new harvest control rule was implemented that requires a cessation of fishing when spawning biomass declines below 20 percent of the unfished stock biomass estimate.

In the Gulf of Alaska approximately 90 percent of the pollock catch is taken using pelagic trawls. During winter, fishing effort usually is targeted primarily on pre-spawning aggregations in Shelikof Strait and near the Shumagin Islands. The pollock fishery has a very low bycatch rate with discards averaging about 2 percent since 1998 (with the 1991–1997 average around 9 percent). Most of the discards in the pollock fishery are juvenile pollock, or pollock too large to fit filleting machines. In the pelagic trawl fishery the catch is almost exclusively pollock.

The eastern Bering Sea pollock fishery primarily harvests mature pollock. The age where fish are selected by the fishery roughly corresponds to the age at maturity (management guidelines are oriented towards conserving spawning biomass). Fishery selectivity increases to a maximum around age 6 to 8 and then declines slightly. The reduced selectivity for older ages is due to pollock becoming increasingly demersal with age. Younger pollock form large schools and are semi-demersal, thereby being easier to locate by fishing vessels. Immature fish (ages 2 and 3) are usually caught in low numbers. Generally the catch of immature pollock increases when strong year-classes occur and the abundance of juveniles increase sharply. This occurred with the 1989 year-class, the second largest year-class on record. Juvenile bycatch increased sharply in 1991 and 1992 when this year-class was age 2 and 3. Under the 1999 American Fisheries Act (AFA) the pollock fishery became rationalized and effectively ended the “race for fish.” This generally slowed the pace of the fishery and also reduced the tendency to catch smaller pollock. A secondary problem is that strong to moderate year-classes may reside in the Russian EEZ adjacent to the U.S. EEZ as juveniles. Russian catch-age data and anecdotal information suggest that juveniles may comprise a major portion of the catch. There is a potential for the Russian fishery to reduce subsequent abundance in the U.S. fishery.

The Gulf of Alaska pollock fishery also targets mature pollock. Fishery selectivity increases to a maximum around age 5 to 7 and then declines. In both the eastern Bering Sea and Gulf of Alaska, the selectivity pattern varies between years due to shifts in fishing strategy and changes in the availability of different age groups over time.

In response to continuing concerns over the possible impacts groundfish fisheries may have on rebuilding populations of Steller sea lions, NMFS and the North Pacific Fishery Management Council (NPFMC) have made changes to the Atka mackerel and pollock fisheries in the Bering Sea/Aleutian Islands (BSAI) and Gulf of Alaska. These have been designed to reduce the possibility of competitive interactions with Steller sea lions. For the pollock fisheries, comparisons of seasonal fishery catch and pollock biomass distributions (from surveys) by area in the eastern Bering Sea led to the conclusion that the pollock fishery had disproportionately high seasonal harvest rates within critical habitat which *could* lead to reduced sea lion prey densities. Consequently, the management measures were designed to redistribute the fishery both temporally and spatially according to pollock biomass distributions. The underlying assumption in this approach was that the independently derived area-wide and annual exploitation rate for pollock would not reduce local prey densities for sea lions. Here we examine the temporal and spatial dispersion of the fishery to evaluate the potential effectiveness of the measures.

Three types of measures were implemented in the pollock fisheries:

- Additional pollock fishery exclusion zones around sea lion rookery or haulout sites,
- Phased-in reductions in the seasonal proportions of TAC that can be taken from critical habitat, and
- Additional seasonal TAC releases to disperse the fishery in time.

Prior to the management measures, the pollock fishery occurred in each of the three major fishery management regions of the north Pacific ocean managed by the NPFMC: the Aleutian Islands (1,001,780 km² inside the EEZ), the eastern Bering Sea (968,600 km²), and the Gulf of Alaska (1,156,100 km²). The marine portion of Steller sea lion critical habitat in Alaska west of 150° W. encompasses 386,770 km² of ocean surface, or 12 percent of the fishery management regions.

Prior to 1999, a total of 84,100 km², or 22 percent of critical habitat, was closed to the pollock fishery. Most of this closure consisted of the 10- and 20-nm radius all-trawl fishery exclusion zones around sea lion rookeries (48,920 km² or 13 percent of critical habitat). The remainder was largely management area 518 (35,180 km², or 9 percent of critical habitat), which was closed pursuant to an international agreement to protect spawning stocks of central Bering Sea pollock.

In 1999, an additional 83,080 km² (21 percent) of critical habitat in the Aleutian Islands was closed to pollock fishing along with 43,170 km² (11 percent) around sea lion haulouts in the Gulf of Alaska and eastern Bering Sea. Consequently, a total of 210,350 km² (54 percent) of critical habitat was closed to the pollock fishery. The portion of critical habitat that remained open to the pollock fishery consisted primarily of the area between 10 nm and 20 nm from rookeries and haulouts in the Gulf of Alaska and parts of the eastern Bering Sea foraging area.

The BSAI pollock fishery was also subject to changes in total catch and catch distribution. Disentangling the specific changes in the temporal and spatial dispersion of the eastern Bering Sea pollock fishery resulting from the Steller sea lion management measures from those resulting from implementation of the 1999 AFA is difficult. The AFA reduced the capacity of the catcher/processor fleet and permitted the formation of cooperatives in each industry sector by 2000. Both of these changes would be expected to reduce the rate at which the catcher/processor sector (allocated 36 percent of the eastern Bering Sea pollock TAC) caught pollock beginning in 1999, and the fleet as a whole in 2000. Because of some of its provisions, the AFA gave the industry the ability to respond efficiently to changes mandated for sea lion conservation that otherwise could have been more disruptive to the industry.

In 2000, further reductions in seasonal pollock catches from BSAI Steller sea lion critical habitat were realized by closing the entire Aleutian Islands region to pollock fishing and by phased-in reductions in the proportions of seasonal TAC that could be caught from the Steller Sea Lion Conservation Area, an area which overlaps considerably with Steller sea lion critical habitat. In 1998, over 22,000 mt of pollock were caught in the Aleutian Islands regions, with over 17,000 mt caught in Aleutian Islands critical habitat. Since 1998 directed fishery removals of pollock have been prohibited.

D.1.3 Relevant Trophic Information

Juvenile pollock through newly maturing pollock primarily utilize copepods and euphausiids for food. At maturation and older ages pollock become increasingly piscivorous, with pollock (cannibalism) a major food item in the Bering Sea. Most of the pollock consumed by pollock are age 0 and 1 pollock, and recent research suggests that cannibalism can regulate year-class size. Weak year-classes appear to be those located within the range of adults, while strong year-classes are those that are transported to areas outside the range of adult abundance.

Being the dominant species in the eastern Bering Sea, pollock is an important food source for other fish, marine mammals, and birds. On the Pribilof Islands hatching success and fledgling survival of marine birds has been tied to the availability of age 0 pollock to nesting birds.

D.1.4 Habitat and Biological Associations

Egg-Spawning: Pelagic on outer continental shelf generally over 100 to 200 m depth in Bering Sea. Pelagic on continental shelf over 100 to 200 m depth in Gulf of Alaska.

Larvae: Pelagic outer to mid-shelf region in Bering Sea. Pelagic throughout the continental shelf within the top 40 m in the Gulf of Alaska.

Juveniles: Age 0 appears to be pelagic, as is age 2 and 3. Age 1 pelagic and demersal with a widespread distribution and no known benthic habitat preference.

Adults: Adults occur both pelagically and demersally on the outer and mid-continental shelf of the Gulf of Alaska, eastern Bering Sea and Aleutian Islands. In the eastern Bering Sea few adult pollock occur in waters shallower than 70 m. Adult pollock also occur pelagically in the Aleutian Basin. Adult pollock range throughout the Bering Sea in both the U.S. and Russian waters; however, the maps provided for this document detail distributions for pollock in the U.S. EEZ and the Aleutian Basin.

Habitat and Biological Associations: Walleye Pollock

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	14 days at 5 °C	None	Feb–Apr	OCS, USP	P	NA	G?	
Larvae	60 days	copepod naupli and small euphausiids	Mar–Jul	MCS, OCS	P	NA	G? F	pollock larvae with jellyfish
Juveniles	0.4 to 4.5 years	pelagic crustaceans, copepods and euphausiids	Aug. +	OCS, MCS, ICS	P, SD	NA	CL, F	
Adults	4.5–16 years	pelagic crustaceans and fish	spawning Feb–Apr	OCS, BSN	P, SD	UNK	F UP	increasingly demersal with age.

D.1.5 Literature

- A'mar, Z. T., Punt, A. E., and Dorn, M. W. 2009. The evaluation of two management strategies for the Gulf of Alaska walleye pollock fishery under climate change. – ICES Journal of Marine Science, 66: 000–000.
- Bailey, K.M. 2000. Shifting control of recruitment of walleye pollock *Theragra chalcogramma* after a major climatic and ecosystem change. Mar. Ecol. Prog. Ser 198:215-224.
- Bailey, K.M., P.J. Stabeno, and D.A. Powers. 1997. The role of larval retention and transport features in mortality and potential gene flow of walleye pollock. J. Fish. Biol. 51(Suppl. A):135-154.
- Bailey, K.M., S.J. Picquelle, and S.M. Spring. 1996. Mortality of larval walleye pollock (*Theragra chalcogramma*) in the western Gulf of Alaska, 1988-91. Fish. Oceanogr. 5 (Suppl. 1):124-136.
- Bailey, K.M., T.J. Quinn II, P. Bentzen, and W.S. Grant. 1999. Population structure and dynamics of walleye pollock, *Theragra chalcogramma*. Advances in Mar. Biol. 37: 179-255.
- Bakkala, R.G., V.G. Wespestad and L.L. Low. 1987. Historical trends in abundance and current condition of walleye pollock in the eastern Bering Sea. Fish. Res.,5:199-215.
- Barbeaux, S. J., and M. W. Dorn. 2003. Spatial and temporal analysis of eastern Bering Sea echo integration-trawl survey and catch data of walleye pollock, *Theragra chalcogramma*. NOAA Technical Memorandum NMFS-AFSC-136.
- Barbeaux, S. J., and D. Fraser (In Press). Aleutian Islands cooperative acoustic survey study 2006.NMFS AFSC NOAA Technical Memorandum. 90 p. NTIS. NTIS number pending
- Bates, R.D. 1987. Ichthyoplankton of the Gulf of Alaska near Kodiak Island, April-May 1984. NWAFC Proc. Rep. 87-11, 53 pp.

- Bond, N.A., and J.E. Overland 2005. The importance of episodic weather events to the ecosystem of the Bering Sea shelf. *Fisheries Oceanography*, Vol. 14, Issue 2, pp. 97-111.
- Brodeur, R.D. and M.T. Wilson. 1996. A review of the distribution, ecology and population dynamics of age-0 walleye pollock in the Gulf of Alaska. *Fish. Oceanogr.* 5 (Suppl. 1):148-166.
- Brown, A.L. and K.M. Bailey. 1992. Otolith analysis of juvenile walleye pollock *Theragra chalcogramma* from the western Gulf of Alaska. *Mar. Bio.* 112:23-30.
- Dorn, M., S. Barbeaux, M. Guttormsen, B. Megrey, A. Hollowed, E. Brown, and K. Spalinger. 2002. Assessment of Walleye Pollock in the Gulf of Alaska. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, 2002. North Pacific Fishery Management Council, Box 103136, Anchorage, AK 99510. 88p.
- Grant, W.S. and F.M. Utter. 1980. Biochemical variation in walleye pollock *Theragra chalcogramma*: population structure in the southeastern Bering Sea and Gulf of Alaska. *Can. J. Fish. Aquat. Sci.* 37:1093-1100.
- Guttormsen, M. A., C. D. Wilson, and S. Stienessen. 2001. Echo integration-trawl survey results for walleye pollock in the Gulf of Alaska during 2001. In Stock Assessment and Fishery Evaluation Report for Gulf of Alaska. Prepared by the Gulf of Alaska Groundfish Plan Team, North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510. North Pacific Fisheries Management Council, Anchorage, AK.
- Hinckley, S. 1987. The reproductive biology of walleye pollock, *Theragra chalcogramma*, in the Bering Sea, with reference to spawning stock structure. *Fish. Bull.* 85:481-498.
- Hollowed, A.B., J.N. Ianelli, P. Livingston. 2000. Including predation mortality in stock assessments: a case study for Gulf of Alaska pollock. *ICES J. Mar. Sci.* 57:279-293.
- Hughes, S. E. and G. Hirschhorn. 1979. Biology of walleye pollock, *Theragra chalcogramma*, in Western Gulf of Alaska. *Fish. Bull.*, U.S. 77:263-274.
- Ianelli, J.N. 2002. Bering Sea walleye pollock stock structure using morphometric methods. Tech. Report Hokkaido National Fisheries Research Inst. No. 5, 53-58.
- Ianelli, J.N., S. Barbeaux, T. Honkalehto, G. Walters, and N. Williamson. 2002. Bering Sea-Aleutian Islands Walleye Pollock Assessment for 2003. In Stock assessment and fishery evaluation report for the groundfish resources of the Eastern Bering Sea and Aleutian Island Region, 2002. North Pacific Fishery Management Council, Box 103136, Anchorage, AK 99510. 88p.
- Kendall, A.W., Jr. and S.J. Picquelle. 1990. Egg and larval distributions of walleye pollock *Theragra chalcogramma* in Shelikof Strait, Gulf of Alaska. *U.S. Fish. Bull.* 88(1):133-154.
- Kim, S. and A.W. Kendall, Jr. 1989. Distribution and transport of larval walleye pollock (*Theragra chalcogramma*) in Shelikof Strait, Gulf of Alaska, in relation to water movement. *Rapp. P.-v. Reun. Cons. int. Explor. Mer* 191:127-136.
- Kotenev B.N., and A.I. Glubokov. 2007. Walleye pollock *Theragra chalcogramma* from the Navarin region and adjacent waters of the Bering sea: ecology, biology and stock structure.—M.: VNIRO Publishing, 2007.
- Kotwicki, S., T.W. Buckley, T. Honkalehto, and G. Walters. 2005. Variation in the distribution of walleye pollock (*Theragra chalcogramma*) with temperature and implications for seasonal migration. *U.S. Fish. Bull.* 103:574-587.
- Kotwicki, S., A. DeRobertis, P vonSzalay, and R. Towler. 2009. The effect of light intensity on the availability of walleye pollock (*Theragra chalcogramma*) to bottom trawl and acoustic surveys. *Can. J. Fish. Aquat. Sci.* 66(6): 983–994
- Livingston, P.A. 1991. Groundfish food habits and predation on commercially important prey species in the eastern Bering Sea from 1884-1986. U. S. Dept. Commerce, NOAA Tech Memo. NMFS F/NWC-207.
- Meuter, F.J. and B.L. Norcross. 2002. Spatial and temporal patterns in the demersal fish community on the shelf and upper slope regions of the Gulf of Alaska. *Fish. Bull.* 100:559-581.
- Mueter, F.J., C. Ladd, M.C. Palmer, and B.L. Norcross. 2006. Bottom-up and top-down controls of walleye pollock (*Theragra chalcogramma*) on the Eastern Bering Sea shelf. *Progress in Oceanography*, Volume 68, 2:152-183.

- Moss, J.H., E.V. Farley, Jr., and A.M. Feldmann, J.N. Ianelli. 2009. Spatial Distribution, Energetic Status, and Food Habits of Eastern Bering Sea Age-0 Walleye Pollock. Transactions of the American Fisheries Society 138:497–505.
- Mulligan, T.J., Chapman, R.W. and B.L. Brown. 1992. Mitochondrial DNA analysis of walleye pollock, *Theragra chalcogramma*, from the eastern Bering Sea and Shelikof Strait, Gulf of Alaska. Can. J. Fish. Aquat. Sci. 49:319-326.
- Olsen, J.B., S.E. Merkouris, and J.E. Seeb. 2002. An examination of spatial and temporal genetic variation in walleye pollock (*Theragra chalcogramma*) using allozyme, mitochondrial DNA, and microsatellite data. Fish. Bull. 100:752-764.
- Rugen, W.C. 1990. Spatial and temporal distribution of larval fish in the western Gulf of Alaska, with emphasis on the period of peak abundance of walleye pollock (*Theragra chalcogramma*) larvae. NWAFC Proc. Rep. 90-01, 162 pp.
- Stram, D. L., and J. N. Ianelli. 2009. Eastern Bering Sea pollock trawl fisheries: variation in salmon bycatch over time and space. In C. C. Krueger and C. E. Zimmerman, editors. Pacific salmon: ecology and management of western Alaska's populations. American Fisheries Society, Symposium 70, Bethesda, Maryland.
- Shima, M. 1996. A study of the interaction between walleye pollock and Steller sea lions in the Gulf of Alaska. Ph.D. dissertation, University of Washington, Seattle, WA 98195.
- Stabeno, P.J., J.D. Schumacher, K.M. Bailey, R.D. Brodeur, and E.D. Cokelet. 1996. Observed patches of walleye pollock eggs and larvae in Shelikof Strait, Alaska: their characteristics, formation and persistence. Fish. Oceanogr. 5 (Suppl. 1): 81-91.
- Wespestad V.G. and T.J. Quinn. II. 1997. Importance of cannibalism in the population dynamics of walleye pollock. In: Ecology of Juvenile Walleye Pollock, *Theragra chalcogramma*. NOAA Technical Report, NMFS 126.
- Wespestad, V.G. 1993. The status of Bering Sea pollock and the effect of the “Donut Hole” fishery. Fisheries 18(3)18-25.
- Wolotira, R.J., Jr., T.M. Sample, S.F. Noel, and C.R. Iten. 1993. Geographic and bathymetric distributions for many commercially important fishes and shellfishes off the west coast of North America, based on research survey and commercial catch data, 1912-84. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-AFSC-6, 184 pp.

D.2 Pacific cod (*Gadus macrocephalus*)

D.2.1 Life History and General Distribution

Pacific cod is a transoceanic species, occurring at depths from shoreline to 500 m. The southern limit of the species' distribution is about 34° N. latitude, with a northern limit of about 63° N. latitude. Adults are largely demersal and form aggregations during the peak spawning season, which extends approximately from January through May. Pacific cod eggs are demersal and adhesive. Eggs hatch in about 15 to 20 days. Little is known about the distribution of Pacific cod larvae, which undergo metamorphosis at about 25 to 35 mm. Juvenile Pacific cod start appearing in trawl surveys at a fairly small size, as small as 10 cm in the eastern Bering Sea. Pacific cod can grow to be more than a meter in length, with weights in excess of 10 kg. Natural mortality is currently estimated to be 0.34 in the Bering Sea and Aleutian Islands (BSAI) and 0.38 in the Gulf of Alaska (GOA). Approximately 50 percent of Pacific cod are mature by age 5 in the BSAI and age 4 in the GOA. The maximum recorded age of a Pacific cod is 17 years in the BSAI and 14 years in the GOA.

The estimated size at 50 percent maturity is 58 cm in the BSAI and 50 cm in the GOA.

D.2.2 Fishery

The fishery is conducted with bottom trawl, longline, pot, and jig gear. The age at 50 percent recruitment varies between gear types and regions. In the BSAI, the age at 50 percent recruitment is 6 years for trawl gear, 4 years for longline, and 5 years for pot gear. In the GOA, the age at 50 percent recruitment is 5 years for trawl gear and 6 years for longline and pot gear. More than 100 vessels participate in each of the three largest fisheries (trawl, longline, pot). The trawl fishery is typically concentrated during the first few months of the year, whereas fixed-gear fisheries may sometimes run, intermittently, at least, throughout the year. Bycatch of crab and halibut sometimes causes the Pacific cod fisheries to close prior to reaching the total allowable catch. In the BSAI, trawl fishing is concentrated immediately north of Unimak Island, whereas the longline fishery is distributed along the shelf edge to the north and west of the Pribilof Islands. In the GOA, the trawl fishery has centers of activity around the Shumagin Islands and south of Kodiak Island, while the longline fishery is located primarily in the vicinity of the Shumagin Islands.

D.2.3 Relevant Trophic Information

The fishery is conducted with bottom trawl, longline, pot, and jig gear. The trawl fishery is typically concentrated during the first few months of the year, whereas fixed-gear fisheries may sometimes run, intermittently, at least, throughout the year. Historically, bycatch of crab and halibut has sometimes caused the Pacific cod fisheries to close prior to reaching the total allowable catch. In the BSAI, trawl fishing is concentrated immediately north of Unimak Island, whereas the longline fishery is distributed along the shelf edge to the north and west of the Pribilof Islands. In the GOA, the trawl fishery has centers of activity around the Shumagin Islands and south of Kodiak Island, while the longline fishery is located primarily in the vicinity of the Shumagin Islands.

D.2.4 Habitat and Biological Associations

Egg/Spawning: Spawning takes place in the sublittoral-bathyal zone (40 to 290 m) near the bottom. Eggs sink to the bottom after fertilization, and are somewhat adhesive. Optimal temperature for incubation is 3 to 6 °C, optimal salinity is 13 to 23 ppt, and optimal oxygen concentration is from 2 to 3 ppm to saturation. Little is known about the optimal substrate type for egg incubation.

Larvae: Larvae are epipelagic, occurring primarily in the upper 45 m of the water column shortly after hatching, moving downward in the water column as they grow.

Juveniles: Juveniles occur mostly over the inner continental shelf at depths of 60 to 150 m.

Adults: Adults occur in depths from the shoreline to 500 m. Average depth of occurrence tends to vary directly with age for at least the first few years of life, with mature fish concentrated on the outer continental shelf. Preferred substrate is soft sediment, from mud and clay to sand.

Habitat and Biological Associations: Pacific cod

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	15–20 days	NA	winter–spring	ICS, MCS, OCS	D	M, SM, MS, S	U	optimum 3–6 °C optimum salinity 13–23 ppt
Larvae	U	copepods (?)	winter–spring	U	P (?), N (?)	U	U	
Early Juveniles	to 2 yrs	small invertebrates (mysids, euphausiids, shrimp)	all year	ICS, MCS	D	M, SM, MS, S	U	
Late Juveniles	to 5 yrs	pollock, flatfish, fishery discards, crab	all year	ICS, MCS, OCS	D	M, SM, MS, S	U	
Adults	5+ yr	pollock, flatfish, fishery discards, crab	spawning (Jan–May)	ICS, MCS, OCS	D	M, SM, MS, S, G	U	
			non-spawning (Jun–Dec)	ICS, MCS, OCS				

D.2.5 Literature

- Abookire, A.A., J.T. Duffy-Anderson, and C.M. Jump. 2007. Habitat associations and diet of young-of-the-year Pacific cod (*Gadus macrocephalus*) near Kodiak, Alaska. *Marine Biology* 150:713-726.
- Albers, W.D., and P.J. Anderson. 1985. Diet of Pacific cod, *Gadus macrocephalus*, and predation on the northern pink shrimp, *Pandalus borealis*, in Pavlof Bay, Alaska. *Fish. Bull.*, U.S. 83:601-610.
- Alderdice, D.F., and C.R. Forrester. 1971. Effects of salinity, temperature, and dissolved oxygen on early development of the Pacific cod (*Gadus macrocephalus*). *J. Fish. Res. Board Can.* 28:883-902.
- Bakkala, R.G. 1984. Pacific cod of the eastern Bering Sea. *Int. N. Pac. Fish. Comm. Bull.* 42:157-179.
- Brodeur, R.D., and W. C. Rugen. 1994. Diel vertical distribution of ichthyoplankton in the northern Gulf of Alaska. *Fish. Bull.*, U.S. 92:223-235.
- Dunn, J.R., and A.C. Matarese. 1987. A review of the early life history of northeast Pacific gadoid fishes. *Fish. Res.* 5:163-184.
- Forrester, C.R., and D.F. Alderdice. 1966. Effects of salinity and temperature on embryonic development of Pacific cod (*Gadus macrocephalus*). *J. Fish. Res. Board Can.* 23:319-340.
- Hirschberger, W.A., and G.B. Smith. 1983. Spawning of twelve groundfish species in Alaska and Pacific Coast regions, 1975-81. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS F/NWC-44. 50 p.
- Hurst, T.P., D.W. Cooper, J.S. Scheingross, E.M. Seale, B.J. Laurel, and M.L. Spencer. 2009. Effects of ontogeny, temperature, and light on vertical movements of larval Pacific cod (*Gadus macrocephalus*). *Fisheries Oceanography* 18:301-311.
- Ketchen, K.S. 1961. Observations on the ecology of the Pacific cod (*Gadus macrocephalus*) in Canadian waters. *J. Fish. Res. Board Can.* 18:513-558.

- Laurel, B.J., T.P. Hurst, L.A. Copeman, and M. W. Davis. 2008. The role of temperature on the growth and survival of early and late hatching Pacific cod larvae (*Gadus macrocephalus*). *Journal of Plankton Research* 30:1051-1060.
- Laurel, B.J., C.H. Ryer, B. Knoth, and A.W. Stoner. 2009. Temporal and ontogenetic shifts in habitat use of juvenile Pacific cod (*Gadus macrocephalus*). *Journal of Experimental Marine Biology and Ecology* 377:28-35.
- Laurel, B.J., A.W. Stoner, C.H. Ryer, T.P. Hurst, and A.A. Abookire. 2007. Comparative habitat associations in juvenile Pacific cod and other gadids using seines, baited cameras and laboratory techniques. 2007. *Journal of Experimental Marine Biology and Ecology* 351:42-55.
- Livingston, P.A. 1989. Interannual trends in Pacific cod, *Gadus macrocephalus*, predation on three commercially important crab species in the eastern Bering Sea. *Fish. Bull.*, U.S. 87:807-827.
- Livingston, P.A. 1991. Pacific cod. In P.A. Livingston (editor), *Groundfish food habits and predation on commercially important prey species in the eastern Bering Sea from 1984 to 1986*, p. 31-88. U.S. Dept. Commerce., NOAA Tech. Memo. NMFS F/NWC-207.
- Matarese, A.C., A.W. Kendall Jr., D.M. Blood, and B.M. Vinter. 1989. Laboratory guide to early life history stages of northeast Pacific fishes. U.S. Dept. Commerce, NOAA Tech. Rep. NMFS 80. 652 p.
- Moiseev, P.A. 1953. Cod and flounders of far eastern waters. *Izv. Tikhookean. Nauchno-issled. Inst. Rybn. Khoz. Okeanogr.* 40. 287 p. (Transl. from Russian: *Fish. Res. Board Can. Transl. Ser.* 119.)
- National Oceanic and Atmospheric Administration (NOAA). 1987. Bering, Chukchi, and Beaufort Seas--Coastal and ocean zones strategic assessment: Data Atlas. U.S. Dept. Commerce, NOAA, National Ocean Service.
- National Oceanic and Atmospheric Administration (NOAA). 1990. West coast of North America--Coastal and ocean zones strategic assessment: Data Atlas. U.S. Dept. Commerce, NOAA, National Ocean Service and National Marine Fisheries Service.
- Phillips, A.C., and J.C. Mason. 1986. A towed, self-adjusting sled sampler for demersal fish eggs and larvae. *Fish. Res.* 4:235-242.
- Poltev, Yu.N. 2007. Specific features of spatial distribution of Pacific cod *Gadus macrocephalus* in waters off the eastern coast of the northern Kuril Islands and the southern extremity of Kamchatka. *Journal of Ichthyology* 47:726-738.
- Rugen, W.C., and A.C. Matarese. 1988. Spatial and temporal distribution and relative abundance of Pacific cod (*Gadus macrocephalus*) larvae in the western Gulf of Alaska. *NWAFRC Proc. Rep.* 88-18. Available from Alaska Fish. Sci. Center, 7600 Sand Point Way NE., Seattle, WA 98115-0070.
- Savin, A.B. 2008. Seasonal distribution and migrations of Pacific cod *Gadus macrocephalus* (Gadidae) in Anadyr Bay and adjacent waters. *Journal of Ichthyology* 48:610-621.
- Shi, Y., D. R. Gunderson, P. Munro, and J. D. Urban. 2007. Estimating movement rates of Pacific cod (*Gadus macrocephalus*) in the Bering Sea and the Gulf of Alaska using mark-recapture methods. NPRB Project 620 Final Report. North Pacific Research Board, 1007 West 3rd Avenue, Suite 100, Anchorage, AK 99501.
- Stone, R.P. 2006. Coral habitat in the Aleutian Islands of Alaska: depth distribution, fine-scale species associations, and fisheries interactions. *Coral Reefs* 25:229-238.
- Thompson, G., J. Ianelli, R. Lauth, S. Gaichas, and K. Aydin. 2008. Assessment of the Pacific cod stock in the Eastern Bering Sea and Aleutian Islands Area. In Plan Team for the Groundfish Fisheries of the Bering Sea and Aleutian Islands (compiler), *Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions*, p. 221-401. North Pacific Fishery Management Council, 605 West 4th Avenue, Suite 306, Anchorage, AK 99501.
- Thompson, G., J. Ianelli, and M. Wilkins. 2008. Assessment of the Pacific cod stock in the Gulf of Alaska. In Plan Team for the Groundfish Fisheries of the Gulf of Alaska (compiler), *Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska*, p. 169-301. North Pacific Fishery Management Council, 605 West 4th Avenue, Suite 306, Anchorage, AK 99501.

- Westrheim, S.J. 1996. On the Pacific cod (*Gadus macrocephalus*) in British Columbia waters, and a comparison with Pacific cod elsewhere, and Atlantic cod (*G. morhua*). Can. Tech. Rep. Fish. Aquat. Sci. 2092. 390 p.
- Yeung, C., and R.A. McConnaughey. 2008. Using acoustic backscatter from a sidescan sonar to explain fish and invertebrate distributions: a case study in Bristol Bay, Alaska. ICES Journal of Marine Science 65:242-254.

D.3 Sablefish (*Anoplopoma fimbria*)

D.3.1 Life History and General Distribution

Sablefish are distributed from Mexico through the Gulf of Alaska to the Aleutian Chain and Bering Sea, along the Asian coast from Sagami Bay, and along the Pacific sides of Honshu and Hokkaido Islands and the Kamchatkan Peninsula. Adult sablefish occur along the continental slope, shelf gulley, and in deep fjords such as Prince William Sound and Southeastern Alaska, at depths generally greater than 200 m. Adults are assumed to be demersal. Spawning or very ripe sablefish are observed in late winter or early spring along the continental slope. Eggs are apparently released near the bottom where they incubate. After hatching and yolk adsorption the larvae rise to the surface where they have been collected with neuston nets. Larvae are oceanic through the spring, and by late summer small pelagic juveniles (10 to 15 cm) have been observed along the outer coasts of Southeast Alaska, where they apparently move into shallow waters to spend their first winter. During most years, there are only a few places where juveniles have been found during their first winter and second summer. It is not clear if the juvenile distribution is highly specific or appears so because sampling is highly inefficient and sparse. During the occasional times of large year-classes the juveniles are easily found in many inshore areas during their second summer. They are typically 30 to 40 cm in length during their second summer, after which they apparently leave the nearshore bays. One or two years later they begin appearing on the continental shelf and move to their adult distribution as they mature.

Pelagic ocean conditions appear to determine when strong young-of-the-year survival occurs. Water mass movements and temperature appear to be related to recruitment success (Sigler et al. 2001). Above-average young of the year survival was somewhat more likely with northerly winter currents and much less likely for years when the drift was southerly. Recruitment success also appeared related to water temperature. Recruitment was above average in 61 percent of the years when temperature was above average, but was above average in only 25 percent of the years when temperature was below average. Recruitment success did not appear to be directly related to the presence of El Niños or eddies, but these phenomena could potentially influence recruitment indirectly in years following their occurrence (Sigler et al. 2001).

While pelagic oceanic conditions determine the egg, larval, and juvenile survival through their first summer, juvenile sablefish spend 3 to 4 years in demersal habitat along the shorelines and continental shelf before they recruit to their adult habitat, primarily along the upper continental slope, outer continental shelf, and deep gulley. As juveniles in the inshore waters and on the continental shelf, they are subject to a myriad of factors that determine their ability to grow, compete for food, avoid predation, and otherwise survive to adults. Perhaps demersal conditions that may have been brought about by bottom trawling (habitat, bycatch, and increased competitors) have limited the ability of the large year classes that, though abundant at the young-of-the-year stage, survive to adults.

The size at 50 percent maturity is 65 cm for males in the Bering Sea, and 67 cm for females. In the Aleutian Islands, size at 50 percent maturity is 61 cm for males, and 65 cm for females; and in the Gulf of Alaska, it is 57 cm for males, and 65 cm for females. At the end of the second summer (approximately 1.5 years old) they are 35 to 40 cm in length.

D.3.2 Fishery

The major fishery for sablefish in Alaska uses longlines, however sablefish are valuable in the trawl fishery as well. Sablefish enter the longline fishery at 4 to 5 years of age, perhaps slightly younger in the trawl fishery. The longline fishery takes place between March 1 and November 15. The take of the trawl share of sablefish occurs primarily in association with fisheries for other species, such as rockfish, where they are taken as allowed bycatch. Grenadier (*Albatrossia pectoralis* and *Corphaenoides acrolepis*), and deeper dwelling rockfish, such as shortraker (*Sebastes borealis*), rougheye (*S. aleutianus*), and thornyhead rockfish (*Sebastolobus alascanus*) are the primary bycatch in the longline sablefish fishery. Halibut (*Hippoglossus stenolepis*) also are taken. By regulation, there is no directed trawl fishery for sablefish. However, directed fishing standards have allowed some trawl hauls to target sablefish, where the bycatch is similar to the longline fishery, in addition, perhaps, to some deep dwelling flatfish. Pot fishing for sablefish has increased in the Bering Sea and Aleutian Islands in recent years as a response to depredation of longline catches by killer whales.

In addition to the fishery for sablefish, there are significant fisheries for other species that may have an effect on the habitat of sablefish, primarily juveniles. As indicated above, before moving to adult habitat on the slope and deep gulleys, sablefish 2 to 4 years of age reside on the continental shelf, where significant trawl fisheries have taken place. It is difficult to evaluate the potential effect such fisheries could have had on sablefish survival, as a clear picture of the distribution and intensity of the groundfish fishery prior to 1997 has not been available. It is worth noting, however, that the most intensely trawled area from 1998 to 2002, which is just north of the Alaska Peninsula, was closed to trawling by Japan in 1959 and apparently was untrawled until it was opened to U.S. trawling in 1983 (Witherell 1997, Fredin 1987). Juvenile sablefish of the 1977 year class were observed in the western portion of this area by the Alaska Fisheries Science Center trawl survey in 1978 to 1980 at levels of abundance that far exceed levels that have been seen since (Umeda et al. 1983). Observations of 1-year-old and young-of-the-year sablefish in inshore waters from 1980 to 1990 indicate that above-average egg to larval survival has occurred for a number of year classes since.

D.3.3 Relevant Trophic Information

Larval sablefish feed on a variety of small zooplankton ranging from copepod naupli to small amphipods. The epipelagic juveniles feed primarily on macrozooplankton and micronekton (i.e., euphausiids).

In their demersal stage, juvenile sablefish less than 60 cm feed primarily on euphausiids, shrimp, and cephalopods (Yang and Nelson 2000, Yang et al. 2006) while sablefish greater than 60 cm feed more on fish. Both juvenile and adult sablefish are considered opportunistic feeders. Fish most important to the sablefish diet include pollock, eulachon, capelin, Pacific herring, Pacific cod, Pacific sand lance, and some flatfish, with pollock being the most predominant (10 to 26 percent of prey weight, depending on year). Squid, euphausiids, pandalid shrimp, tanner crabs, and jellyfish were also found, squid being the most important of the invertebrates (Yang and Nelson 2000, Yang et al. 2006). Feeding studies conducted in Oregon and California found that fish made up 76 percent of the diet (Laidig et al. 1997). Off the southwest coast of Vancouver Island, euphausiids dominated sablefish diet. Among other groundfish in the Gulf of Alaska, the diet of sablefish overlaps mostly with that of large flatfish, arrowtooth flounder, and Pacific halibut (Yang and Nelson 2000).

Nearshore residence during their second year provide the opportunity to feed on salmon fry and smolts during the summer months, while young-of-the-year sablefish are commonly found in the stomachs of salmon taken in the southeast Alaska troll fishery during the late summer.

D.3.4 Habitat and Biological Associations

Stock condition — The estimated productivity and sustainable yield of the combined Gulf of Alaska, Bering Sea, and Aleutian Islands sablefish stock have declined steadily since the late 1970s. This is demonstrated

by a decreasing trend in recruitment and subsequent estimates of biomass reference points and the inability of the stock to rebuild to the target biomass levels despite the decreasing level of the targets and fishing rates below the target fishing rate. While years of strong young-of-the-year survival has occurred in the 1980s and the 1990s, the failure of strong recruitment to the mature stage suggests a decreased survival of juveniles during their residence as 2 to 4 year olds on the continental shelf.

Habitat and Biological Associations: Sablefish

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	14–20 days	NA	late winter–early spring: Dec–Apr	USP, LSP, BSN	P, 200–3,000 m	NA	U	
Larvae	up to 3 months	copepod nauplii, small copepodites	spring–summer: Apr–July	MCS, OCS, USP, LSP, BSN	N, neustonic near surface	NA	U	
Early Juveniles	to 3 yrs	small prey fish, sandlance, salmon, herring		OCS, MCS, ICS, during first summer, then observed in BAY, IP, till end of 2 nd summer; not observed till found on shelf	P when offshore during first summer, then D, SD/SP when inshore	NA when pelagic. The bays where observed were soft bottomed, but not enough observed to assume typical.	U	
Late Juveniles	3–5 yrs	opportunistic: other fish, shellfish, worms, jellyfish, fishery discards	all year	continental slope, and deep shelf gulleys and fjords.	caught with bottom tending gear. presumably D	varies	U	
Adults	5 yrs to 35+	opportunistic: other fish, shellfish, worms, jellyfish, fishery discards	apparently year round, spawning movements (if any) are undescribed	continental slope, and deep shelf gulleys and fjords.	caught with bottom tending gear. presumably D	varies	U	

D.3.5 Literature

- Allen, M.J., and G.B. Smith. 1988. Atlas and Zoogeography of common fishes in the Bering Sea and northeastern Pacific. U.S. Dep. Commer., NOAA Tech. Rept. NMFS 66, 151 p.
- Boehlert, G.W., and M.M. Yoklavich. 1985. Larval and juvenile growth of sablefish, *Anoplopoma fimbria*, as determined from otolith increments. Fish. Bull. 83:475-481.
- Fredin, R. A. 1987. History of regulation of Alaska groundfish fisheries. NWAFC Processed Report 87_07.
- Grover, J.J., and B.L. Olla. 1986. Morphological evidence for starvation and prey size selection of sea-caught larval sablefish, *Anoplopoma fimbria*. Fish. Bull. 84:484-489.
- Grover, J.J., and B.L. Olla. 1987. Effects of and El Niño event on the food habits of larval sablefish, *Anoplopoma fimbria*, off Oregon and Washington. Fish. Bull. 85: 71-79.

- Grover, J.J., and B.L. Olla. 1990. Food habits of larval sablefish, *Anoplopoma fimbria* from the Bering Sea. Fish Bull. 88:811-814.
- Hunter, J.R., B.J. Macewicz, and C.A. Kimbrell. 1989. Fecundity and other aspects of the reproduction of Sablefish, *Anoplopoma fimbria*, in Central California Waters. Calif. Coop. Fish. Invest. Rep. 30: 61-72.
- Kendall, A.W., Jr., and A.C. Matarese. 1984. Biology of eggs, larvae, and epipelagic juveniles of sablefish, *Anoplopoma fimbria*, in relation to their potential use in management. Mar. Fish. Rev. 49(1):1-13.
- Laidig, T. E., P. B. Adams, and W. M. Samiere. 1997. Feeding habits of sablefish, *Anoplopoma fimbria*, off the coast of Oregon and California. In M. Saunders and M. Wilkins (eds.). Proceedings of the International Symposium on the Biology and Management of Sablefish. pp 65-80. NOAA Tech. Rep. 130. Mason, J.C. , R.J. Beamish, and G.A. McFralen. 1983. Sexual maturity, fecundity, spawning, and early life history of sablefish (*Anoplopoma fimbria*) off the Pacific coast of Canada. Can. J. Fish. Aquat. Sci. 40:2121-2134.
- McFarlane, G.A., and R.J. Beamish. 1992. Climatic influence linking copepod production with strong year-classes in sablefish, *Anoplopoma fimbria*. Can J. Fish. Aquat. Sci. 49:743-753.
- Moser, H.G., R.L. Charter, P.E. Smith, N.C.H. Lo., D.A. Ambrose, C.A. Meyer, E.M. Sanknop, and W. Watson. 1994. Early life history of sablefish, *Anoplopoma fimbria*, off Washington, Oregon, and California with application to biomass estimation. Calif. Coop. Oceanic Fish. Invest. Rep. 35:144-159.
- NOAA (National Oceanic and Atmospheric Administration). 1990. Sablefish, *Anoplopoma fimbria*. PI 3.2.22. In: West Coast of North America Coastal and Ocean Zones Strategic Assessment Data Atlas. Invertebrate and Fish Volume. U.S. Dep. Commer. NOAA. OMA/NOS, Ocean Assessment Division, Strategic Assessment Branch.
- Rutecki, T.L. and E.R. Varosi. 1993. Distribution, age, and growth of juvenile sablefish in Southeast Alaska. Paper presented at International Symposium on the Biology and Management of Sablefish. Seattle, Wash. April 1993.
- Rutecki, T.L. and E.R. Varosi. 1993. Migrations of Juvenile Sablefish in Southeast Alaska. Paper presented at International Symposium on the Biology and Management of Sablefish. Seattle, Wash. April 1993.
- Sasaki, T. 1985. Studies on the sablefish resources in the North Pacific Ocean. Bulletin 22, (1-108), Far Seas Fishery Laboratory. Shimizu, 424, Japan.
- Sigler, M.F., E.R. Varosi, and T.R. Rutecki. 1993. Recruitment curve for sablefish in Alaska based on recoveries of fish tagged as juveniles. Paper presented at International Symposium on the Biology and Management of Sablefish. Seattle, Wash. April 1993.
- Sigler, M. F., T. L. Rutecki, D. L. Courtney, J. F. Karinen, and M.-S. Yang. 2001. Young-of-the-year sablefish abundance, growth, and diet. Alaska Fisheries Research Bulletin 8(1): 57-70.
- Smith, G.B., G.E. Walters, P.A. Raymore, Jr., and W.A. Hirschberger. 1984. Studies of the distribution and abundance of juvenile groundfish in the northwestern Gulf of Alaska, 1980-82: Part I, Three-year comparisons. NOAA Tech. Memo. NMFS F/NWC-59. 100p. Tanasichuk, R. W. 1997. Diet of sablefish, *Anoplopoma fimbria*, from the southwest coast of Vancouver Island. In M. Saunders and M. Wilkins (eds.). Proceedings of the International Symposium on the Biology and Management of Sablefish. pp 93-98. NOAA Tech. Rep. 130.
- Umeda, Y., T. Sample, and R. G. Bakkala. 1983. Recruitment processes of sablefish in the EBS. In Proceedings of the International Sablefish Symposium March 1983, Anchorage, Alaska. Alaska Sea Grant Report 83-8.
- Walters, G.E., G.B. Smith, P.A. Raymore, and W.A. Hirschberger. 1985. Studies of the distribution and abundance of juvenile groundfish in the northwestern Gulf of Alaska, 1980-82: Part II, Biological characteristics in the extended region. NOAA Tech. Memo. NMFS F/NWC-77. 95 p.
- Wing, B.L. 1985. Salmon Stomach contents from the Alaska Troll Logbook Program, 1977-84. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-91, 41 p.
- Wing, B.L. 1997. Distribution of sablefish, *Anoplopoma fimbria*, larvae in the eastern Gulf of Alaska: Neuston-net tows versus oblique tows. In: M. Wilkins and M. Saunders (editors), Proc. Int. Sablefish Symp., April 3-4, 1993, p. 13-25.. U.S. Dep. Commer., NOAA Tech. Rep. 130.

- Wing, B.L. and D.J. Kamikawa. 1995. Distribution of neustonic sablefish larvae and associated ichthyoplankton in the eastern Gulf of Alaska, May 1990. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-53, 48 p.
- Wing, B.L., C. Derrah, and V. O'Connell. 1997. Ichthyoplankton in the eastern Gulf of Alaska, May 1990. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-376, 42 p.
- Witherell, D. 1997. A brief history of bycatch management measures for EBS groundfish fisheries. Marine Fisheries Review. Wolotera, R.J., Jr., T.M. Sample, S.F. Noel, and C.R. Iten. 1993. Geographic and bathymetric distributions for many commercially important fishes and shellfishes off the west coast of North America, based on research survey and commercial catch data, 1912-1984. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-6, 184 p.
- Yang, M-S. 1993. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990. NOAA Tech. Memo. NMFS-AFSC-22. 150 p.
- Yang, M-S. and M.W. Nelson. 2000. Food habits of the commercially important groundfishes in the GOA in 1990, 1993, and 1996. NOAA Technical Memorandum NMFS-AFSC-112.
- Yang, M-S., K. Dodd, R. Hibshman, and A. Whitehouse. 2006. Food habits of groundfishes in the Gulf of Alaska in 1999 and 2001. NOAA Technical Memorandum NMFS-AFSC-164.

D.4 Yellowfin sole (*Limanda aspera*)

D.4.1 Life History and General Distribution

Yellowfin sole are distributed in North American waters from off British Columbia, Canada, (approximately latitude 49° N.) to the Chukchi Sea (about latitude 70° N.) and south along the Asian coast to about latitude 35° N. off the South Korean coast in the Sea of Japan. Adults exhibit a benthic lifestyle and occupy separate winter spawning and summertime feeding distributions on the eastern Bering Sea shelf. From over-winter grounds near the shelf margins, adults begin a migration onto the inner shelf in April or early May each year for spawning and feeding. A protracted and variable spawning period may range from as early as late May through August occurring primarily in shallow water. Fecundity varies with size and was reported to range from 1.3 to 3.3 million eggs for fish 25 to 45 cm long. Eggs have been found to the limits of inshore ichthyoplankton sampling over a widespread area to at least as far north as Nunivak Island. Larvae have been measured at 2.2 to 5.5 mm in July and 2.5 to 12.3 mm in late August and early September. The age or size at metamorphosis is unknown. Upon settlement in nearshore areas, juveniles preferentially select sediment suitable for feeding on meiofaunal prey and burrowing for protection. Juveniles are separate from the adult population, remaining in shallow areas until they reach approximately 15 cm. The estimated age of 50 percent maturity is 10.5 years (approximately 29 cm) for females based on samples collected in 1992 and 1993. Natural mortality rate is believed to range from 0.12 to 0.16.

The approximate upper size limit of juvenile fish is 27 cm.

D.4.2 Fishery

Caught in bottom trawls both as a directed fishery and in the pursuit of other bottom-dwelling species. Recruitment begins at about age 6 and they are fully selected at age 13. Historically, the fishery has occurred throughout the mid- and inner Bering Sea shelf during ice-free conditions, although much effort has been directed at the spawning concentrations in nearshore northern Bristol Bay. They are caught as bycatch in Pacific cod, bottom pollock, and other flatfish fisheries and are caught with these species and Pacific halibut in yellowfin sole directed fisheries.

D.4.3 Relevant Trophic Information

Groundfish predators include Pacific cod, skates, and Pacific halibut, mostly on fish ranging from 7 to 25 cm standard length.

D.4.4 Habitat and Biological Associations

Larvae/Juveniles: Planktonic larvae for at least 2 to 3 months until metamorphosis occurs, usually inhabiting shallow areas.

Adults: Summertime spawning and feeding on sandy substrates of the eastern Bering Sea shelf. Widespread distribution mainly on the middle and inner portion of the shelf, feeding mainly on bivalves, polychaete, amphipods, and echinurids. Wintertime migration to deeper waters of the shelf margin to avoid extreme cold water temperatures, feeding diminishes.

Habitat and Biological Associations: Yellowfin sole

Stage - EFH Level	Duration or Age	Diet/Prey	Season/Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs		NA	summer	BAY, BCH	P			
Larvae	2–3 months?	U phyto/zoo plankton?	summer autumn?	BAY, BCH ICS	P			
Early Juveniles	to 5.5 yrs	polychaete bivalves amphipods echinurids	all year	BAY, ICS OCS	D	S		
Late Juveniles	5.5 to 10 yrs	polychaete bivalves amphipods echinurids	all year	BAY, ICS OCS	D	S		
Adults	10+ years	polychaete bivalves amphipods echinurids	spawning/ feeding May–August non-spawning Nov–April	BAY BCH ICS, MCS OCS	D	S	ice edge	

D.4.5 Literature

- Auster, P.J., Malatesta, R.J., Langton, R.W., L. Watling, P.C. Valentine, C.S. Donaldson, E.W. Langton, A.N. Shepard, and I.G. Babb. 1996. The impacts of mobile fishing gear on seafloor habitats in the Gulf of Maine (Northwest Atlantic): Implications for conservation of fish populations. *Rev. in Fish. Sci.* 4(2): 185-202.
- Bakkala, R.G., V.G. Wespestad, and L.L. Low. 1982. The yellowfin sole (*Limanda aspera*) resource of the eastern Bering Sea—Its current and future potential for commercial fisheries. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-33, 43 p.
- Fadeev, N.W. 1965. Comparative outline of the biology of fishes in the southeastern part of the Bering Sea and condition of their resources. [In Russ.] *Tr. Vses. Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* 58 (Izv. Tikhookean. Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 53):121-138. (Trans. By Isr. Prog. Sci. Transl., 1968), p 112-129. In P.A. Moiseev (Editor), *Soviet Fisheries Investigations in the northeastern Pacific*, Pt. IV. Avail. Natl. Tech. Inf. Serv., Springfield, VA as TT 67-51206.
- Kashkina, A.A. 1965. Reproduction of yellowfin sole (*Limanda aspera*) and changes in its spawning stocks in the eastern Bering Sea. *Tr. Vses. Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* 58 (Izv. Tikhookean.

- Nauchno-issled. Inst. Rbn. Khoz. Okeanogr. 53):191-199. [In Russ.] Transl. By Isr. Prog. Sci. Transl., 1968, p. 182-190. In P.A. Moiseev (Editor), Soviet fisheries investigations in the northeastern Pacific, Part IV. Avail. Natl. Tech. Inf. Serv., Springfield, VA., as TT67-51206.
- Livingston, P.A. and Y. DeReynier. 1996. Groundfish food habits and predation on commercially important prey species in the eastern Bering Sea from 1990 to 1992. AFSC processed Rep. 96-04, 51 p. Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Seattle, WA 98115.
- Moles, A., and B. L. Norcross. 1995. Sediment preference in juvenile Pacific flatfishes. Netherlands J. Sea Res. 34(1-3):177-182 (1995).
- Musienko, L.N. 1963. Ichthyoplankton of the Bering Sea (data of the Bering Sea expedition of 1958-59). Tr. Vses Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 48 (Izv. Tikhookean. Nauchno-issled. Inst. Rybn. Khoz. Okeanogr. 50)239-269. [In Russ.] Transl. By Isr. Prog. Sci. Transl., 1968, p. 251-286. In P.A. Moiseev (Editor), Soviet fisheries investigations in the northeastern Pacific, Part I. Avail. Natl. Tech. Inf. Serv., Springfield, VA, as TT67-51203.
- Musienko, L.N. 1970. Reproduction and Development of Bering Sea. Tr. Vses Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 70 (Izv. Tikhookean. Nauchno-issled. Inst. Rybn. Khoz. Okeanogr. 72)161-224. [In Russ.] Transl. By Isr. Prog. Sci. Transl., 1972, p. 161-224. In P.A. Moiseev (Editor), Soviet fisheries investigations in the northeastern Pacific, Part V. Avail. Natl. Tech. Inf. Serv., Springfield, VA., as TT71-50127.
- Nichol, D.G. 1994. Maturation and Spawning of female yellowfin sole in the Eastern Bering Sea. Preceding of the International North Pacific Flatfish Symposium, Oct. 26-28, 1994, Anchorage, AK. Alaska Sea Grant Program.
- Wakabayashi, K. 1986. Interspecific feeding relationships on the continental shelf of the eastern Bering Sea, with special reference to yellowfin sole. Int. N. Pac. Fish. Comm. Bull. 47:3-30.
- Waldron, K.D. 1981. Ichthyoplankton. In D.W. Hood and J.A. Calder (Editors), The eastern Bering Sea shelf: Oceanography and resources, Vol. 1, p. 471-493. U.S. Dep. Commer., NOAA, Off. Mar. Poll. Assess., U.S. Gov. Print. Off., Wash., D.C.
- Wilderbuer, T.K., G.E. Walters, and R.G. Bakkala. 1992. Yellowfin sole, *Pleuronectes asper*, of the Eastern Bering Sea: Biological Characteristics, History of Exploitation, and Management. Mar. Fish. Rev. 54(4) p 1-18.
- Wilderbuer, T.K., D.G. Nichol, and J. Ianelli. 2010. Yellowfin sole. In Stock Assessment and Fishery Evaluation Report for Groundfish Resources of the Bering Sea/Aleutian Islands Regions. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, Alaska 99501. Pp. 565-644.

D.5 Greenland turbot (*Reinhardtius hippoglossoides*)

D.5.1 Life History and General Distribution

Greenland turbot has an amphiboreal distribution, occurring in the North Atlantic and North Pacific, but not in the intervening Arctic Ocean. In the North Pacific, species abundance is centered in the eastern Bering Sea and, secondly, in the Aleutian Islands. On the Asian side, they occur in the Gulf of Anadyr along the Bering Sea coast of Russia, in the Okhotsk Sea, around the Kurile Islands, and south to the east coast of Japan to northern Honshu Island (Hubbs and Wilimovsky 1964, Mikawa 1963, Shuntov 1965). Adults exhibit a benthic lifestyle, living in deep waters of the continental slope but are known to have a tendency to feed off the sea bottom. During their first few years as immature fish, they inhabit relatively shallow continental shelf waters (less than 200 m) until about age 4 or 5 before joining the adult population (200 to 1,000 m or more, Templeman 1973). Adults appear to undergo seasonal shifts in depth distribution moving deeper in winter and shallower in summer (Chumakov 1970, Shuntov 1965). Spawning is reported to occur in winter in the eastern Bering Sea and may be protracted starting in September or October and continuing until March with an apparent peak period in November to February (Shuntov 1965, Bulatov 1983). Females

spawn relatively small numbers of eggs with fecundity ranging from 23,900 to 149,300 for fish 83 cm and smaller in the Bering Sea (D'yakov 1982).

Eggs and early larval stages are benthypelagic (Musienko 1970). In the Atlantic Ocean, larvae (10 to 18 cm) have been found in benthypelagic waters which gradually rise to the pelagic zone in correspondence to absorption of the yolk sac which is reported to occur at 15 to 18 mm with the onset of feeding (Pertseva-Ostroumova 1961). The period of larval development extends from April to as late as August or September (Jensen 1935) which results in an extensive larval drift and broad dispersal from the spawning waters of the continental slope. Metamorphosis occurs in August or September at about 7 to 8 cm in length at which time the demersal life begins. Juveniles are reported to be quite tolerant of cold temperatures to less than 0 °C (Hognestad 1969) and have been found on the northern part of the Bering Sea shelf in summer trawl surveys (Alton et al. 1988).

The age of 50 percent maturity is estimated to range from 5 to 10 years (D'yakov 1982, 60 cm used in stock assessment) and a natural mortality rate of 0.18 has been used in the most recent stock assessments (Ianelli et al. 2010). The approximate upper size limit of juvenile fish is 59 cm.

D.5.2 Fishery

Greenland turbot are caught in bottom trawls and on longlines both as a directed fishery and in the pursuit of other bottom-dwelling species (primarily sablefish). Recruitment begins at about 50 and 60 cm in the trawl and longline fisheries, respectively. The fishery operates on the continental slope throughout the eastern Bering Sea and on both sides of the Aleutian Islands. Bycatch primarily occurs in the sablefish directed fisheries and also to a smaller extent in the Pacific cod fishery.

D.5.3 Relevant Trophic Information

Groundfish predators include Pacific cod, pollock, and yellowfin sole, mostly on fish ranging from 2 to 5 cm standard length (probably age 0).

D.5.4 Habitat and Biological Associations

Larvae/Juveniles: Planktonic larvae for up to 9 months until metamorphosis occurs, usually with a widespread distribution inhabiting shallow waters. Juveniles live on the continental shelf until about age 4 or 5 feeding primarily on euphausiids, polychaetes, and small walleye pollock.

Adults: Inhabit continental slope waters with annual spring/fall migrations from deeper to shallower waters. Diet consists of walleye pollock and other miscellaneous fish species.

Habitat and Biological Associations: Greenland turbot

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs		NA	winter	OCS, MCS	SD, SP			
Larvae	8–9 months	U phyto/zoo plankton?	spring summer	OCS, ICS MCS	P			
Juveniles	1–5 yrs	euphausiids polychaetes small pollock	all year	ICS, MCS OCS, USP	D, SD	MS, M		
Adults	5+ years	pollock small fish	spawning Nov–February	OCS, USP LSP	D, SD	MS, M		
			non-spawning March–Oct	USP, LSP				

D.5.5 Literature

- Alton, M.S., R.G. Bakkala, G.E. Walters and P.T. Munro. 1988. Greenland turbot, *Reinhardtius hippoglossoides*, of the Eastern Bering Sea and Aleutian Islands. U.S. Dept. Commer., NOAA Tech. Rpt. NMFS 71, 31 pages.
- Auster, P.J., Malatesta, R.J., Langton, R.W., L. Watling, P.C. Valentine, C.S. Donaldson, E.W. Langton, A.N. Shepard, and I.G. Babb. 1996. The impacts of mobile fishing gear on seafloor habitats in the Gulf of Maine (Northwest Atlantic): Implications for conservation of fish populations. Rev. in Fish. Sci. 4(2): 185-202.
- Bulatov, O.A. 1983. Distribution of eggs and larvae of Greenland halibut, *Reinhardtius hippoglossoides*, (Pleuronectidae) in the eastern Bering Sea. J. Ichthyol. [Engl. Transl. Vopr. Ikhtiol.] 23(1):157-159.
- Chumakov, A.K. 1970. The Greenland halibut, *Reinhardtius hippoglossoides*, in the Iceland area-The halibut fisheries and tagging. Tr. Polyarn. Nauchno-Issled. Proekt. Inst. Morsk. Rybn. Khoz. 1970:909-912.
- D'yakov, Yu. P. 1982. The fecundity of the Greenland halibut, *Reinhardtius hippoglossoides* (Pleuronectidae), from the Bering Sea. J. Ichthyol. [Engl. Trans. Vopr. Ikhtiol.] 22(5):59-64.
- Hognestad, P.T. 1969. Notes on Greenland halibut, *Reinhardtius hippoglossoides*, in the eastern Norwegian Sea. Fiskeridir. Skr. Ser. Havunders. 15(3):139-144.
- Hubbs, C.L., and N.J. Wilimovsky. 1964. Distribution and synonymy in the Pacific Ocean and variation of the Greenland halibut, *Reinhardtius hippoglossoides* (Walbaum). J. Fish. Res. Board Can. 21:1129-1154.
- Ianelli, J.N., T.K. Wilderbuer, and D. Nichol. 2010. Greenland turbot. In Stock Assessment and Fishery Evaluation Report for Groundfish Resources of the Bering Sea/Aleutian Islands Regions. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, Alaska 99501.
- Jensen, A.S. 1935. (*Reinhardtius hippoglossoides*) its development and migrations. K. dan. Vidensk. Selsk. Skr. 9 Rk., 6:1-32.
- Livingston, P.A. and Y. DeReynier. 1996. Groundfish food habits and predation on commercially important prey species in the eastern Bering Sea from 1990 to 1992. AFSC processed Rep. 96-04, 51 p. Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way, NE., Seattle, WA 98115.
- Mikawa, M. 1963. Ecology of the lesser halibut, *Reinhardtius hippoglossoides matsuurae* Jordan and Snyder. Bull. Tohoku Reg. Fish. Res. Lab. 29:1-41.
- Musienko, L.N. 1970. Reproduction and Development of Bering Sea. Tr. Vses Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 70 (Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr. 72)161-224. [In Russ.] Transl. By Isr. Prog. Sci. Transl., 1972, p. 161-224. In P. A. Moiseev (Editor), Soviet fisheries investigations in the northeastern Pacific, Part V. Avail. Natl. Tech. Inf. Serv., Springfield, VA., as TT71-50127.

- Pertseva-Ostroumova, T.A. 1961. The reproduction and development of far eastern flounders. Izdatel'stvo Akad. Nauk. SSSR, 483 p. [Transl. By Fish. Res. Board Can., 1967, Transl. Ser. 856, 1003 p.]
- Shuntov, V.P. 1965. Distribution of the Greenland halibut and arrowtooth halibuts in the North Pacific. Tr. Vses. Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 58 (Izv. Tikhookean. Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 53):155-163. [Transl. In Soviet Fisheries Investigation in the Northeastern Pacific, Part IV, p. 147-156, by Israel Prog. Sci. Transl., 1972, avail. Natl. Tech. Inf. Serv., Springfield, VA as TT71-50127.]
- Templeman, W. 1973. Distribution and abundance of the Greenland halibut, *Reinhardtius hippoglossoides* (Walbaum), in the Northwest Atlantic. Int. Comm. Northwest Atl. Fish. Res. Bull. 10:82-98.

D.6 Arrowtooth flounder (*Atheresthes stomias*)

D.6.1 Life History and General Distribution

Arrowtooth flounder are distributed in North American waters from central California to the eastern Bering Sea on the continental shelf and upper slope.

Adults exhibit a benthic lifestyle and occupy separate winter and summer distributions on the eastern Bering Sea shelf. From over-winter grounds near the shelf margins and upper slope areas, adults begin a migration onto the middle and outer shelf in April or early May each year with the onset of warmer water temperatures. A protracted and variable spawning period may range from as early as September through March (Rickey 1994, Hosie 1976). Total fecundity may range from 250,000 to 2,340,000 oocytes (Zimmerman 1997). Larvae have been found from ichthyoplankton sampling over a widespread area of the eastern Bering Sea shelf in April and May and also on the continental shelf east of Kodiak Island during winter and spring (Waldron and Vinter 1978, Kendall and Dunn 1985). The age or size at metamorphosis is unknown. Juveniles are separate from the adult population, remaining in shallow areas until they reach the 10 to 15 cm range (Martin and Clausen 1995). The estimated length at 50 percent maturity is 28 cm for males (4 years) and 37 cm for females (5 years) from samples collected in the Gulf of Alaska (Zimmerman 1997). The natural mortality rate used in stock assessments differs by sex and is estimated at 0.2 for females and 0.35 to 0.37 for males (Turnock et al. 2009, Wilderbuer et al. 2010).

The approximate upper size limit of juvenile fish is 27 cm for males and 37 cm for females.

D.6.2 Fishery

Arrowtooth flounder are caught in bottom trawls usually in pursuit of other higher value bottom-dwelling species. Historically have been undesirable to harvest due to a flesh softening condition caused by protease enzyme activity. Recruitment begins at about age 3 and females are fully selected at age 10. They are caught as bycatch in Pacific cod, bottom pollock, sablefish, and other flatfish fisheries by both trawls and longliners.

D.6.3 Relevant Trophic Information

Arrowtooth flounder are very important as a large, aggressive, and abundant predator of other groundfish species. Groundfish predators include Pacific cod and pollock, mostly on small fish.

D.6.4 Habitat and Biological Associations

Larvae/Juveniles: Planktonic larvae for at least 2 to 3 months until metamorphosis occurs; juveniles usually inhabit shallow areas until about 10 cm in length.

Adults: Widespread distribution mainly on the middle and outer portions of the continental shelf, feeding mainly on walleye pollock and other miscellaneous fish species when arrowtooth flounder attain lengths

greater than 30 cm. Wintertime migration to deeper waters of the shelf margin and upper continental slope to avoid extreme cold water temperatures and for spawning.

Habitat and Biological Associations: Arrowtooth flounder

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs		NA	winter, spring?	ICS, MCS, OCS	P			
Larvae	2–3 months?	U phyto/zoo plankton?	spring summer?	BAY, ICS, MCS, OCS	P			
Early Juveniles	to 2 yrs	euphausiids crustaceans amphipods pollock	all year	ICS, MCS	D	GMS		
Late Juveniles	males 2–4 yrs females 2–5 yrs	euphausiids crustaceans amphipods pollock	all year	ICS, MCS, OCS, USP	D	GMS		
Adults	males 4+ yrs females 5+ yrs	pollock misc. fish Gadidae sp. euphausiids	spawning Nov–March	MCS, OCS, USP	D	GMS	ice edge (EBS)	
			non-spawning April–Oct					

D.6.5 Literature

- Auster, P.J., Malatesta, R.J., Langton, R.W., L. Watling, P.C. Valentine, C.S. Donaldson, E.W. Langton, A.N. Shepard, and I G. Babb. 1996. The impacts of mobile fishing gear on seafloor habitats in the Gulf of Maine (Northwest Atlantic): Implications for conservation of fish populations. *Rev. in Fish. Sci.* 4(2): 185-202.
- Hart, J.L. 1973. Pacific fishes of Canada. *Fish. Res. Board Can. Bull.* 180, 740 p.
- Hosie, M.J. 1976. The arrowtooth flounder. *Oregon Dep. Fish. Wildl. Info. Rep.* 76-3, 4 p.
- Kendall, A.W. Jr. and J.R. Dunn. 1985. Ichthyoplankton of the continental shelf near Kodiak Island, Alaska. NOAA Tech. Rep. NMFS 20, U. S. Dep. Commer, NOAA, Natl. Mar. Fish. Serv.
- Livingston, P.A. and Y. DeReynier. 1996. Groundfish food habits and predation on commercially important prey species in the eastern Bering Sea from 1990 to 1992. AFSC processed Rep. 96-04, 51 p. Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Seattle, WA 98115.
- Martin, M.H. and D.M. Clausen. 1995. Data report: 1993 Gulf of Alaska Bottom Trawl Survey. U.S. Dept. Commer., NOAA, Natl. Mar. Fish. Serv., NOAA Tech. Mem. NMFS-AFSC-59, 217 p.
- Rickey, M.H. 1994. Maturity, spawning, and seasonal movement of arrowtooth flounder, *Atheresthes stomias*, off Washington. *Fish. Bull.* 93:127-138 (1995).
- Turnock, B.J., T.K. Wilderbuer and E.S. Brown 2009. Arrowtooth flounder. *In* Appendix B Stock Assessment and Fishery Evaluation Report for the groundfish resources of the Gulf of Alaska. North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage, AK 99501.
- Waldron, K.D. and B.M. Vinter 1978. Ichthyoplankton of the eastern Bering Sea. U. S. Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv. Seattle, WA, Processed rep., 88 p.

Wilderbuer, T.K., D. Nichol, and K. Aydin. 2010. Arrowtooth flounder. In Stock Assessment and Fishery Evaluation Report for Groundfish Resources of the Bering Sea/Aleutian Islands Regions. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, Alaska 99501. Pp. 697-762.

Zimmermann, Mark. 1997. Maturity and fecundity of arrowtooth flounder, *Atheresthes stomias*, from the Gulf of Alaska. Fish Bull. 95:598-611.

D.7 Northern rock sole (*Lepidopsetta polyxystra*)

D.7.1 Life History and General Distribution

Members of the genus *Lepidopsetta* are distributed from California waters north into the Gulf of Alaska and Bering Sea to as far north as the Gulf of Anadyr. The distribution continues along the Aleutian Islands westward to the Kamchatka Peninsula and then southward through the Okhotsk Sea to the Kurile Islands, Sea of Japan, and off Korea. Centers of abundance occur off the Kamchatka Peninsula (Shubnikov and Lisovenko 1964), British Columbia (Forrester and Thompson 1969), the central Gulf of Alaska, and in the southeastern Bering Sea (Alton and Sample 1976). Two forms were recently found to exist in Alaska by Orr and Matarese (2000), a southern rock sole (*L. bilineatus*) and a northern rock sole (*L. polyxystra*). Resource assessment trawl surveys indicate that northern rock sole comprise more than 95 percent of the Bering Sea population. Adults exhibit a benthic lifestyle and, in the eastern Bering Sea, occupy separate winter (spawning) and summertime feeding distributions on the continental shelf. Northern rock sole spawn during the winter and early spring period of December through March. Soviet investigations in the early 1960s established two spawning concentrations: an eastern concentration north of Unimak Island at the mouth of Bristol Bay and a western concentration eastward of the Pribilof Islands between 55°30' N. and 55°0' N. and approximately 165°2' W. (Shubnikov and Lisovenko, 1964). Rock sole spawning in the eastern and western Bering Sea was found to occur at depths of 125 to 250 m, close to the shelf/slope break. Spawning females deposit a mass of eggs which are demersal and adhesive (Alton and Sample 1976). Fertilization is believed to be external. Incubation time is temperature dependent and may range from 6.4 days at 11 °C to about 25 days at 2.9 °C (Forrester 1964). Newly hatched larvae are pelagic and have occurred sporadically in eastern Bering Sea plankton surveys (Waldron and Vinter 1978). Kamchatka larvae are reportedly 20 mm in length when they assume their side-swimming, bottom-dwelling form (Alton and Sample 1976). Norcross et al. (1996) found newly settled larvae in the 40 to 50 mm size range. Forrester and Thompson (1969) report that by age 1 they are found with adults on the continental shelf during summer.

In the springtime, after spawning, rock sole begin actively feeding and commence a migration to the shallow waters of the continental shelf. This migration has been observed on both the eastern (Alton and Sample 1976) and western (Shvetsov 1978) areas of the Bering Sea. During this time they spread out and form much less dense concentrations than during the spawning period. Summertime trawl surveys indicate most of the population can be found at depths from 50 to 100 m (Armistead and Nichol 1993). The movement from winter/spring to summer grounds is in response to warmer temperatures in the shallow waters and the distribution of prey on the shelf seafloor (Shvetsov 1978). In September, with the onset of cooling in the northern latitudes, rock sole begin the return migration to the deeper wintering grounds. Fecundity varies with size and was reported to be 450,000 eggs for fish 42 cm long. Larvae are pelagic but their occurrence in plankton surveys in the eastern Bering Sea are rare (Musienko 1963). Juveniles are separate from the adult population, remaining in shallow areas until they reach age 1 (Forrester 1969). The estimated age of 50 percent maturity is 9 years (approximately 35 cm) for southern rock sole females and 7 years for northern rock sole females (Stark and Somerton 2002). Natural mortality rate is believed to range from 0.18 to 0.20.

The approximate upper size limit of juvenile fish is 34 cm.

D.7.2 Fishery

Northern rock sole are caught in bottom trawls both as a directed fishery and in the pursuit of other bottom-dwelling species. Recruitment begins at about age 4 and they are fully selected at age 11. Historically, the fishery has occurred throughout the mid- and inner Bering Sea shelf during ice-free conditions and on spawning concentrations north of the Alaska Peninsula during winter for their high-value roe. They are caught as bycatch in Pacific cod, bottom pollock, yellowfin sole, and other flatfish fisheries and are caught with these species and Pacific halibut in rock sole directed fisheries.

D.7.3 Relevant Trophic Information

Groundfish predators include Pacific cod, walleye pollock, skates, Pacific halibut, and yellowfin sole, mostly on fish ranging from 5 to 15 cm standard length.

D.7.4 Habitat and Biological Associations

Larvae/Juveniles: Planktonic larvae for at least 2 to 3 months until metamorphosis occurs, juveniles inhabit shallow areas at least until age 1.

Adults: Summertime feeding on primarily sandy substrates of the eastern Bering Sea shelf. Widespread distribution mainly on the middle and inner portion of the shelf, feeding on bivalves, polychaete, amphipods, and miscellaneous crustaceans. Wintertime migration to deeper waters of the shelf margin for spawning and to avoid extreme cold water temperatures, feeding diminishes.

Habitat and Biological Associations: Rock sole

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs		NA	winter	OCS	D			
Larvae	2–3 months?	U phyto/zoo plankton?	winter/spring	OCS, MCS, ICS	P			
Early Juveniles	to 3.5 yrs	polychaete bivalves amphipods misc. crustaceans	all year	BAY, ICS	D	S G		
Late Juveniles	to 9 years	polychaete bivalves amphipods misc. crustaceans	all year	BAY, ICS, MCS, OCS	D	S G		
Adults	9+ years	polychaete bivalves amphipods misc. crustaceans	feeding May–September spawning Dec.–April	MCS, ICS OCS	D	S G	ice edge	

D.7.5 Literature

Alton, M.S. and Terry M. Sample 1976. Rock sole (Family Pleuronectidae) p. 461-474. *In*: Demersal fish and shellfish resources in the Bering Sea in the baseline year 1975. Principal investigators Walter T. Pereyra, Jerry E. Reeves, and Richard Bakkala. U.S. Dep. Comm., Natl. Oceanic Atmos. Admin., Natl. Mar. Serv., Northwest and Alaska Fish Center, Seattle, WA. Processed Rep., 619 p.

- Armistead, C.E. and D.G. Nichol 1993. 1990 Bottom Trawl Survey of the Eastern Bering Sea Continental Shelf. U.S. Dep. Commer., NOAA Tech. Mem. NMFS-AFSC-7, 190 p.
- Auster, P.J., Malatesta, R.J., Langton, R.W., L. Watling, P.C. Valentine, C.S. Donaldson, E.W. Langton, A.N. Shepard, and I.G. Babb. 1996. The impacts of mobile fishing gear on seafloor habitats in the Gulf of Maine (Northwest Atlantic): Implications for conservation of fish populations. Rev. in Fish. Sci. 4(2): 185-202.
- Forrester, C.R. 1964. Demersal Quality of fertilized eggs of rock sole. J. Fish. Res. Bd. Canada, 21(6), 1964. P. 1531.
- Forrester, C.R. and J.A. Thompson 1969. Population studies on the rock sole, *Lepidopsetta bilineata*, of northern Hecate Strait British Columbia. Fish. Res. Bd. Canada, Tech. Rep. No. 108, 1969. 104 p.
- Livingston, P.A. and Y. DeReynier. 1996. Groundfish food habits and predation on commercially important prey species in the eastern Bering Sea from 1990 to 1992. AFSC processed Rep. 96-04, 51 p. Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Seattle, WA 98115.
- Musienko, L.N. 1963. Ichthyoplankton of the Bering Sea (data of the Bering Sea expedition of 1958-59). Tr. Vses Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 48 (Izv. Tikhookean. Nauchno-issled. Inst. Rybn. Khoz. Okeanogr. 50)239-269. [In Russ.] Transl. By Isr. Prog. Sci. Transl., 1968, p. 251-286. In P. A. Moiseev (Editor), Soviet fisheries investigations in the northeastern Pacific, Part I. Avail. Natl. Tech. Inf. Serv., Springfield, VA., as TT67-51203.
- Norcross, B.L., B.A. Holladay, S. C. Dressel, and M. Frandsen. 1996. Recruitment of juvenile flatfishes in Alaska: habitat preference near Kodiak Island. U. Alaska, Coastal Marine Institute, OCS study MMS 96-003. Vol. 1.
- Orr, J. M. and A. C. Matarese. 2000. Revision of the genus *Lepidipsetta* Gill, 1862 (Teleostei: Pleuronectidae) based on larval and adult morphology, with a description of a new species from the North Pacific Ocean and Bering Sea. Fish. Bull.98:539-582 (2000).
- Shubnikov, D.A. and L.A. Lisovenko 1964. Data on the biology of rock sole in the southeastern Bering Sea. Tr. Vses. Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 49 (Izv. Tikhookean. Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 51) : 209-214. (Transl. In Soviet Fisheries Investigations in the Northeast Pacific, Part II, p. 220-226, by Israel Program Sci. Transl., 1968, available Natl. Tech. Inf. Serv., Springfield, VA, as TT 67-51204).
- Shvetsov, F.G. 1978. Distribution and migrations of the rock sole, *Lepidopsetta bilineata*, in the regions of the Okhotsk Sea coast of Paramushir and Shumshu Islands. J. Ichthol., 18 (1), 56-62, 1978.
- Stark, J. W. and D. A. Somerton. 2002. Maturation, spawning and growth of rock sole off Kodiak Island in the Gulf of Alaska. J. Fish. Biology (2002)61, 417-431.
- Waldron, K.D. And B. M. Vinter 1978. Ichthyoplankton of the eastern Bering Sea. U. S. Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv. Seattle, WA, Processed rep., 88 p.
- Wilderbuer, T.K. and D.G. Nichol. 2010. Northern Rock sole. In Stock Assessment and Fishery Evaluation Report for Groundfish Resources of the Bering Sea/Aleutian Islands Regions. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, Alaska 99501. Pp. 781-868.

D.8 Flathead sole (*Hippoglossoides elassodon*)

D.8.1 Life History and General Distribution

Flathead sole are distributed from northern California, off Point Reyes, northward along the west coast of North America, and throughout the Gulf of Alaska and the Bering Sea, the Kuril Islands and possibly the Okhotsk Sea (Hart 1973).

Adults exhibit a benthic lifestyle and occupy separate winter spawning and summertime feeding distributions on the eastern Bering Sea shelf and in the Gulf of Alaska. From over-winter grounds near the shelf margins, adults begin a migration onto the mid- and outer continental shelf in April or May each year for feeding. The spawning period may start as early as January but is known to occur in March and April,

primarily in deeper waters near the margins of the continental shelf. Eggs are large (2.75 to 3.75 mm) and females have egg counts ranging from about 72,000 (20 cm fish) to almost 600,000 (38 cm fish). Eggs hatch in 9 to 20 days depending on incubation temperatures within the range of 2.4 to 9.8°C (Forrester and Alderdice 1967) and have been found in ichthyoplankton sampling on the southern portion of the Bering Sea shelf in April and May (Waldron 1981). Larvae absorb the yolk sac in 6 to 17 days but the extent of their distribution is unknown. Size at metamorphosis is 18 to 35 mm (Matarese et al. 2003). Juveniles less than age 2 have not been found with the adult population, remaining in shallow areas. Age at 50 percent maturity is 9.7 years (Stark 2004). The natural mortality rate used in recent stock assessments is 0.2 (Stockhausen et al. 2008).

D.8.2 Fishery

Flathead sole are caught in bottom trawls both as a directed fishery and in the pursuit of other bottom-dwelling species. Recruitment begins at about age 3. Historically, the fishery has occurred throughout the mid- and outer Bering Sea shelf during ice-free conditions (mostly summer and fall). They are caught as bycatch in Pacific cod, bottom pollock, and other flatfish fisheries and are caught with these species and Pacific halibut in flathead sole directed fisheries.

D.8.3 Relevant Trophic Information

Groundfish predators include Pacific cod, Pacific halibut, arrowtooth flounder, and cannibalism by large flathead sole, mostly on fish less than 20 cm standard length (Livingston and DeReynier 1996).

D.8.4 Habitat and Biological Associations

Larvae/Juveniles: Planktonic larvae for an unknown time period until metamorphosis occurs, usually inhabiting shallow areas.

Adults: Winter spawning and summer feeding on sand and mud substrates of the continental shelf. Widespread distribution mainly on the middle and outer portion of the shelf, feeding mainly on ophiuroids, tanner crab, osmerids, bivalves, and polychaete (Pacunski 1990).

Habitat and Biological Associations: Flathead sole

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	9–20 days	NA	winter	ICS, MCS, OCS	P			
Larvae	U	U phyto/zoo plankton?	spring summer	ICS, MCS, OCS	P			
Early Juveniles	to 2 yrs	polychaete bivalves ophiuroids	all year	MCS, ICS	D	S, M		
Late Juveniles	age 3–9 yrs	polychaete bivalves ophiuroids pollock and Tanner crab	all year	MCS, ICS, OCS	D	S, M	Juveniles	
Adults	age 9–30 yrs	polychaete bivalves ophiuroids pollock and Tanner crab	spawning Jan–April non-spawning May–December	MCS, OCS, ICS	D	S, M	ice edge	

D.8.5 Literature

- Auster, P.J., Malatesta, R.J., Langton, R.W., L. Watling, P.C. Valentine, C.S. Donaldson, E.W. Langton, A.N. Shepard, and I.G. Babb. 1996. The impacts of mobile fishing gear on sea floor habitats in the Gulf of Maine (Northwest Atlantic): Implications for conservation of fish populations. *Rev. in Fish. Sci.* 4(2): 185-202.
- Forrester, C.R. and D.F. Alderdice. 1967. Preliminary observations on embryonic development of the flathead sole (*Hippoglossoides elassodon*). *Fish. Res. Board Can. Tech. Rep.* 100: 20 p
- Hart, J.L. 1973. Pacific fishes of Canada. *Fish. Res. Board Canada, Bull. No. 180.* 740 p.
- Livingston, P.A. and Y. DeReynier. 1996. Groundfish food habits and predation on commercially important prey species in the eastern Bering Sea from 1990 to 1992. AFSC processed Rep. 96-04, 51 p. Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Seattle, WA 98115.
- Matarese, A.C., D.M. Blood, S.J. Piquelle and J. Benson. 2003. Atlas of abundance and distribution patterns of ichthyoplankton from the northeast Pacific Ocean and Bering Sea ecosystems based on research conducted by the Alaska Fisheries Science Center (1972-1996). NOAA Prof. Paper NMFS 1. 281 p.
- McConnaughey, R.A. and K.R. Smith. 2000. Associations between flatfish abundance and surficial sediments in the eastern Bering Sea. *Can. J. Fish. Aquat. Sci.* 57: 2410-2419.
- Miller, B.S. 1969. Life history observations on normal and tumor bearing flathead sole in East Sound, Orcas Island (Washington). Ph.D. Thesis. Univ. Wash. 131 p.
- Pacunski, R.E. 1990. Food habits of flathead sole (*Hippoglossoides elassodon*) in the eastern Bering Sea. M.S. Thesis. Univ. Wash. 106 p.
- Stark, J.W. 2004. A comparison of the maturation and growth of female flathead sole in the central Gulf of Alaska and south-eastern Bering Sea. *J. Fish. Biol.* 64: 876-889.
- Stockhausen, W.T., P.D. Spencer and D. Nichol. 2008. Chapter 8: Flathead sole. In Appendix A Stock Assessment and Fishery Evaluation Document for the Groundfish Resources of the Bering Sea/Aleutian Islands Region. Pages 777-864. North Pacific Fishery Management Council, 605 West 4th Avenue, Suite 306, Anchorage AK 99501.

- Waldron, K.D. 1981. Ichthyoplankton. In D.W. Hood and J.A. Calder (Editors), The eastern Bering Sea shelf: Oceanography and resources, Vol. 1, p. 471-493. U.S. Dep. Commer., NOAA, Off. Mar. Poll. Assess., U.S. Gov. Print. Off., Wash., D.C.
- Walters, G.E. and T.K. Wilderbuer 1996. Flathead sole. In Stock assessment and fishery evaluation Report for the groundfish resources of the Bering Sea/Aleutian Islands Regions. p 279-290. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.

D.9 Alaska plaice (*Pleuronectes quadrituberculatus*)

Formerly a constituent of the “other flatfish” management category, Alaska plaice were split out in recent years and are managed as a separate stock.

D.9.1 Life History and General Distribution

Alaska plaice inhabit continental shelf waters of the North Pacific ranging from the Gulf of Alaska to the Bering and Chukchi Seas and in Asian waters as far south as Peter the Great Bay (Pertseva-Ostroumova 1961; Quast and Hall 1972). Adults exhibit a benthic lifestyle and live year round on the shelf and move seasonally within its limits (Fadeev 1965). From over-winter grounds near the shelf margins, adults begin a migration onto the central and northern shelf of the eastern Bering Sea, primarily at depths of less than 100 m. Spawning usually occurs in March and April on hard sandy ground (Zhang 1987). The eggs and larvae are pelagic and transparent and have been found in ichthyoplankton sampling in late spring and early summer over a widespread area of the continental shelf (Waldron and Favorite 1977).

Fecundity estimates (Fadeev 1965) indicate female fish produce an average of 56 thousand eggs at lengths of 28 to 30 cm and 313 thousand eggs at lengths of 48 to 50 cm. The age or size at metamorphosis is unknown. The estimated length of 50 percent maturity is 32 cm from collections made in March and 28 cm from April, which corresponds to an age of 6 to 7 years. Natural mortality rate estimates range from 0.19 to 0.22 (Wilderbuer and Zhang 1999).

The approximate upper size limit of juvenile fish is 27 cm.

D.9.2 Fishery

Alaska plaice are caught in bottom trawls both as a directed fishery and in the pursuit of other bottom-dwelling species. Recruitment begins at about age 6 and they are fully selected at age 12. The fishery occurs throughout the mid- and inner Bering Sea shelf during ice-free conditions. In recent years catches have been low due to a lack of targeting, and they are now primarily caught as bycatch in Pacific cod, bottom pollock, yellowfin sole, and other flatfish fisheries and are caught with these species and Pacific halibut in the directed fishery.

D.9.3 Relevant Trophic Information

Groundfish predators include Pacific halibut (Novikov 1964) yellowfin sole, beluga whales, and fur seals (Salveson 1976).

D.9.4 Habitat and Biological Associations

Larvae/Juveniles: Planktonic larvae for at least 2 to 3 months until metamorphosis occurs, usually inhabiting shallow areas.

Adults: Summertime feeding on sandy substrates of the eastern Bering Sea shelf. Wide-spread distribution mainly on the middle, northern portion of the shelf, feeding on polychaete, amphipods,

and echiurids (Livingston and DeReynier 1996). Wintertime migration to deeper waters of the shelf margin to avoid extreme cold water temperatures. Feeding diminishes until spring after spawning.

Habitat and Biological Associations: Alaska plaice

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs		NA	spring and summer	ICS, MCS OCS	P			
Larvae	2–4 months?	U phyto/zoo plankton?	spring and summer	ICS, MCS	P			
Juveniles	up to 7 years	polychaete amphipods echiurids	all year	ICS, MCS	D	S, M		
Adults	7+ years	polychaete amphipods echiurids	spawning March–May non-spawning and feeding June–February	ICS, MCS ICS, MCS	D	S, M	ice edge	

D.9.5 Literature

- Auster, P.J., Malatesta, R.J., Langton, R.W., L. Watling, P.C. Valentine, C.S. Donaldson, E.W. Langton, A.N. Shepard, and I.G. Babb. 1996. The impacts of mobile fishing gear on seafloor habitats in the Gulf of Maine (Northwest Atlantic): Implications for conservation of fish populations. *Rev. in Fish. Sci.* 4(2): 185-202.
- Fadeev, N.W. 1965. Comparative outline of the biology of fishes in the southeastern part of the Bering Sea and condition of their resources. [In Russ.] *Tr. Vses. Nauchno-issled. Inst.Morsk. Rybn. Khoz. Okeanogr.* 58 (*Izv.Tikhookean. Nauchno-issled Inst. Morsk. Rybn. Khoz. Okeanogr.* 53):121-138. (Trans. By Isr. Prog. Sci. Transl., 1968), p 112-129. In P.A. Moiseev (Editor), *Soviet Fisheries Investigations in the northeastern Pacific*, Pt. IV. Avail. Natl. Tech. Inf. Serv., Springfield, Va. As TT 67-51206.
- Livingston, P.A. and Y. DeReynier. 1996. Groundfish food habits and predation on commercially important prey species in the eastern Bering Sea from 1990 to 1992. AFSC processed Rep. 96-04, 51 p. Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Seattle, WA 98115.
- Novikov, N.P. 1964. Basic elements of the biology of the Pacific Halibut (*Hippoglossus stenolepis* Schmidt) in the Bering Sea. *Tr. Vses. Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* 49 (*Izv. Tikhookean. Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* 51):167-204. (Transl. In *Soviet Fisheries Investigations in the Northeast Pacific*, Part II, p.175-219, by Israel Program Sci. Transl., 1968, avail. Natl. Tech. Inf. Serv. Springfield, VA, as TT67-51204.)
- Pertseva-Ostroumova, T.A. 1961. The reproduction and development of far eastern flounders. (Transl. By Fish. Res. Bd. Can. 1967. Transl. Ser. 856, 1003 p.).
- Quast, J.C. and E.L. Hall. 1972. List of fishes of Alaska and adjacent waters with a guide to some of their literature. U.S. Dep. Commer. NOAA, Tech. Rep. NMFS SSRF-658, 48p.
- Salveson, S.J. 1976. Alaska plaice. In *Demersal fish and shellfish resources of the eastern Bering Sea in the baseline year 1975* (eds. W.T. Pereyra, J.E. Reeves, and R.G. Bakkala). Processed Rep., 619 p. NWAFC, NMFS, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.
- Waldron, K.D. and F. Favorite. 1977. Ichthyoplankton of the eastern Bering Sea. In *Environmental assessment of the Alaskan continental shelf*, Annual reports of principal investigators for the year ending March 1977, Vol. IX.

- Receptors-Fish, littoral, benthos, p. 628-682. U.S. Dep. Comm., NOAA, and U.S. Dep. Int., Bur. Land. Manage.
- Wilderbuer, T.K. and C.I. Zhang. 1999. Evaluation of the population dynamics and yield characteristics of Alaska plaice (*Pleuronectes quadrituberculatus*) in the eastern Bering Sea Fisheries Research 41 (1999) 183-200.
- Wilderbuer, T.K., D.G. Nichol, and P.D. Spencer. 2010. Alaska Plaice. In Stock Assessment and Fishery Evaluation Report for Groundfish Resources of the Bering Sea/Aleutian Islands Regions. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, Alaska 99501. Pp. 969-1020.
- Zhang, C.I. 1987. Biology and Population Dynamics of Alaska plaice, *Pleuronectes quadrituberculatus*, in the Eastern Bering Sea. PhD. dissertation, University of Washington: p.1-225.

D.10 Rex sole (*Glyptocephalus zachirus*)

Rex sole are a constituent of the “other flatfish” management category in the Bering Sea and Aleutian Islands where they are less abundant than in the Gulf of Alaska.

Other members of the “other flatfish” category include:

- Dover sole (*Microstomus pacificus*)
- Starry flounder (*Platichthys stellatus*)
- Longhead dab (*Pleuronectes proboscidea*)
- Butter sole (*Pleuronectes isolepis*)

D.10.1 Life History and General Distribution

Rex sole are distributed from Baja California to the Bering Sea and western Aleutian Islands (Hart 1973, Miller and Lea 1972), and are widely distributed throughout the Gulf of Alaska. Adults exhibit a benthic lifestyle and are generally found in water deeper than 300 meters. From over-winter grounds near the shelf margins, adults begin a migration onto the mid- and outer continental shelf in April or May each year. The spawning period off Oregon is reported to range from January through June with a peak in March and April (Hosie and Horton 1977). Spawning in the Gulf of Alaska was observed from February through July, with a peak period in April and May (Hirschberger and Smith 1983). Eggs have been collected in neuston and bongo nets mainly in the summer, east of Kodiak Island (Kendall and Dunn 1985), but the duration of the incubation period is unknown. Larvae were captured in bongo nets only in summer over midshelf and slope areas (Kendall and Dunn 1985). Fecundity estimates from samples collected off the Oregon coast ranged from 3,900 to 238,100 ova for fish 24 to 59 cm (Hosie and Horton 1977). The age or size at metamorphosis is unknown. Maturity studies from Oregon indicate that males were 50 percent mature at 16 cm and females at 24 cm. Abookire (2006) estimated the female length at 50 percent maturity from Gulf of Alaska samples at 35 cm and 5.6 years. Juveniles less than 15 cm are rarely found with the adult population. The natural mortality rate used in recent stock assessments is 0.17 (Wilderbuer et al. 2010).

The approximate upper size limit of juvenile fish is 15 cm for males and 23 cm for females.

D.10.2 Fishery

Caught in bottom trawls mostly in the pursuit of other bottom-dwelling species. Recruitment begins at about age 3 or 4. They are caught as bycatch in the Pacific ocean perch, Pacific cod, bottom pollock, and other flatfish fisheries.

D.10.3 Relevant Trophic Information

Groundfish predators include Pacific cod and most likely arrowtooth flounder.

D.10.4 Habitat and Biological Associations

Larvae/Juveniles: Planktonic larvae for an unknown time period (at least 8 months from October through May) until metamorphosis occurs; juvenile distribution is unknown.

Adults: Spring spawning and summer feeding on a combination of sand, mud and gravel substrates of the continental shelf. Widespread distribution mainly on the middle and outer portion of the shelf, feeding mainly on polychaete, amphipods, euphausiids and snow crabs.

Habitat and Biological Associations: Rex sole

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs		NA	Feb–May	ICS? MCS, OCS	P			
Larvae	U	U phyto/zoo plankton?	spring summer	ICS? MCS, OCS	P			
Juveniles	2 years	polychaete amphipods euphausiids Tanner crab	all year	MCS, ICS, OCS	D	G, S, M		
Adults	2+ years	polychaete amphipods euphausiids Tanner crab	spawning Feb–May non-spawning May–January	MCS, OCS USP MCS, OCS, USP	D	G, S, M		

D.10.5 Literature

- Abookire, A.A. 2006. Reproductive biology, spawning season, and growth of female rex sole (*Glyptocephalus zachirus*) in the Gulf of Alaska. Fish. Bull. 104: 350-359.
- Auster, P.J., Malatesta, R.J., Langton, R.W., L. Watling, P.C. Valentine, C.S. Donaldson, E.W. Langton, A.N. Shepard, and I.G. Babb. 1996. The impacts of mobile fishing gear on seafloor habitats in the Gulf of Maine (Northwest Atlantic): Implications for conservation of fish populations. Rev. in Fish. Sci. 4(2): 185-202.
- Hart, J.L. 1973. Pacific fishes of Canada. Fish. Res. Board Canada, Bull. No. 180. 740 p.
- Hosie, M.J. and H.F. Horton. 1977. Biology of the rex sole, *Glyptocephalus zachirus*, in waters off Oregon. Fish. Bull. Vol. 75, No. 1, 1977, p. 51-60.
- Hirschberger, W.A. and G.B. Smith. 1983. Spawning of twelve groundfish species in the Alaska and Pacific coast regions. 50 p. NOAA Tech. Mem. NMFS F/NWC-44. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv.
- Kendall, A.W. Jr. and J.R. Dunn. 1985. Ichthyoplankton of the continental shelf near Kodiak Island, Alaska. NOAA Tech. Rep. NMFS 20, U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv.
- Livingston, P.A. and B.J. Goiney, Jr. 1983. Food habits literature of North Pacific marine fishes: a review and selected bibliography. NOAA Tech. Mem. NMFS F/NWC-54, U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv.
- Miller, D.J. and R.N. Lea. 1972. Guide to the coastal marine fishes of California. Calif. Dep. Fish. Game, Fish. Bull. 157, 235 p.
- Wilderbuer, T. K., D. G. Nichol and P. D. Spencer. 2010. Other flatfish. In Stock Assessment and Fishery Evaluation Report for the groundfish resources of the Eastern Bering Sea and Aleutian Islands. Compiled by the Plan Team for the fishery resources of the Bering Sea and Aleutian Islands. North Pacific Fisheries

Management Council, Anchorage, AK.

D.11 Dover sole (*Microstomus pacificus*)

D.11.1 Life History and General Distribution

Dover sole are distributed in deep waters of the continental shelf and upper slope from northern Baja California to the Bering Sea and the western Aleutian Islands (Hart 1973, Miller and Lea 1972), and exhibit a widespread distribution throughout the Gulf of Alaska. Adults are demersal and are mostly found in water deeper than 300 meters. The spawning period off Oregon is reported to range from January through May (Hunter et al. 1992). Spawning in the Gulf of Alaska has been observed from January through August, with a peak period in May (Hirschberger and Smith 1983). Eggs have been collected in neuston and bongo nets in the summer, east of Kodiak Island (Kendall and Dunn 1985), but the duration of the incubation period is unknown. Larvae were captured in bongo nets only in summer over mid-shelf and slope areas (Kendall and Dunn 1985). The age or size at metamorphosis is unknown but the pelagic larval period is known to be protracted and may last as long as two years (Markle et al. 1992). Pelagic postlarvae as large as 48 mm have been reported and the young may still be pelagic at 10 cm (Hart 1973). Dover sole are batch spawners and Hunter et al. (1992) concluded that the average 1 kg female spawns its 83,000 advanced yolked oocytes in about nine batches. Maturity studies from Oregon indicate that females were 50 percent mature at 33 cm total length. Juveniles less than 25 cm are rarely found with the adult population from bottom trawl surveys (Martin and Clausen 1995). The natural mortality rate used in recent stock assessments is 0.2 (Turnock et al. 1996).

The approximate upper size limit of juvenile fish is 32 cm.

D.11.2 Fishery

Dover sole are caught in bottom trawls both as a directed fishery and in the pursuit of other bottom-dwelling species. Recruitment begins at about age 5. They are caught as bycatch in the rex sole, thornyhead rockfish, and sablefish fisheries and are caught with these species and Pacific halibut in Dover sole directed fisheries.

D.11.3 Relevant Trophic Information

Groundfish predators include Pacific cod and most likely arrowtooth flounder.

D.11.4 Habitat and Biological Associations

Larvae/Juveniles: Planktonic larvae for up to 2 years until metamorphosis occurs, juvenile distribution is unknown.

Adults: Winter and spring spawning and summer feeding on soft substrates (combination of sand and mud) of the continental shelf and upper slope. Shallower summer distribution mainly on the middle to outer portion of the shelf and upper slope, feeding mainly on polychaete, annelids, crustaceans, and molluscs (Livingston and Goiney 1983).

Habitat and Biological Associations: Dover sole

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs		NA	spring summer	ICS? MCS, OCS, UCS	P			
Larvae	up to 2 years	U phyto/ zooplankton?	all year	ICS? MCS, OCS, UCS	P			
Early Juveniles	to 3 years	polychaetes amphipods annelids	all year	MCS? ICS?	D	S, M		
Late Juveniles	3–5 years	polychaetes amphipods annelids	all year	MCS? ICS?	D	S, M		
Adults	5+ years	polychaetes amphipods annelids molluscs	spawning Jan–August non-spawning July–Jan	MCS, OCS, UCS	D	S, M		

D.11.5 Literature

- Auster, P.J., Malatesta, R.J., Langton, R.W., L. Watling, P.C. Valentine, C.S. Donaldson, E.W. Langton, A.N. Shepard, and I.G. Babb. 1996. The impacts of mobile fishing gear on seafloor habitats in the Gulf of Maine (Northwest Atlantic): Implications for conservation of fish populations. *Rev. in Fish. Sci.* 4(2): 185-202.
- Hart, J.L. 1973. Pacific fishes of Canada. *Fish. Res. Board Canada, Bull. No. 180.* 740 p.
- Hunter, J.R., B.J. Macewicz, N.C. Lo and C.A. Kimbrell. 1992. Fecundity, spawning, and maturity of female Dove sole *Microstomus pacificus*, with an evaluation of assumptions and precision. *Fish. Bull.* 90:101-128(1992).
- Hirschberger, W.A. and G.B. Smith. 1983. Spawning of twelve groundfish species in the Alaska and Pacific coast regions. 50 p. NOAA Tech. Mem. NMFS F/NWC-44. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv.
- Kendall, A.W. Jr. and J.R. Dunn. 1985. Ichthyoplankton of the continental shelf near Kodiak Island, Alaska. NOAA Tech. Rep. NMFS 20, U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv.
- Livingston, P.A. and B.J. Goiney, Jr. 1983. Food habits literature of North Pacific marine fishes: a review and selected bibliography. NOAA Tech. Mem. NMFS F/NWC-54, U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv.
- Markle, D.F., Harris, P. and Toole, C. 1992. Metamorphosis and an overview of early-life-history stages in Dover sole *Microstomus pacificus*. *Fish. Bull.* 90:285-301.
- Martin, M.H. and D.M. Clausen. 1995. Data report: 1993 Gulf of Alaska Bottom Trawl Survey. U.S. Dept. Commer., NOAA, Natl. Mar. Fish. Serv., NOAA Tech. Mem. NMFS-AFSC-59, 217 p.
- Miller, D.J. and R.N. Lea. 1972. Guide to the coastal marine fishes of California. Calif. Dept. Fish. Game, Fish. Bull. 157, 235 p.
- Turnock, B.J., T.K. Wilderbuer and E.S. Brown. 1996. Flatfish. In Stock assessment and fishery evaluation Report for the groundfish resources of the Gulf of Alaska. p 279-290. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.
- Wilderbuer, T. K., D. G. Nichol and P. D. Spencer. 2010. Other flatfish. *In* Stock Assessment and Fishery Evaluation Report for the groundfish resources of the Eastern Bering Sea and Aleutian Islands. Compiled by the Plan Team for the fishery resources of the Bering Sea and Aleutian Islands. North Pacific Fisheries

Management Council, Anchorage, AK.

D.12 Pacific ocean perch (*Sebastes alutus*)

D.12.1 Life History and General Distribution

Pacific ocean perch has a wide distribution in the North Pacific from southern California around the Pacific rim to northern Honshu Island, Japan, including the Bering Sea. The species appears to be most abundant in northern British Columbia, the Gulf of Alaska, and the Aleutian Islands. Adults are found primarily offshore along the continental slope in depths of 180 to 420 m. Seasonal differences in depth distribution have been noted by many investigators. In the summer, adults inhabit shallower depths, especially those between 180 m and 250 m. In the fall, the fish apparently migrate farther offshore to depths of approximately 300 to 420 m. They reside in these deeper depths until about May, when they return to their shallower summer distribution. This seasonal pattern is probably related to summer feeding and winter spawning. Although small numbers of Pacific ocean perch are dispersed throughout their preferred depth range on the continental slope, most of the population occurs in patchy, localized aggregations. At present, the best evidence indicates that Pacific ocean perch is mostly a demersal species. A number of investigators have speculated that there is also a pelagic component to their distribution, especially at night when they may move off-bottom to feed, but hard evidence for this is lacking.

There is much uncertainty about the life history of Pacific ocean perch, although generally more is known than for other rockfish species. The species appears to be viviparous, with internal fertilization and the release of live young. Insemination occurs in the fall, and sperm are retained within the female until fertilization takes place approximately 2 months later. The eggs develop and hatch internally, and parturition (release of larvae) occurs in April and May. Information on early life history is very sparse, especially for the first year of life. Positive identification of Pacific ocean perch larvae is not possible at present, but the larvae are thought to be pelagic and to drift with the current. Transformation to an adult form and the assumption of a demersal existence may take place within the first year. Small juveniles probably reside inshore in mixed sand and boulder substrates, and by age 3 begin to migrate to deeper offshore waters of the continental shelf. As they grow, they continue to migrate deeper, eventually reaching the continental slope, where they attain adulthood.

Pacific ocean perch is a very slow growing species, with a low rate of natural mortality (estimated at 0.06), a relatively old age at 50 percent maturity (10.5 years for females in the Gulf of Alaska), and a very old maximum age of 104 years in Aleutian Islands. Despite their viviparous nature, the fish is relatively fecund with number of eggs per female in Alaska ranging from 10,000 to 300,000, depending upon size of the fish.

For the Gulf of Alaska, the approximate upper size limit of juvenile fish is 38 cm for females and unknown for males, but presumed to be slightly smaller than for females based on what is commonly the case in other species of *Sebastes*. For the Bering Sea and Aleutian Islands (BSAI), the upper size limit is unknown for both sexes.

D.12.2 Fishery

Pacific ocean perch are caught almost exclusively with bottom trawls. Age at 50 percent recruitment has been estimated to be about 7.0 years. Historically, the Pacific ocean perch harvest has occurred in July, when the Pacific ocean perch fishery would open. However, implementation in 2008 of Amendment 80 to the Fishery Management Plan for Groundfish of the Bering Sea and Aleutian Islands Management Area allowed year-round harvest of Pacific ocean perch. In 2008, 43 percent of the Pacific ocean perch harvest in the Aleutian Islands was taken in July, as compared to 74 percent from 2004 to 2007. There is no directed fishery for Pacific ocean perch in the eastern Bering Sea management area.

The harvest of Pacific ocean perch is distributed across the Aleutian Islands subareas in proportion to relative biomass. In 2008, approximately 44 percent of the Aleutian Islands harvest occurred in area 543, with 28 percent in both the eastern and the central Aleutians Islands. Pacific ocean perch are patchily distributed, and are harvested in relatively few areas within the broad management subareas of the Aleutian Islands.

The 2008 catch data indicates that about 27 percent of the harvested BSAI Pacific ocean perch is obtained as bycatch in the Atka mackerel fishery, with approximately 71 percent of the harvest of Pacific ocean perch occurring in the Pacific ocean perch fishery; a similar pattern was observed from 2004 to 2007. The BSAI Pacific ocean perch target fishery consists largely of Pacific ocean perch, with percentages ranging from 81 to 89 percent from 2004 to 2007; in 2008, this percentage dropped to 73 percent. Other species obtained as bycatch in the BSAI Pacific ocean perch fishery include Atka mackerel, arrowtooth flounder, walleye pollock, northern rockfish, shortraker rockfish, and blackspotted/rougheye rockfish.

D.12.3 Relevant Trophic Information

All food studies of Pacific Ocean perch have shown them to be overwhelmingly planktivorous. Small juveniles eat mostly calanoid copepods, whereas larger juveniles and adults consume euphausiids as their major prey items. Adults, to a much lesser extent, may also eat small shrimp and squids. It has been suggested that Pacific ocean perch and walleye pollock compete for the same euphausiid prey. Consequently, the large removals of Pacific ocean perch by foreign fishermen in the Gulf of Alaska in the 1960s may have allowed walleye pollock stocks to greatly expand in abundance.

Documented predators of adult Pacific ocean perch include Pacific halibut and sablefish, and it is likely that Pacific cod and arrowtooth flounder also prey on Pacific ocean perch. Pelagic juveniles are consumed by salmon, and benthic juveniles are eaten by lingcod and other large demersal fish.

D.12.4 Habitat and Biological Associations

Egg/Spawning: Little information is known. Insemination is thought to occur after adults move to deeper offshore waters in the fall. Parturition is reported to occur from 20 to 30 m off the bottom at depths of 360 to 400 m.

Larvae: Little information is known. Earlier information suggested that after parturition, larvae rise quickly to near surface, where they become part of the plankton. More recent data from British Columbia indicates that larvae may remain at depths greater than 175 m for some period of time (perhaps two months), after which they slowly migrate upward in the water column.

Juveniles: Again, information is very sparse, especially for younger juveniles. After metamorphosis from the larval stage, juveniles may reside in a pelagic stage for an unknown length of time. They eventually become demersal, and at age 1 through 3 probably live in very rocky inshore areas. Afterward, they move to progressively deeper waters of the continental shelf. Older juveniles are often found together with adults at shallower locations of the continental slope in the summer months. Juvenile Pacific ocean perch are associated with boulders, sponges, and upright coral, and these habitat structures may play an important role for the juvenile stage of Pacific ocean perch.

Adults: Commercial fishery data have consistently indicated that adult Pacific ocean perch are found in aggregations over reasonably smooth, trawlable bottom of the continental slope. Generally, they are found in shallower depths (180 to 250 m) in the summer, and deeper (300 to 420 m) in the fall, winter, and early spring. In addition, investigators in the 1960s and 1970s speculated that the fish sometimes inhabited the mid-water environment off bottom and also might be found in rough, untrawlable areas. Hard evidence to support these latter two conjectures, however, has been lacking. The best information available at present suggests that adult Pacific ocean perch are mostly a

demersal species that prefer a flat, pebbled substrate along the continental slope. More research is needed, however, before definitive conclusions can be drawn as to its habitat preferences.

Habitat and Biological Associations: Pacific ocean perch

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	Internal incubation; ~90 d	NA	Winter	NA	NA	NA	NA	NA
Larvae	U; assumed between 60 and 180 days	U; assumed to be micro-zooplankton	spring–summer	ICS, MCS, OCS, USP, LSP, BSN	P	NA	U	U
Juveniles	3–6 months to 10 years	early juvenile: calanoid copepods; late juvenile: euphausiids	All year	ICS, MCS, OCS, USP	P? (early juv. only), D	R (<age 3)	U	U
Adults	10–98 years of age	euphausiids	insemination (fall); fertilization, incubation (winter); larval release (spring); feeding in shallower depths (summer)	OCS, USP	D	CB, G, M?, SM?, MS?	U	U

D.12.5 Literature

- Allen, M.J., and G.B. Smith. 1988. Atlas and zoogeography of common fishes in the Bering Sea and northeastern Pacific. U.S. Dep. Commer., NOAA Tech. Rept. NMFS 66, 151 p.
- Carlson, H.R., and R.E. Haight. 1976. Juvenile life of Pacific ocean perch, *Sebastes alutus*, in coastal fiords of southeastern Alaska: their environment, growth, food habits, and schooling behavior. Trans. Am. Fish. Soc. 105:191-201.
- Carlson, H.R., and R.R. Straty. 1981. Habitat and nursery grounds of Pacific rockfish, *Sebastes* spp., in rocky coastal areas of Southeastern Alaska. Mar. Fish. Rev. 43: 13-19.
- Doyle, M.J. 1992. Patterns in distribution and abundance of ichthyoplankton off Washington, Oregon, and Northern California (1980-1987). U.S. Dep. Commer. NOAA NMFS AFSC Processed Rept. 92-14, 344 p.
- Gillespie, G.E., R.D. Stanley, and B.M. Leaman. 1992. Early life history of rockfishes in British Columbia; preliminary results of the first year of investigation. Proc. 1992 W. Groundfish Conf. Alderbrook Inn Resort, Union, WA, Jan 27-30, 1992.
- Gunderson, D.R. 1971. Reproductive patterns of Pacific ocean perch (*Sebatodes alutus*) off Washington and British Columbia and their relation to bathymetric distribution and seasonal abundance. J. Fish. Res. Bd. Can. 28: 417-425.
- Gunderson, D.R., and M.O. Nelson. 1977. Preliminary report on an experimental rockfish survey conducted off Monterey, California and in Queen Charlotte Sound, British Columbia during August-September, 1976. Prepared for Feb. 15-16, 1977, Interagency Rockfish Survey Coordinating Committee Meeting, NWAFC, Seattle, WA. Unpubl. manuscr. 82 p.

- Harrison, R.C. 1993. Data report: 1991 bottom trawl survey of the Aleutian Islands area. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-12. 144 p.
- Heifetz, J., and D. Ackley. 1997. Bycatch in rockfish fisheries in the Gulf of Alaska. Unpubl. Manuscr. 20 p. (Available from NMFS Auke Bay Laboratory, 11305 Glacier Hwy., Juneau, AK 99801.
- Heifetz, J., J.N. Ianelli, and D.M. Clausen. 1996. Slope rockfish. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p.229-269. North Pacific Fishery Management Council, 605 W. 4th. Ave., Suite 306, Anchorage, AK 99501-2252.
- Ito, D.H. 1982. A cohort analysis of Pacific ocean perch stocks from the Gulf of Alaska and Bering Sea regions. U.S. Dep. Commer., NWAFC Processed Rept. 82-15, 157 p.
- Ito, D.H., and J.N. Ianelli. 1996. Pacific ocean perch. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p.331-359. North Pacific Fishery Management Council, 605 W. 4th. Ave., Suite 306, Anchorage, AK 99501-2252.
- Kendall, A.W., and W.H. Lenarz. 1986. Status of early life history studies of northeast Pacific rockfishes. Proc. Int. Rockfish Symp. Oct. 1986, Anchorage Alaska; p. 99-117.
- Krieger, K.J. 1993. Distribution and abundance of rockfish determined from a submersible and by bottom trawling. Fish. Bull., U.S. 91:87-96.
- Martin, M.H. and D.M. Clausen. 1995. Data report: 1993 Gulf of Alaska bottom trawl survey. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-59. 217 p.
- Matarese, A.C., A.W. Kendall, Jr., D.M. Blood, and B.M. Vinter. 1989. Laboratory guide to early life history stages of northeast Pacific fishes. U.S. Dep. Commer. NOAA Tech. Rept. NMFS 80, 652 p.
- Matthews, K.R., J.R. Candy, L.J. Richards, and C.M. Hand. 1989. Experimental gill net fishing on trawlable and untrawlable areas off northwestern Vancouver Island, from the MV Caledonian, August 15-28, 1989. Can. Manuscr. Rep. Fish. Aquat. Sci. 2046, 78 p.
- Mattson, C.R., and B.L. Wing. 1978. Ichthyoplankton composition and plankton volumes from inland coastal waters of southeastern Alaska, April-November 1972. U.S. Dep. Commer., NOAA Tech. Rept. NMFS SSRF-723, 11 p.
- Moser, H.G., 1996. SCORPAENIDAE: scorpionfishes and rockfishes. *In*: Moser, H.G., editor. The early stages of fishes in the California Current region, p. 733-795. CalCOFI Atlas No.33. 1505 p.
- NOAA (National Oceanic and Atmospheric Administration). 1990. Pacific ocean perch, *Sebastes alutus*. *In*: West coast of North America coastal and ocean zones strategic assessment: data atlas. Invertebrate and fish volume, Plate 3.2.20. U.S. Dep. Commer. NOAA. OMA/NOS, Ocean Assessments Division, Strategic Assessment Branch.
- Ronholt, L.L., K. Teshima, and D.W. Kessler. 1994. The groundfish resources of the Aleutian Islands region and southern Bering Sea 1980, 1983, and 1986. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-31. 351 p.
- Rooper, C.N. and J. L. Boldt. 2005. Distribution of juvenile Pacific ocean perch *Sebastes alutus* in the Aleutian Islands in relation to benthic habitat. Alaska Fisheries Research Bulletin 11(2):102-112.
- Rooper, C.N. , J. L. Boldt, and M. Zimmermann. 2007. An assessment of juvenile Pacific Ocean perch (*Sebastes alutus*) habitat use in a deepwater nursery. Estuarine, Coastal and Shelf Science 75:371-380
- Seeb, L.W. 1993. Biochemical identification of larval rockfishes of the genus *Sebastes*. Final Report Contract #43ABNF001082. U.S. Dept. Commer. NOAA/NMFS NWAFC/RACE Division, Seattle, WA. 28 p.
- Seeb, L.W., and A.W. Kendall, Jr. 1991. Allozyme polymorphisms permit the identification of larval and juvenile rockfishes of the genus *Sebastes*. Environmental Biology of Fishes 30:191-201.
- Spencer, P.D., and J.N. Ianelli. 2008. Pacific ocean perch. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands region as projected for 2009, pp. 917-972. North Pacific Fishery Management Council, 605 W. 4th Ave, suite 306. Anchorage, AK 99501
- Stark, J.W., and D.M. Clausen. 1995. Data report: 1990 Gulf of Alaska bottom trawl survey. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-49. 221 p.

- Westrheim, S.J. 1970. Survey of rockfishes, especially Pacific ocean perch, in the northeast Pacific Ocean, 1963-66. J. Fish. Res. Bd. Canada 27: 1781-1809.
- Westrheim, S.J. 1975. Reproduction, maturation, and identification of larvae of some *Sebastes* (Scorpaenidae) species in the northeast Pacific Ocean. J. Fish. Res. Board Can. 32: 2399-2411.
- Wing, B.L. 1985. Salmon stomach contents from the Alaska troll logbook program, 1977-84. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-91. 41 p.
- Wing, B.L., C. Derrah, and V. O'Connell. 1997. Ichthyoplankton in the eastern Gulf of Alaska, May 1990. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-376, 42 p.
- Wolotira, R.J., Jr., T.M. Sample, S.F. Noel, and C.R. Iten. 1993. Geographic and bathymetric distributions for many commercially important fishes and shellfishes off the west coast of North America, based on research survey and commercial catch data, 1912-1984. U. S. Dep. Commer., NOAA Tech. Memo. NMFS - AFSC-6, 184 p.
- Yang, M-S. 1993. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-22, 150 p.
- Yang, M-S. 1996. Diets of the important groundfishes in the Aleutian Islands in summer 1991. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-60, 105 p.
- Yang, M-S, K. Dodd, R. Hibshman, and A. Whitehouse. 1996. Food Habits of Groundfishes in the Gulf of Alaska in 1999 and 2001. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-164, 199 p.

D.13 Northern rockfish (*Sebastes polyspinus*)

D.13.1 Life History and General Distribution

Northern rockfish range from northern British Columbia through the Gulf of Alaska and Aleutian Islands to eastern Kamchatka, including the Bering Sea. The species is most abundant from about Portlock Bank in the central Gulf of Alaska to the western end of the Aleutian Islands. Within this range, adult fish appear to be concentrated at discrete, relatively shallow offshore banks of the outer continental shelf. Typically, these banks are separated from land by an intervening stretch of deeper water. The preferred depth range is approximately 75 to 125 m in the Gulf of Alaska, and approximately 100 to 150 m in the Aleutian Islands. The fish appear to be demersal, although small numbers are occasionally taken in pelagic tows. In common with many other rockfish species, northern rockfish tend to have a localized, patchy distribution, even within their preferred habitat, and most of the population occurs in aggregations. Most of what is known about northern rockfish is based on data collected during the summer months from the commercial fishery or in research surveys. Consequently, there is little information on seasonal movements or changes in distribution for this species.

Life history information on northern rockfish is extremely sparse. The fish are assumed to be viviparous, as are other *Sebastes*, with internal fertilization and incubation of eggs. Observations during research surveys in the Gulf of Alaska suggest that parturition (larval release) occurs in the spring, and is mostly completed by summer. Pre-extrusion larvae have been described, but field-collected larvae cannot be identified to species at present. Length of the larval stage is unknown, but the fish apparently metamorphose to a pelagic juvenile stage, which also has been described. There is no information on when the juveniles become benthic or what habitat they occupy. Older juveniles are found on the continental shelf, generally at locations inshore of the adult habitat.

Northern rockfish is a slow growing species, with a low rate of natural mortality (estimated at 0.06), a relatively old age at 50 percent maturity (12.8 years for females in the Gulf of Alaska), and an old maximum age of 74 years in the Aleutian Islands. No information on fecundity is available.

For the Gulf of Alaska, the upper size limit for juveniles is 38 cm for females and unknown for males, but presumed to be slightly smaller than for females based on what is commonly the case in other species of *Sebastes*. For the Aleutian Islands and Bering Sea, the upper size limit for juveniles is unknown for both

sexes. Because northern rockfish in the Aleutian Islands attain a much smaller size than in the Gulf, the upper size limit of juveniles there is probably much less than in the Gulf.

D.13.2 Fishery

In the Bering Sea and Aleutian Islands (BSAI) management area, there is no directed fishery for northern rockfish. Harvest data from 2000 through 2002 indicate that approximately 89 percent of the BSAI northern rockfish are harvested in the Atka mackerel fishery, with a large amount of the catch occurring in September in the western Aleutian Islands (area 543). The distribution of northern rockfish harvest by Aleutian Islands subarea reflects both the spatial regulation of the Atka mackerel fishery and the increased biomass of northern rockfish in the western Aleutian Islands. The average proportion of northern rockfish biomass occurring in the western, central, and eastern Aleutian Islands, based on trawl surveys from 1991 through 2006, were 70, 24, and 6 percent, respectively. Northern rockfish are patchily distributed, and are harvested in relatively few areas within the broad management subareas of the Aleutian Islands, with important fishing grounds being Petral Bank, Sturdevant Rock, south of Amchitka Island, and Seguam Pass (Dave Clausen, NMFS-AFSC, personal communication).

D.13.3 Relevant Trophic Information

Although no comprehensive food study of northern rockfish has been done, several smaller studies have all shown euphausiids to be the predominant food item of adults in both the Gulf of Alaska and Bering Sea. Copepods, hermit crabs, and shrimp have also been noted as prey items in much smaller quantities.

Predators of northern rockfish have not been documented, but likely include species that are known to consume rockfish in Alaska, such as Pacific halibut, sablefish, Pacific cod, and arrowtooth flounder.

D.13.4 Habitat and Biological Associations

Egg/Spawning: No information known, except that parturition probably occurs in the spring.

Larvae: No information known.

Juveniles: No information known for small juveniles (less than 20 cm), except that juveniles apparently undergo a pelagic phase immediately after metamorphosis from the larval stage. Larger juveniles have been taken in bottom trawls at various localities of the continental shelf, usually inshore of the adult fishing grounds.

Adults: Commercial fishery and research survey data have consistently indicated that adult northern rockfish are primarily found over reasonably flat, trawlable bottom of offshore banks of the outer continental shelf at depths of 75 to 150 m. Preferred substrate in this habitat has not been documented, but observations from trawl surveys suggest that large catches of northern rockfish are often associated with hard bottoms. Generally, the fish appear to be demersal, and most of the population occurs in large aggregations. There is no information on seasonal migrations. Northern rockfish often co-occur with dusky rockfish.

Habitat and Biological Associations: Northern Rockfish

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	U	NA	U	NA	NA	NA	NA	NA
Larvae	U	U	spring–summer?	U	P (assumed)	NA	U	U
Early Juveniles	from end of larval stage to ?	U	all year	ICS, MCS, OCS	P? (early juvenile only), D	U (juvenile < 20 cm); substrate (juvenile > 20 cm)	U	U
Late Juveniles	to 13 yrs	U	all year	OCS		CB, R	U	U
Adults	13–57 years of age	euphausiids	U, except that larval release is probably in the spring in the Gulf of Alaska	OCS, USP	SD	CB, R	U	U

D.13.5 Literature

- Allen, M.J., and G.B. Smith. 1988. Atlas and zoogeography of common fishes in the Bering Sea and northeastern Pacific. U.S. Dep. Commerce, NOAA Tech. Rept. NMFS 66, 151 p.
- Harrison, R.C. 1993. Data report: 1991 bottom trawl survey of the Aleutian Islands area. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-AFSC-12. 144 p.
- Heifetz, J., and D. Ackley. 1997. Bycatch in rockfish fisheries in the Gulf of Alaska. Unpubl. Manuscr. 20 p. (Available from NMFS Auke Bay Laboratory, 11305 Glacier Hwy., Juneau, AK 99801.)
- Heifetz, J., J.N. Ianelli, and D.M. Clausen. 1996. Slope rockfish. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p.229-269. North Pacific Fishery Management Council, 605 W. 4th. Ave., Suite 306, Anchorage, AK 99501-2252.
- Kendall, A.W. 1989. Additions to knowledge of *Sebastes* larvae through recent rearing. NWAFC Proc.Rept. 89-21. 46 p.
- Martin, M.H. and D.M. Clausen. 1995. Data report: 1993 Gulf of Alaska bottom trawl survey. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-AFSC-59. 217 p.
- Matarese, A.C., A.W. Kendall, Jr., D.M. Blood, and B.M. Vinter. 1989. Laboratory guide to early life history stages of Northeast Pacific fishes. U.S. Dep. Commerce NOAA Tech. Rept. NMFS 80, 652 p.
- Ronholt, L.L., K. Teshima, and D.W. Kessler. 1994. The groundfish resources of the Aleutian Islands region and southern Bering Sea 1980, 1983, and 1986. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-AFSC-31. 351 p.
- Spencer, P.D., and J.N. Ianelli. 2008. Northern rockfish. In Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands region as projected for 2009, pp. 973-1016. North Pacific Fishery Management Council, 605 W. 4th Ave, suite 306. Anchorage, AK 99501
- Stark, J.W., and D.M. Clausen. 1995. Data report: 1990 Gulf of Alaska bottom trawl survey. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-AFSC-49. 221 p.
- Westrheim, S.J., and H. Tsuyuki. 1971. Taxonomy, distribution, and biology of the northern rockfish, *Sebastes polypin*. J. Fish. Res. Bd. Can. 28: 1621-1627.

Yang, M-S, K. Dodd, R. Hibpshman, and A. Whitehouse. 1996. Food Habits of Groundfishes in the Gulf of Alaska in 1999 and 2001. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-164, 199 p.

D.14 Shortraker rockfish (*Sebastes borealis*)

D.14.1 Life History and General Distribution

Shortraker rockfish are found along the northwest slope of the eastern Bering Sea, throughout the Aleutian Islands and south to Point Conception, California. Information for the larval and juvenile stages of shortraker rougheye is very limited. Shortraker rougheye are viviparous, as females release larvae rather than eggs. Parturition (the release of larvae) can occur from February through August (McDermott 1994). Identification of larvae can be made with genetic techniques (Gray et al. 2006), although this technique has not been used to produce a broad scale distribution of the larval stage. Species identification based on morphological characteristics is difficult because of overlapping characteristics among species, as few rockfishes species in the north Pacific have published descriptions of the complete larval developmental series. However, Kendall (2003) was able to identify archived *Sebastes* ichthyoplankton from the Gulf of Alaska to four distinct morphs. One of the morphs consists solely of shortraker rockfish, although the occurrence of this morph was relatively rare (18 of 3,642 larvae examined). Post-larval and juvenile shortraker rockfish do occur in the Aleutian Islands trawl survey, but these data have not been spatially analyzed with respect to their habitat characteristics. As adults, shortraker rockfish occur primarily at depths from 300 to 500 m.

Though relatively little is known about their biology and life history, shortraker rockfish appear to be *K*-selected with late maturation, slow growth, extreme longevity, and low natural mortality. Age at 50 percent maturity has been estimated at 21.4 years for female shortraker rockfish in the Gulf of Alaska (Hutchinson 2004); maturity information is not available for the Bering Sea and Aleutian Islands (BSAI) management area. Hutchinson (2004) estimated a maximum age of 116 years. Shortraker rockfish are among the largest *Sebastes* species in Alaskan waters; samples as large as 109 cm have been obtained in Aleutian Islands trawl surveys.

D.14.2 Fishery

A directed fishery does not exist for shortraker rockfish in the BSAI area. Harvest data from 2006 through 2008 indicates that 69 percent of the harvest of BSAI shortraker rockfish is taken in the Aleutian Islands, with subarea 542 contributing 60 percent of the Aleutian Islands catch. Prior to 2008, bycatch in the July Pacific ocean perch fishery composed the largest component of shortraker rockfish catch in the Aleutian Islands. With the creation of fishing cooperatives in 2008, the catch of shortraker rockfish has become more dispersed in time, with substantial catches in the spring sablefish longline fishery and the fall Atka mackerel trawl fishery. In the eastern Bering Sea, shortraker rockfish are captured in a variety of fisheries, including Pacific cod and halibut longline fisheries and the pollock trawl fishery. From 2006 through 2008, catch in the eastern Bering Sea was relatively evenly split between longline and trawl gear types. In the Aleutian Islands, longline gear contributed 63 percent of the bycatch in 2006 and 2007, but was reduced to 29 percent in 2008.

D.14.3 Relevant Trophic Information

The limited information available suggests that the diet of shortraker rockfish consists largely of squid, shrimp, and myctophids. From data collected in the 1994 and 1997 Aleutian Islands trawl surveys, Yang (2003) also found that the diet of large shortraker rockfish had proportionally more fish (e.g. myctophids) than small shortrakers, whereas smaller shortrakers consumed proportionally more shrimp. It is uncertain what are the main predators of shortraker rockfish.

D.14.4 Habitat and Biological Associations

Egg/Spawning: The timing of reproductive events is apparently protracted. Parturition (the release of larvae) may occur from February through August (McDermott 1994), although Westrheim (1975) found that April was the peak month for parturition.

Larvae: Limited information is available regarding the habitats and biological associations of shortraker rockfish larvae, in part because of the difficulty of using morphological characteristics to identify shortraker rockfish larvae

Juveniles: Very little information is available regarding the habitats and biological associations of juvenile shortraker rockfish.

Adults: Adults are demersal and generally occur at depths between 300 m and 500 m. Krieger (1992) used a submersible to find that shortraker rockfish occurred over a wide range of habitats, with the highest density of fish on sand or sand or mud substrates. Additional submersible work in southeast Alaska indicates that rougheye/shortraker rockfish were associated with habitats containing frequent boulders, steep slopes (more than 20°) and sand-mud substrates (Krieger and Ito 1999). Krieger and Wing (2002) found that large rockfish had a strong association with *Primnoa* spp. coral growing on boulders, and it is likely that many of these large rockfish were shortraker rougheye.

Habitat and Biological Associations: Shortraker and Rougheye Rockfish

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	NA	NA	NA	NA	NA	NA	NA	
Larvae	U	U	parturition: Feb–Aug	U	probably P	NA	U	
Early Juveniles	U	U	U	U, MCS, OCS?	probably N	U	U	
Late Juveniles	Up to ~ 20 years	U	U	U, MCS, OCS?	probably D	U	U	
Adults	> 20 years	shrimp squid myctophids	year-round?	OCS, USP	D	M, S, R, SM, CB, MS, G	U	

D.14.5 Literature

- Allen, M.J., and G.B. Smith. 1988. Atlas and zoogeography of common fishes in the Bering Sea and Northeastern Pacific. U.S. Dep. Commerce, NOAA Tech. Rept. NMFS 66, 151 p.
- Archibald, C. P., W. Shaw, and B. M. Leaman. 1981. Growth and mortality estimates of rockfishes (Scorpaenidae) from B.C. coastal waters, 1977-79. Can. Tech. Rep. Fish. Aquat. Sci. 1048, 57 p.
- Chilton, D. E., and R. J. Beamish. 1982. Age determination methods for fishes studied by the Groundfish Program at the Pacific Biological Station. Can. Spec. Publ. Fish. Aquat. Sci. 60, 102 p.
- Gray, A.K., A.W. Kendall, B.L. Wing, M.G. Carls, J. Heifetz, Z. Li, and A.J. Gharrett. 2006. Identification and first documentation of larval rockfishes in Southeast Alaskan waters was possible using mitochondrial markers but not pigmentation patterns. Trans. Am. Fish. Soc. 135: 1-11.

- Heifetz, J., J.N. Ianelli, and D.M. Clausen. 1996. Slope rockfish. *In* Stock assessment and fishery evaluation report for the 1997 Gulf of Alaska groundfish fishery, p. 230-270. North Pacific Fishery Management Council, 605 W. 4th Avenue, Suite 306, Anchorage, AK 99501.
- Hutchinson, C.E. 2004. Using radioisotopes in the age determination of shortraker (*Sebastes borealis*) and canary (*Sebastes pinniger*) rockfish. Master's Thesis. Univ. Washington, Seattle. 84 p.
- Kendall, A.W. 2003. Analysis of *Sebastes* larvae in the Gulf of Alaska based upon the AFSC ichthyoplankton database, and other sources of information. Unpublished manuscript, Alaska Fisheries Science Center, Seattle, WA.
- Kramer, D.E., and V.M. O'Connell. 1986. Guide to northeast Pacific rockfishes, Genera *Sebastes* and *Sebastolobus*. Marine Advisory Bulletin No. 25: 1-78. Alaska Sea Grant College Program, University of Alaska.
- Krieger, K. 1992. Shortraker rockfish, *Sebastes borealis*, observed from a manned submersible. *Mar. Fish. Rev.*, 54(4): 34-37.
- Krieger, K.J. 1993. Distribution and abundance of rockfish determined from a submersible and by bottom trawling. *Fish. Bull.* 91:87-96.
- Krieger, K.J., and D.H. Ito. 1999. Distribution and abundance of shortraker rockfish, *Sebastes borealis*, and rougheye rockfish, *S. aleutianus*, determined from a manned submersible. *Fish. Bull.* 97: 264-272.
- Krieger, K.J., and B.L. Wing. 2002. Megafauna associations with deepwater corals (*Primnoa* spp.) in the GOA. *Hydrobiologia* 471: 83-90.
- McDermott, S.F. 1994. Reproductive biology of rougheye and shortraker rockfish, *Sebastes aleutianus* and *Sebastes borealis*. Masters Thesis. Univ. Washington, Seattle. 76 p.
- Sigler, M.F., and H.H. Zenger, Jr. 1994. Relative abundance of Gulf of Alaska sablefish and other groundfish based on the domestic longline survey, 1989. NOAA Tech. Memo. NMFS-AFSC-40.
- Westrheim, S.J. 1975. Reproduction, maturation, and identification of larvae of some *Sebastes* (Scorpaenidae) species in the northeast Pacific Ocean. *J. Fish. Res. Board Can.* 32:2399-2411.
- Wolotira, R.J., Jr., T.M. Sample, S.F. Noel, and C.R. Iten. 1993. Geographic and bathymetric distributions for many commercially important fishes and shellfishes off the west coast of North America, based on research survey and commercial catch data, 1912-84. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-AFSC-6, 184 p.
- Yang, M-S. 1993. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-AFSC-22, 150 p.
- Yang, M-S. 1996. Diets of the important groundfishes in the Aleutian Islands in summer 1991. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-AFSC-60, 105 p.
- Yang, M-S. 2003. Food habits of the important groundfishes in the AI in 1994 and 1999. AFSC Proc. Rep 2003-07. 233 p. (Available from NMFS, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115).

D.15 Blackspotted rockfish (*Sebastes melanostictus*) and rougheye rockfish (*S. aleutianus*)

D.15.1 Life History and General Distribution

Fish in Alaska previously referred to as rougheye rockfish have recently been recognized as consisting of two species, the rougheye rockfish (*Sebastes aleutianus*) and blackspotted rockfish (*Sebastes melanostictus*) (Orr and Hawkins 2008). Most of the information on blackspotted/rougheye rockfish was obtained prior to recognition of blackspotted rockfish as a separate species, and thus refers to the two species complex. Love et al. (2002) reports that rougheye rockfish are found along the northwest slope of the eastern Bering Sea, throughout the Aleutian Islands and south to Point Conception, California, although this distribution likely

reflects the combined blackspotted/rougheye group. Recent trawl surveys indicate that rougheye rockfish are uncommon in the Aleutian Islands, where the two species complex is predominately composed of blackspotted rockfish. However, methods for distinguishing the two species from each other are still being refined.

Information for the larval and juvenile stages of blackspotted/rougheye rockfish are very limited. Blackspotted/rougheye rockfish are viviparous, as females release larvae rather than eggs. Parturition (the release of larvae) can occur from December through April (McDermott 1994). Identification of larvae can be made with genetic techniques (Gray et al. 2006), although this technique has not been used to produce a broad scale distribution of the larval stage. Species identification based on morphological characteristics is difficult because of overlapping characteristics among species, as few rockfishes species in the north Pacific have published descriptions of the complete larval developmental series. Length frequency distributions from Aleutian Islands summer trawl survey indicate that small blackspotted/rougheye rockfish (less than 35 cm) are found throughout a range of depths but primarily in shallower water (200 to 300 m) than larger fish. As adults, blackspotted/rougheye rockfish occur primarily at depths from 300 to 500 m.

Though relatively little is known about their biology and life history, blackspotted/rougheye rockfish appear to be *K*-selected with late maturation, slow growth, extreme longevity, and low natural mortality. Age at 50 percent maturity has been estimated at 20.3 years for female blackspotted/rougheye rockfish in the Gulf of Alaska (McDermott 1994); maturity information is not available for the Bering Sea and Aleutian Islands (BSAI) management area. A maximum age of 121 has been reported from sampling in the Aleutian Islands trawl survey.

D.15.2 Fishery

A directed fishery does not exist for blackspotted/rougheye rockfish in the BSAI area. Harvest data from 2006 through 2008 indicates that 93 percent of the harvest of BSAI blackspotted/rougheye rockfish is taken in the Aleutian Islands, with the contributions of the three Aleutian Islands subareas to the total Aleutian Islands catch ranging from 29 percent (area 542) to 40 percent (area 543). Prior to 2008, bycatch in the July Pacific ocean perch fishery comprised the largest component of blackspotted/rougheye catch in the Aleutian Islands. With the creation of fishing cooperatives in 2008, the catch of blackspotted/rougheye rockfish has become more dispersed in time, with catches in the spring, and in the fall Atka mackerel trawl and Pacific cod longline fisheries. In the eastern Bering Sea, shortraker rockfish are captured in a variety of fisheries, including Pacific cod longline and pollock trawl fisheries. From 2006 through 2008, longline fisheries captured about one-half the blackspotted/rougheye catch in the eastern Bering Sea. In the Aleutian Islands, the proportion of catch in the trawl and longline fisheries in 2006 and 2007 were 82 percent and 18 percent, respectively. In 2008, the relative proportion of the Aleutian Islands catch in the longline fisheries increased to 24 percent.

D.15.3 Relevant Trophic Information

Pandalid and hippolytid shrimp are the largest components of the blackspotted/rougheye rockfish diet (Yang 1993, 1996, Yang and Nelson 2000). In a study of diet data collected from specimens from the Aleutian Islands trawl survey, Yang (2003) found that the diet of large blackspotted/rougheye rockfish had proportionally more fish (e.g., myctophids) than small blackspotted/rougheye, whereas smaller blackspotted/rougheye consumed proportionally more shrimp. It is uncertain what are the main predators of blackspotted/rougheye rockfish.

D.15.4 Habitat and Biological Associations

Egg/Spawning: The timing of reproductive events is apparently protracted. Parturition (the release of larvae) may occur from December to April (McDermott 1994).

Larvae: Limited information is available regarding the habitats and biological associations of blackspotted/rougheye rockfish larvae, in part because of the difficulty of using morphological characteristics to identify blackspotted/rougheye rockfish larvae.

Juveniles: Very little information is available regarding the habitats and biological associations of juvenile blackspotted/rougheye rockfish.

Adults: Adults are demersal and generally occur at depths between 300 m and 500 m. Submersible work in southeast Alaska indicates that blackspotted/rougheye rockfish were associated with habitats containing frequent boulders, steep slopes (more than 20°) and sand-mud substrates (Krieger and Ito 1999). Krieger and Wing (2002) found that large rockfish had a strong association with *Primnoa* spp. coral growing on boulders, and it is likely that many of these large rockfish were blackspotted/rougheye rockfish.

Habitat and Biological Associations: Shortraker and Rougheye Rockfish

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	NA	NA	NA	NA	NA	NA	NA	
Larvae	U	U	parturition: Dec–Apr	U	probably P	NA	U	
Early Juveniles	U	U	U	U, MCS, OCS?	probably N	U	U	
Late Juveniles	up to ~ 20 years	U	U	U, MCS, OCS?	probably D	U	U	
Adults	> 20 years	shrimp squid myctophids	year-round?	OCS, USP	D	M, S, R, SM, CB, MS, G	U	

D.15.5 Literature

- Allen, M.J., and G.B. Smith. 1988. Atlas and zoogeography of common fishes in the Bering Sea and Northeastern Pacific. U.S. Dep. Commerce, NOAA Tech. Rept. NMFS 66, 151 p.
- Archibald, C. P., W. Shaw, and B. M. Leaman. 1981. Growth and mortality estimates of rockfishes (Scorpaenidae) from B.C. coastal waters, 1977-79. Can. Tech. Rep. Fish. Aquat. Sci. 1048, 57 p.
- Chilton, D. E., and R. J. Beamish. 1982. Age determination methods for fishes studied by the Groundfish Program at the Pacific Biological Station. Can. Spec. Publ. Fish. Aquat. Sci. 60, 102 p.
- Gray, A.K., A.W. Kendall, B.L. Wing, M.G. Carls, J. Heifetz, Z. Li, and A.J. Gharrett. 2006. Identification and first documentation of larval rockfishes in Southeast Alaskan waters was possible using mitochondrial markers but not pigmentation patterns. Trans. Am. Fish. Soc. 135: 1-11.
- Heifetz, J., J.N. Ianelli, and D.M. Clausen. 1996. Slope rockfish. In Stock assessment and fishery evaluation report for the 1997 Gulf of Alaska groundfish fishery, p. 230-270. North Pacific Fishery Management Council, 605 W. 4th Avenue, Suite 306, Anchorage, AK 99501.
- Kramer, D.E., and V.M. O'Connell. 1986. Guide to northeast Pacific rockfishes, Genera *Sebastes* and *Sebastolobus*. Marine Advisory Bulletin No. 25: 1-78. Alaska Sea Grant College Program, University of Alaska.
- Krieger, K. 1992. Shortraker rockfish, *Sebastes borealis*, observed from a manned submersible. Mar. Fish. Rev., 54(4): 34-37.
- Krieger, K.J. 1993. Distribution and abundance of rockfish determined from a submersible and by bottom trawling. Fish. Bull. 91:87-96.

- Krieger, K.J., and D.H. Ito. 1999. Distribution and abundance of shortraker rockfish, *Sebastes borealis*, and rougheye rockfish, *S. aleutianus*, determined from a manned submersible. Fish. Bull. 97: 264-272.
- Krieger, K.J., and B.L. Wing. 2002. Megafauna associations with deepwater corals (*Primnoa* spp.) in the GOA. Hydrobiologia 471: 83-90.
- Love, M.S., M. Yoklavich, and L. Thorsteinson. 2002. The rockfishes of the northeast Pacific. University of California Press, Berkeley. 405 p.
- McDermott, S.F. 1994. Reproductive biology of rougheye and shortraker rockfish, *Sebastes aleutianus* and *Sebastes borealis*. Masters Thesis. Univ. Washington, Seattle. 76 p.
- Orr, J.W. and S. Hawkins. 2008. Species of the rougheye rockfish complex: resurrection of *Sebastes melanostictus* (Matsubara 1934) and a redescription of *Sebastes aleutianus* (Jordan and Evermann, 1898) (Teleostei: Scorpaeniformes). Fish. Bull. 106(2):111-134
- Sigler, M.F., and H.H. Zenger, Jr. 1994. Relative abundance of Gulf of Alaska sablefish and other groundfish based on the domestic longline survey, 1989. NOAA Tech. Memo. NMFS-AFSC-40.
- Wolotira, R.J., Jr., T.M. Sample, S.F. Noel, and C.R. Iten. 1993. Geographic and bathymetric distributions for many commercially important fishes and shellfishes off the west coast of North America, based on research survey and commercial catch data, 1912-84. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-AFSC-6, 184 p.
- Yang, M-S. 1993. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-AFSC-22, 150 p.
- Yang, M-S. 1996. Diets of the important groundfishes in the Aleutian Islands in summer 1991. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-AFSC-60, 105 p.
- Yang, M-S. 2003. Food habits of the important groundfishes in the AI in 1994 and 1999. AFSC Proc. Rep 2003-07. 233 p. (Available from NMFS, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115).
- Yang, M.S. and M.W. Nelson. 2000. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990, 1993, and 1996. NOAA Tech. Memo. NMFS-AFSC-112. 174 p.

D.16 Dusky rockfish (*Sebastes variabilis*)

D.16.1 Life History and General Distribution

In 2004, Orr and Blackburn described two distinct species that were being labeled as a single species (*Sebastes ciliatus*) with two color varieties: dark and light dusky rockfish. What was labeled as the light dusky rockfish is now a distinct species *Sebastes variabilis* and is commonly referred to as dusky rockfish. Dusky rockfish range from central Oregon through the North Pacific Ocean and Bering Sea in Alaska and Russia to Japan. The center of abundance for dusky rockfish appears to be the Gulf of Alaska (Reuter 1999). The species is much less abundant in the Aleutian Islands and Bering Sea (Reuter and Spencer 2002). Adult dusky rockfish have a very patchy distribution, and are usually found in large aggregations at specific localities of the outer continental shelf. These localities are often relatively shallow offshore banks. Because the fish are taken with bottom trawls, they are presumed to be mostly demersal. Whether they also have a pelagic distribution is unknown, but there is no evidence of a pelagic tendency based on the information available at present. Most of what is known about dusky rockfish is based on data collected during the summer months from the commercial fishery or in research surveys. Consequently, there is little information on seasonal movements or changes in distribution for this species.

Life history information on dusky rockfish is extremely sparse. The fish are assumed to be viviparous, as are other *Sebastes*, with internal fertilization and incubation of eggs. Observations during research surveys in the Gulf of Alaska suggest that parturition (larval release) occurs in the spring, and is probably completed by summer. Another, older source, however, lists parturition as occurring “after May.” Pre-extrusion larvae

have been described, but field-collected larvae cannot be identified to species at present. Length of the larval stage, and whether a pelagic juvenile stage occurs, are unknown. There is no information on habitat and abundance of young juveniles (less than 25 cm fork length), as catches of these have been virtually nil in research surveys. Even the occurrence of older juveniles has been very uncommon in surveys, except for one year. In this latter instance, older juveniles were found on the continental shelf, generally at locations inshore of the adult habitat.

Dusky rockfish is a slow growing species, with a low rate of natural mortality estimated at 0.09. However, it appears to be faster growing than many other rockfish species. Maximum age is 49 to 59 years. No information on age of maturity or fecundity is available.

The approximate upper size limit for juvenile fish is 47 cm for females; unknown for males, but presumed to be slightly smaller than for females based on what is commonly the case in other species of *Sebastes*.

D.16.2 Fishery

Dusky rockfish are caught almost exclusively with bottom trawls. Age at 50 percent recruitment is unknown. There is no directed fishery in the Aleutian Islands and Bering Sea, and catches there have been generally sparse.

D.16.3 Relevant Trophic Information

Although no comprehensive food study of dusky rockfish has been done, one smaller study in the Gulf of Alaska showed euphausiids to be the predominate food item of adults. Larvaceans, cephalopods, pandalid shrimp, and hermit crabs were also consumed.

Predators of dusky rockfish have not been documented, but likely include species that are known to consume rockfish in Alaska, such as Pacific halibut, sablefish, Pacific cod, and arrowtooth flounder.

D.16.4 Habitat and Biological Associations

Egg/Spawning: No information known, except that parturition probably occurs in the spring, and may extend into summer.

Larvae: No information known.

Juveniles: No information known for small juveniles less than 25 cm fork length. Larger juveniles have been taken infrequently in bottom trawls at various localities of the continental shelf, usually inshore of the adult fishing grounds.

Adults: Commercial fishery and research survey data suggest that adult dusky rockfish are primarily found over reasonably flat, trawlable bottom of offshore banks of the outer continental shelf at depths of 75 to 200 m. Type of substrate in this habitat has not been documented. During submersible dives on the outer shelf (40 to 50 m) in the eastern Gulf, dusky rockfish were observed in association with rocky habitats and in areas with extensive sponge beds where adult dusky rockfishes were observed resting in large vase sponges (V. O'Connell, ADFG, personal communication). Generally, the fish appear to be demersal, and most of the population occurs in large aggregations. Dusky rockfish are the most highly aggregated of the rockfish species caught in Gulf of Alaska trawl surveys. Outside of these aggregations, the fish are sparsely distributed. Because the fish are taken with bottom trawls, they are presumed to be mostly demersal. Whether they also have a pelagic distribution is unknown, but there is no evidence of a pelagic tendency based on the information available at present. There is no information on seasonal migrations. Dusky rockfish often co-occur with northern rockfish.

Habitat and Biological Associations: Dusky Rockfish

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	U	NA	U	NA	NA	NA	NA	NA
Larvae	U	U	spring–summer?	U	P (assumed)	NA	U	U
Early Juveniles	U	U	all year	ICS, MCS, OCS,	U (small juvenile< 25 cm): D? (larger juvenile)	U (juvenile<25 cm); Trawlable substrate? (juvenile>25 cm)	U	U
Late Juveniles	U	U	U	U	U	CB, R, G	U	observed associated with <i>primnoa</i> coral
Adults	Up to 49–50 years.	euphausiids	U, except that larval release may be in the spring in the Gulf of Alaska	OCS, USP	SD, SP	CB, R, G	U	observed associated with large vase type sponges

D.16.5 Literature

- Allen, M.J., and G.B. Smith. 1988. Atlas and zoogeography of common fishes in the Bering Sea and northeastern Pacific. U. S. Dep. Commerce, NOAA Tech. Rept. NMFS 66, 151 p.
- Clausen, D.M., and J. Heifetz. 1996. Pelagic shelf rockfish. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p.271-288. North Pacific Fishery Management Council, 605 W. 4th. Ave., Suite 306, Anchorage, AK 99501-2252.
- Harrison, R.C. 1993. Data report: 1991 bottom trawl survey of the Aleutian Islands area. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-AFSC-12. 144 p.
- Heifetz, J., and D. Ackley. 1997. Bycatch in rockfish fisheries in the Gulf of Alaska. Unpubl. Manuscr. 20 p. (Available from NMFS Auke Bay Laboratory, 11305 Glacier Hwy., Juneau, AK 99801.
- Kendall, A.W. 1989. Additions to knowledge of *Sebastes* larvae through recent rearing. NWAFC Proc.Rept. 89-21. 46 p.
- Martin, M.H. and D.M. Clausen. 1995. Data report: 1993 Gulf of Alaska bottom trawl survey. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-AFSC-59. 217 p.
- Matarese, A.C., A.W. Kendall, Jr., D.M. Blood, and B.M. Vinter. 1989. Laboratory guide to early life history stages of northeast Pacific fishes. U.S. Dep. Commerce NOAA Tech. Rept. NMFS 80, 652 p.
- Orr, J.W., and J.E. Blackburn. 2004. The dusky rockfishes (Teleostei: Scorpaeniformes) of the North Pacific Ocean: resurrection of *Sebastes variabilis* (Pallas, 1814) and a redescription of *Sebastes ciliatus* (Tilesius, 1813). Fish Bull., U.S. 1002:328-348. Online.
- Reuter, R.F. 1999. Describing Dusky rockfish (*Sebastes ciliatus*) habitat in the Gulf of Alaska using Historical data. M.S. thesis. California State University, Hayward 83 p.
- Reuter, R.F. and P.D. Spencer. 2002. Other rockfish. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea and Aleutian Islands, p. 579-608.

- Stark, J.W., and D.M. Clausen. 1995. Data report: 1990 Gulf of Alaska bottom trawl survey. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-AFSC-49. 221 p.
- Westrheim, S.J. 1973. Preliminary information on the systematics, distribution, and abundance of the dusky rockfish, *Sebastes ciliatus*. J. Fish. Res. Bd. Can. 30: 1230-1234.
- Westrheim, S.J. 1975. Reproduction, maturation, and identification of larvae of some *Sebastes* (Scorpaenidae) species in the northeast Pacific Ocean. J. Fish. Res. Board Can. 32: 2399-2411.

D.17 Thornyhead rockfish (*Sebastolobus* sp.)

D.17.1 Life History and General Distribution

Thornyhead rockfish of the northeastern Pacific Ocean are comprised of two species, the shortspine thornyhead (*Sebastolobus alascanus*) and the longspine thornyhead (*S. altivelis*). The longspine thornyhead is not common in the Bering Sea and Aleutian Islands. The shortspine thornyhead is a demersal species which inhabits deep waters from 93 to 1,460 m from the Bering Sea to Baja California. This species is common throughout the Gulf of Alaska, eastern Bering Sea, and Aleutian Islands. The population structure of shortspine thornyheads, however, is not well defined. Thornyhead rockfish are slow-growing and long-lived with maximum age in excess of 50 years and maximum size greater than 75 cm and 2 kg. Thornyheads spawn buoyant masses of eggs during the late winter and early spring that resemble bilobate “balloons” which float to the surface (Pearcy 1962). Juvenile shortspine thornyhead rockfish have a pelagic period of about 14 to 15 months and settle out on the shelf (100 m) at about 22 to 27 mm (Moser 1974). Fifty percent of female shortspine thornyheads are sexually mature at about 21 cm and 12 to 13 years of age.

The approximate upper size limit of juvenile fish is 27 mm at the pelagic stage, and 60 mm at the benthic stage (see Moser 1974). Female shortspine thornyheads appear to be mature at about 21 to 22 cm (Miller 1985).

D.17.2 Fishery

There is no directed fishery for thornyhead rockfish in the Bering Sea and Aleutian Islands. Shortspine thornyhead rockfish are caught in the eastern Bering Sea Greenland turbot and pollock trawl fisheries, as well as in the Aleutian Islands sablefish fishery. Nearly 100 percent of all shortspine thornyheads are retained when caught as bycatch to a directed fishery.

D.17.3 Relevant Trophic Information

Shortspine thornyhead rockfish prey mainly on epibenthic shrimp and fish. Yang (1996, 2003) showed that shrimp were the top prey item for shortspine thornyhead rockfish in the Gulf of Alaska; whereas, cottids were the most important prey item in the Aleutian Islands region. Differences in abundance of the main prey between the two areas might be the main reason for the observed diet differences. Predator size might be another reason for the difference since the average shortspine thornyhead in the Aleutian Islands area was larger than that in the Gulf of Alaska (33.4 cm vs 29.7 cm).

D.17.4 Habitat and Biological Associations

Egg/Spawning: Eggs float in masses of various sizes and shapes. Frequently the masses are bilobed with the lobes 15 to 61 cm in length, consisting of hollow conical sheaths containing a single layer of eggs in a gelatinous matrix. The masses are transparent and not readily observed in the daylight. Eggs are 1.2 to 1.4 mm in diameter with a 0.2 mm oil globule. They move freely in the matrix. Complete hatching time is unknown but is probably more than 10 days.

Larvae: Three day-old larvae are about 3 mm long and apparently float to the surface. It is believed that the larvae remain in the water column for about 14 to 15 months before settling to the bottom.

Juveniles: Very little information is available regarding the habitats and biological associations of juvenile shortspine thornyheads.

Adults: Adults are demersal and can be found at depths ranging from about 90 to 1,500 m. Groundfish species commonly associated with thornyheads include: arrowtooth flounder (*Atheresthes stomias*), Pacific ocean perch (*Sebastes alutus*), sablefish (*Anoplopoma fimbria*), rex sole (*Glyptocephalus zachirus*), Dover sole (*Microstomus pacificus*), shorttraker rockfish (*Sebastes borealis*), rougheye rockfish (*Sebastes aleutianus*), and grenadiers (family Macrouridae). Two congeneric thornyhead species, the longspine thornyhead (*Sebastolobus altivelis*) and a species common off of Japan, *S. macrochir*, are infrequently encountered in the Gulf of Alaska.

Habitat and Biological Associations: Thornyhead Rockfish

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	U	U	spawning: late winter and early spring	U	P	U	U	
Larvae	<15 months	U	early spring through summer	U	P	U	U	
Juveniles	> 15 months when settling to bottom occurs (?)	U shrimp, amphipods, mysids, euphausiids?	U	MCS, OCS, USP	D	M, S, R, SM, CB, MS, G	U	
Adults	U	shrimp fish (cottids), small crabs	year-round?	MCS, OCS, USP, LSP	D	M, S, R, SM, CB, MS, G	U	

D.17.5 Literature

- Allen, M.J., and G.B. Smith. 1988. Atlas and zoogeography of common fishes in the Bering Sea and Northeastern Pacific. U.S. Dep. Commerce, NOAA Tech. Rept. NMFS 66, 151 p.
- Aton, M. 1981. Gulf of Alaska bottomfish and shellfish resources. U.S. Dep. Commerce Tech. Memo. NMFS F/NWC-10, 51 p.
- Archibald, C.P., W. Shaw, and B.M. Leaman. 1981. Growth and mortality estimates of rockfishes (Scorpaenidae) from B.C. coastal waters, 1977-79. Can. Tech. Rep. Fish. Aquat. Sci. 1048, 57 p.
- Chilton, D.E., and R.J. Beamish. 1982. Age determination methods for fishes studied by the Groundfish Program at the Pacific Biological Station. Can. Spec. Publ. Fish. Aquat. Sci. 60, 102 p.
- Heifetz, J., J.N. Ianelli, and D.M. Clausen. 1996. Slope rockfish. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 230-270. North Pacific Fishery Management Council, 605 West 4th Avenue, Suite 306, Anchorage, AK 99501.
- Ianelli, J.N., D.H. Ito, and M. Martin. 1996. Thornyheads (*Sebastolobus sp.*). In Stock Assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 303-330. North Pacific Fishery Management Council, 605 West 4th Avenue, Suite 306, Anchorage, AK 99501.

- Jacobson, L.D. 1993. Thornyheads. *In* Status of living marine resources off the Pacific coast of the United States for 1993. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-AFSC-26, 35-37 p.
- Kramer, D.E., and V.M. O'Connell. 1986. Guide to northeast Pacific rockfishes, Genera *Sebastes* and *Sebastolobus*. Marine Advisory Bulletin No. 25: 1-78. Alaska Sea Grant College Program, University of Alaska.
- Low, L.L. 1994. Thornyheads. *In* Status of living marine resources off Alaska, 1993. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-AFSC-27, 56-57 p.
- Miller, P.P. 1985. Life history study of the shortspine thornyhead, *Sebastolobus alascanus*, at Cape Ommaney, south-eastern Alaska. M.S. Thesis, Univ. Alaska, Fairbanks, AK, 61p.
- Moser, H.G. 1974. Development and distribution of larvae and juveniles of *Sebastolobus* (Pisces: family Scorpaenidae). Fish. Bull. 72: 865-884.
- Pearcy, W.G. 1962. Egg masses and early developmental stages of the scorpaenid fish, *Sebastolobus*. J. Fish. Res. Board Can. 19: 1169-1173.
- Sigler, M.F., and H.H. Zenger, Jr. 1994. Relative abundance of Gulf of Alaska sablefish and other groundfish based on the domestic longline survey, 1989. NOAA Tech. Memo. NMFS-AFSC-40.
- Wolotira, R.J., Jr., T.M. Sample, S.F. Noel, and C.R. Iten. 1993. Geographic and bathymetric distributions for many commercially important fishes and shellfishes off the west coast of North America, based on research survey and commercial catch data, 1912-84. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-AFSC-6, 184 p.
- Yang, M-S. 1996. Diets of the important groundfishes in the Aleutian Islands in summer 1991. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-AFSC-60, 105 p.
- Yang, M-S. 2003. Food Habits of the Important Groundfishes in the Aleutian Islands in 1994 and 1997. AFSC processed report 2003-07.

D.18 Atka mackerel (*Pleurogrammus monopterygius*)

D.18.1 Life History and General Distribution

Atka mackerel are distributed from the Gulf of Alaska to the Kamchatka Peninsula, most abundant along the Aleutian Islands. Adult Atka mackerel occur in large localized aggregations usually at depths less than 200 m and generally over rough, rocky, and uneven bottom near areas where tidal currents are swift. Associations with corals and sponges have been observed for Aleutian Islands Atka mackerel. Adults are semi-demersal, displaying strong diel behavior with vertical movements away from the bottom occurring almost exclusively during the daylight hours, presumably for feeding, and little to no movement at night. Spawning is demersal in moderately shallow waters (down to bottom depths of 144 m) and peaks in June through September, but may occur intermittently throughout the year. Female Atka mackerel deposit eggs in nests built and guarded by males on rocky substrates or on kelp in shallow water. Eggs develop and hatch in 40 to 45 days, releasing planktonic larvae which have been found up to 800 km from shore. Little is known of the distribution of young Atka mackerel prior to their appearance in trawl surveys and the fishery at about age 2 to 3 years. Atka mackerel exhibit intermediate life history traits. R-traits include young age at maturity (approximately 50 percent are mature at age 3), fast growth rates, high natural mortality (mortality equals 0.3) and young average and maximum ages (about 5 and 14 years, respectively). K-selected traits include low fecundity (only about 30,000 eggs/female/year, large egg diameters (1 to 2 mm) and male nest-guarding behavior).

The approximate upper size limit of juvenile fish is 35 cm.

D.18.2 Fishery

The directed fishery is conducted with bottom trawls in the Aleutian Islands, at depths between about 70 m and 300 m, in trawlable areas on rocky, uneven bottom, along edges, and in lee of submerged hills during periods of high current. The fishery generally catches fish ages 3 to 11 years old. Currently, the fishery occurs on reefs west of Kiska Island, south and west of Amchitka Island, in Tanaga Pass and near the Delarof Islands, and south of Seguam and Umnak Islands. Historically a fishery occurred east into the Gulf of Alaska as far as Kodiak Island (through the mid 1980s), but is no longer conducted there. Directed fishing for Atka mackerel in the Gulf of Alaska is prohibited by Steller sea lion protection measures. The Aleutian Islands fishery is conducted during two seasons: an A season from 20 January to 15 April and a B season from 1 September to 1 November. Fifty percent of the total allowable catch is allocated to each season.

D.18.3 Relevant Trophic Information

Atka mackerel are an important food for Steller sea lions in the Aleutian Islands, particularly during summer, and for other marine mammals (minke whales, Dall's porpoise, and northern fur seal). Juveniles are eaten by thick billed murres and tufted puffins. Main groundfish predators are Pacific halibut, arrowtooth flounder, and Pacific cod. Adult Atka mackerel consume a variety of prey, but principally calanoid copepods and euphausiids. Predation on Atka mackerel eggs by cottids and other hexagrammids is prevalent during the spawning season as is cannibalism by other Atka mackerel.

D.18.4 Habitat and Biological Associations

Egg/Spawning: Adhesive eggs are deposited in nests built and guarded by males on rocky substrates or on kelp in shallow water.

Larvae/Juveniles: Planktonic larvae have been found up to 800 km from shore, usually in upper water column (neuston), but little is known of the distribution of Atka mackerel until they are about 2 years old and appear in fishery and surveys.

Adults: Adults occur in localized aggregations usually at depths less than 200 m and generally over rough, rocky and uneven bottom near areas where tidal currents are swift. Associations with corals and sponges have been observed for Aleutian Islands Atka mackerel. Adults are semi-demersal/pelagic during much of the year, but the males become demersal during spawning; females move between nesting and offshore feeding areas.

Habitat and Biological Associations: Atka mackerel

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	40–45 days	NA	summer	IP, ICS, MCS	D	G, R, K, CB	U	develop 3–15 °C optimum 3.9–10.5 °C
Larvae	up to 6 mos	U copepods?	fall–winter	U	U, N?	U	U	2–12 °C optimum 5–7 °C
Juveniles	½–2 yrs of age	U copepods & euphausiids?	all year	U	N	U	U	3–5 °C
Adults	3+ yrs of age	copepods euphausiids meso-pelagic fish (myctophids)	spawning (June–Oct) non-spawning (Nov–May) tidal/diurnal, year-round?	ICS and MCS, IP MCS and OCS, IP ICS, MCS, OCS, IP	D (males) SD females SD/D all sexes D when currents high/day SD slack tides/night	G, R, CB, K	F, E	3–5 °C all stages >17 ppt only

D.18.5 Literature

- Allen, M.J., and G.B. Smith. 1988. Atlas and zoogeography of common fishes in the Bering Sea and Northeastern Pacific. U.S. Dep. Commer., NOAA Tech. Rept. NMFS 66, 151 p.
- Boldt, J.L. (Ed). 2005. Ecosystem indicators for the North Pacific and their implications for stock assessment: Proceedings of first annual meeting of NOAA's Ecological Indicators research program. AFSC Processed Rep.2005-04, Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115.
- Byrd, G.V., J.C. Williams, and R. Walder. 1992. Status and biology of the tufted puffin in the Aleutian Islands, Alaska, after a ban on salmon driftnets. U.S. Fish and Wildlife Service, Alaska Maritime National Wildlife Refuge, Aleutian Islands Unit, PSC 486, Box 5251, FPO AP 96506-5251, Adak, Alaska.
- Cooper, D., and S. McDermott. 2008. Variation in Atka mackerel, *Pleurogrammus monopterygius*, spatial and temporal distribution by maturity stage. Pages 11-42 in S. F. McDermott, M. Canino, N. Hillgruber, D. W. Cooper, I. Spies, J. Guthridge, J. N. Ianelli, P. Woods. 2008. Atka mackerel *Pleurogrammus monopterygius* reproductive ecology in Alaska. North Pacific Research Board Final report, 163p.
- Doyle, M.J., W.C. Ruge, and R.D. Brodeur. 1995. Neustonic ichthyoplankton in the western Gulf of Alaska during spring. Fishery Bulletin 93: 231-253.
- Dragoo, D.E., G.V. Byrd, and D.B. Irons. 2001. Breeding status, population trends, and diets of seabirds in Alaska, 2000. U.S. Fish and Wildl. Serv. Report AMNWR 01/07.
- Francis, R.C., and S.R. Hare. 1994. Decadal scale regime shifts in the large marine ecosystems of the northeast Pacific: A case for historical science. Fish. Oceanogr. 3(1):279-291.
- Fritz, L.W. 1993. Trawl locations of walleye pollock and Atka mackerel fisheries in the Bering Sea, Aleutian Islands, and Gulf of Alaska from 1977-1992. AFSC Processed Report 93-08, NMFS, 7600 Sand Point Way, NE, Seattle, WA 98115. 162 pp.

- Fritz, L.W. and S.A. Lowe. 1998. Seasonal distributions of Atka mackerel (*Pleurogrammus monopterygius*) in commercially-fished areas of the Aleutian Islands and Gulf of Alaska. NOAA Tech. Memo. NMFS-AFSC-92. 29p.
- Gorbunova, N.N. 1962. Razmnozhenie i razvite ryb semeistva terpugovykh (Hexagrammidae) Spawning and development of greenlings (family Hexagrammidae). Tr. Inst. Okeanol., Akad. Nauk SSSR 59:118-182. In Russian. (Trans. by Isr. Program Sci. Trans., 1970, p. 121-185 in T.S. Rass (editor), Greenlings: taxonomy, biology, interoceanic transplantation; available from the U.S. Dep. Commerce, Natl. Tech. Inf. Serv., Springfield, VA., as TT 69-55097).
- Guthridge, J. L. and N. Hillgruber. 2008. Embryonic development of Atka mackerel (*Pleurogrammus monopterygius*) and the effect of temperature. Pages 43-65 in S. F. McDermott, M. Canino, N. Hillgruber, D. W. Cooper, I. Spies, J. Guthridge, J. N. Ianelli, P. Woods. 2008. Atka mackerel *Pleurogrammus monopterygius* reproductive ecology in Alaska. North Pacific Research Board Final report, 163p.
- Hare, S.R., and N.J. Mantua. 2000. Empirical evidence for North Pacific regime shifts in 1977 and 1989. Prog. Oceanogr. 47:103-145.
- Hollowed, A.B., S.R. Hare, and W.S. Wooster. 2001. Pacific Basin climate variability and patterns of Northeast Pacific marine fish production. Prog. Oceanogr. 49:257-282.
- Hunt, G.L. Jr., H. Kato, and S.M. McKinnell [eds.] 2000. Predation by marine birds and mammals in the subarctic north Pacific Ocean. North Pacific Marine Science Organization (PICES) Scientific Report #25. 165 p.
- Kajimura, H. 1984. Opportunistic feeding of the northern fur seal *Callorhinus ursinus*, in the eastern north Pacific Ocean and eastern Bering Sea. NOAA Tech. Rept. NMFS SSRF-779. USDOC, NOAA, NMFS, 49 pp.
- Kendall, A.W., Jr., and J.R. Dunn. 1985. Ichthyoplankton of the continental shelf near Kodiak Island, Alaska. U.S. Dep. Commer., NOAA Tech. Rept NMFS 20, 89 p.
- Kendall, A.W., Jr., J.R. Dunn, and R.J. Wolotira, Jr. 1980. Zooplankton, including ichthyoplankton and decapod larvae, of the Kodiak shelf. NWAFC Processed Rept. 80-8, AFSC-NMFS, 7600 Sand Point Way, NE, Seattle, WA 98115. 393 p.
- Lauth, R. R., J. Guthridge, D. Nichol, S. W. McEntire, and N. Hillgruber. 2007a. Timing and duration of mating and brooding periods of Atka mackerel (*Pleurogrammus monopterygius*) in the North Pacific Ocean. Fish. Bull., U.S. 105:560-570. <http://fishbull.noaa.gov/1054/lauth.pdf>
- Lauth, R. R., S. W. McEntire, and H. H. Zenger, Jr. 2007b. Geographic distribution, depth range, and description of Atka mackerel *Pleurogrammus monopterygius* nesting habitat in Alaska. Alaska Fish. Res. Bull. 12:165-186. http://www.adfg.state.ak.us/pubs/afrb/vol12_n2/lautv12n2.pdf
- Lee, J.U. 1985. Studies on the fishery biology of the Atka mackerel *Pleurogrammus monopterygius* (Pallas) in the north Pacific Ocean. Bull. Fish. Res. Dev. Agency, 34, pp.65-125.
- Levada, T.P. 1979. Comparative morphological study of Atka mackerel. Pac. Sci. Res. Inst. Fish. Oceanogr. (TINRO), Vladivostok, U.S.S.R., Unpublished manuscript.
- Levada, T.P. 1979. Some data on biology and catch of Atka mackerel. Pac. Sci. Res. Inst. Fish. Oceanogr. (TINRO), Vladivostok, U.S.S.R., Unpublished manuscript.
- Malecha, P.W., R.P. Stone, and J. Heifetz. 2005. Living substrate in Alaska: Distribution, abundance, and species associations. Pages 289-299 in P.W. Barnes and J.P. Thomas, editors. Benthic habitats and the effects of fishing. American Fisheries Society, Symposium 41, Bethesda, Maryland.
- McDermott, S.F. and S.A. Lowe. 1997. The reproductive cycle and sexual maturity of Atka mackerel (*Pleurogrammus monopterygius*) in Alaskan waters. Fishery Bulletin 95: 321-333.
- McDermott, S.F., K.E. Pearson and D.R. Gunderson. 2007. Annual fecundity, batch fecundity, and oocyte atresia of Atka mackerel (*Pleurogrammus monopterygius*) in Alaskan waters. Fish Bull. 105:19-29.
- Mel'nikov, I.V. and A. YA. Efimkin. 2003. the young of the northern Atka mackerel *Pleurogrammus monopterygius* in the epipelagic zone over deep-sea areas of the northern Pacific Ocean. J. Ichthyol. 43: 424-437.

- Merrick, R.L., M.K. Chumbley, and G.V. Byrd. 1997. Diet diversity of Steller sea lions (*Eumetopias jubatus*) and their population decline in Alaska: a potential relationship. *Can. J. Fish. Aquat. Sci.* 54:1342-1348.
- Morris, B.F. 1981. An assessment of the living marine resources of the central Bering Sea and potential resource use conflicts between commercial fisheries and Petroleum development in the Navarin Basin, Proposed sale No. 83. Anchorage, AK: USDOC, NOAA, NMFS, Environmental Assessment Division.
- Musienko, L.N. 1970. Razmnozheine i razvitie ryb Beringova morya (Reproduction and development of Bering Sea fishes). *Tr. Vses. Nauchno-issled. Inst. Morsk. Rybn. Koz. Okeanogr.* 70: 161-224 In P.A. Moiseev (ed.), Soviet fisheries investigations in the northeastern Pacific, Pt. 5, Avail. Natl. Tech. Info. Serv., Springfield, VA as TT 74-50127.
- Nichol D.G., Somerton D.A. 2002. Diurnal vertical migration of the Atka mackerel *Pleurogrammus monopterygius* as shown by archival tags. *Mar Ecol Prog Ser* 239: 193-207.
- NMFS. 1995. Status review of the United States Steller sea lion (*Eumetopias jubatus*) population. National Marine Mammal Laboratory, Alaska Fishery Science Center, National Marine Fisheries Service, 7600 Sand Point Way, NE, Seattle, WA 98115.
- Orlov, A.M. 1996. The role of mesopelagic fishes in feeding of Atka mackerel in areas of the North Kuril islands. *Publ. Abstract in Role of forage fishes in marine ecosystems. Symposium held Nov 1996, AK Sea Grant, U. Alaska, Fairbanks.*
- Ortiz, I. 2007. Ecosystem Dynamics of the Aleutian Islands. Ph.D. Thesis. University of Washington, Seattle.
- Rugen, W.C. 1990. Spatial and temporal distribution of larval fish in the western Gulf of Alaska, with emphasis on the period of peak abundance of walleye pollock (*Theragra chalcogramma*) larvae. NWAFC Processed Rept 90-01, AFSC-NMFS, 7600 Sand Point Way, NE, Seattle, WA 98115. 162 p.
- Sinclair E.H. and T.K. Zeppelin 2002. Seasonal and spatial differences in diet in the western stock of Steller sea lions (*Eumetopias jubatus*). *Journal of Mammalogy* 83(4).
- Springer, A.M., J.F. Piatt, V.P. Shuntov, G.B. Van Vliet, V.L. Vladimirov, A.E. Kuzin, A.S. Perlov. 1999. *Prog. in Oceanogr.* 43(1999)443-487.
- Stone, R.P. 2006. Coral habitat in the Aleutian Islands of Alaska: depth distribution, fine-scale species associations, and fisheries interactions. *Coral Reefs* 25:229-238.
- Waldron, K.D. 1978. Ichthyoplankton of the eastern Bering Sea, 11 February-16 March 1978. REFM Report, AFSC, NMFS, 7600 Sand Point Way, NE, Seattle, WA 98115. 33 p.
- Waldron, K.D., and B.M. Vinter. 1978. Ichthyoplankton of the eastern Bering Sea. Final Report (RU 380), Environmental Assessment of the Alaskan continental shelf, REFM, AFSC, NMFS, 7600 Sand Point Way, NE, Seattle, WA 98115. 88 p.
- Wolotira, R.J., Jr., T.M. Sample, S.F. Noel, and C.R. Iten. 1993. Geographic and bathymetric distributions for many commercially important fishes and shellfishes off the west coast of North America, based on research survey and commercial catch data, 1912-84. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-AFSC-6, 184 p.
- Yang, M-S. 1996. Diets of the important groundfishes in the Aleutian Islands in summer 1991. NOAA Technical Memorandum, NMFS-AFSC-60, U.S. Department of Commerce, NOAA. p. 105.
- Yang, M-S. 1999. The trophic role of Atka mackerel, *Pleurogrammus monopterygius*, in the Aleutian Islands area. *Fishery Bulletin* 97(4):1047-1057.
- Yang, M-S. 2003. Food habits of the important groundfishes in the Aleutian Islands in 1994 and 1997. AFSC Processed Rep.2003-07, Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115. p. 233.
- Zolotov, O.G. 1993. Notes on the reproductive biology of *Pleurogrammus monopterygius* in Kamchatkan waters. *J. of Ichthy.* 33(4), pp. 25-37.

D.19 Squids (*Cephalopoda*, *Teuthida*)

The species representatives for squids are:

Gonaditae:	Red or magistrate armhook squid (<i>Berryteuthis magister</i>)
Onychoteuthidae:	Boreal clubhook squid (<i>Onychoteuthis banksii borealjaponicus</i>)
	Giant or robust clubhook squid (<i>Moroteuthis robusta</i>)
Sepiolidae:	eastern Pacific bobtail squid (<i>Rossia pacifica</i>)

D.19.1 Life History and General Distribution:

Squids are members of the molluscan class Cephalopoda, along with octopus, cuttlefish, and nautiloids. In the Bering Sea and Aleutian Islands (BSAI) and Gulf of Alaska (GOA), gonatid and onychoteuthid squids are generally the most common, along with chiroteuthids. All cephalopods are stenohaline, occurring only at salinities greater than 30 ppt. Fertilization is internal, and development is direct (“larval” stages are only small versions of adults). The eggs of inshore neritic species are often enveloped in a gelatinous matrix attached to rocks, shells, or other hard substrates, while the eggs of some offshore oceanic species are extruded as large, sausage-shaped drifting masses. Little is known of the seasonality of reproduction, but most species probably breed in spring and early summer, with eggs hatching during the summer. Most small squids are generally thought to live only 2 to 3 years, but the giant *Moroteuthis robusta* clearly lives longer.

B. magister is widely distributed in the boreal north Pacific from California, throughout the Bering Sea, to Japan in waters of depth 30 to 1,500 m; adults most often found at mesopelagic depths or near bottom on shelf, rising to the surface at night; juveniles are widely distributed across shelf, slope, and abyssal waters in mesopelagic and epipelagic zones, and rise to surface at night. Migrates seasonally, moving northward and inshore in summer, and southward and offshore in winter, particularly in the western north Pacific. The maximum size for females is 50 cm mantle length (ML), and for males is 40 cm ML. Spermatophores transferred into the mantle cavity of female, and eggs are laid on the bottom on the upper slope (200 to 800 m). Fecundity estimated at 10,000 eggs/female. Spawning of eggs occurs in February and March in Japan, but apparently all year-round in the Bering Sea. Eggs hatch after 1 to 2 months of incubation; development is direct. Adults are gregarious prior to, and most die, after mating.

O. banksii borealjaponicus, an active, epipelagic species, is distributed in the north Pacific from the Sea of Japan, throughout the Aleutian Islands and south to California, but is absent from the Sea of Okhotsk and not common in the Bering Sea. Juveniles can be found over shelf waters at all depths and near shore. Adults apparently prefer the upper layers over slope and abyssal waters and are diel migrators and gregarious. Development includes a larval stage; maximum size is about 55 cm.

M. robusta, a giant squid, lives near the bottom on the slope, and mesopelagically over abyssal waters; it is rare on the shelf. It is distributed in all oceans, and is found in the Bering Sea, Aleutian Islands, and GOA. Mantle length can be up to 2.5 m long (at least 7 m with tentacles), but most are about 2 m long.

R. pacifica is a small (maximum length with tentacles of less than 20 cm) demersal, neritic and shelf, boreal species, distributed from Japan to California in the North Pacific and in the Bering Sea in waters of about 20 to 300 m depth. Other *Rossia* spp. deposit demersal egg masses.

For *B. magister*, the approximate upper size limit of juvenile fish is 20 cm ML for males and 25 cm ML for females; both are at approximately 1 year of age.

D.19.2 Fishery

Not currently a target of groundfish fisheries of BSAI or GOA. A Japanese fishery catching up to 9,000 metric tons (mt) of squid annually existed until the early 1980s for *B. magister* in the Bering Sea and *O. banksii borealjaponicus* in the Aleutian Islands. Since 1990, annual squid bycatch has been about 1,000 mt or less in the BSAI, and between 30 mt and 150 mt in the GOA; in the BSAI, almost all squid bycatch is in the midwater pollock fishery near the continental shelf break and slope, while in the GOA, trawl fisheries for rockfish and pollock (again mostly near the edge of the shelf and on the upper slope) catch most of the squid bycatch.

D.19.3 Relevant Trophic Information

The principal prey items of squid are small forage fish pelagic crustaceans (e.g., euphausiids and shrimp), and other cephalopods; cannibalism is not uncommon. After hatching, small planktonic zooplankton (copepods) are eaten. Squid are preyed upon by marine mammals, seabirds, and to a lesser extent by fish and occupy an important role in marine food webs worldwide. Perez (1990) estimated that squids comprise over 80 percent of the diets of sperm whales, bottlenose whales, and beaked whales, and about half of the diet of Dall's porpoise in the eastern Bering Sea and Aleutian Islands. Seabirds (e.g., kittiwakes, puffins, murres) on island rookeries close to the shelf break (e.g., Buldir Island, Pribilof Islands) are also known to feed heavily on squid (Hatch et al. 1990; Byrd et al. 1992; Springer 1993). In the GOA, only about 5 percent or less of the diets of most groundfish consisted of squid (Yang 1993). However, squid play a larger role in the diet of salmon (Livingston and Goiney 1983).

D.19.4 Habitat and Biological Associations for *B. magister*

Egg/Spawning: Eggs are laid on the bottom on the upper slope (200 to 800 m); incubate for 1 to 2 months.

Young Juveniles: Distributed epipelagically (top 100 m) from the coast to open ocean.

Old Juveniles and Adults: Distributed mesopelagically (most from 150 to 500 m) on the shelf (summer only?), but mostly in outer shelf/slope waters (to lesser extent over the open ocean). Migrate to slope waters to mate and spawn demersally.

Habitat and Biological Associations: *Berryteuthis magister* (red squid)

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceano-graphic Features	Other
Eggs	1–2 months	NA	varies	USP, LSP	D	M, SM, MS	U	
Young juveniles	4–6 months	zooplankton	varies	all shelf, slope, BSN	P, N	NA	UP, F?	
Older Juveniles and Adults	1–2 years (may be up to 4 yrs)	euphausiids, shrimp, small forage fish, and other cephalopods	summer winter	all shelf, USP, LSP, BSN OS, USP, LSP, BSN	SP SP	U U	UP, F? UP, F?	euhaline waters, 2–4 °C

D.19.5 Literature

Arkhipkin, A.I., V.A. Bizikov, V.V. Krylov, and K.N. Nesis. 1996. Distribution, stock structure, and growth of the squid *Berryteuthis magister* (Berry, 1913) (Cephalopoda, Gonatidae) during summer and fall in the western Bering Sea. Fish. Bull. 94: 1-30.

- Akimushkin, I.I. 1963. Cephalopods of the seas of the U.S.S.R. Academy of Sciences of the U.S.S.R., Institute of Oceanology, Moscow. Translated from Russian by Israel Program for Scientific Translations, Jerusalem 1965. 223 p.
- Byrd, G.V., J.C. Williams, and R. Walder. 1992. Status and biology of the tufted puffin in the Aleutian Islands, Alaska, after a ban on salmon driftnets. U. S. Fish and Wildlife Service, Alaska Maritime National Wildlife Refuge, Aleutian Islands Unit, PSC 486, Box 5251, FPO AP 96506-5251, Adak, Alaska.
- Fritz, L.W. 1996. Other species *In* Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions as Projected for 1997. North Pacific Fishery Management Council, 605 West 4th Avenue, Suite 306, Anchorage, AK.
- Hatch, S.A., G.V. Byrd, D.B. Irons, and G.L. Hunt, Jr. 1990. Status and ecology of kittiwakes in the North Pacific. Proc. Pacific Seabird Group Symposium, Victoria, B.C., 21-25 February 1990.
- Livingston, P.A., and B.J. Goiney, Jr. 1983. Food habits literature of North Pacific marine fishes: a review and selected bibliography. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS F/NWC-54, 81 p.
- Nesis, K. N. 1987. Cephalopods of the world. TFH Publications, Neptune City, NJ, USA. 351 pp.
- Perez, M. 1990. Review of marine mammal population and prey information for Bering Sea ecosystem studies. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS F/NWC-186, 81 p.
- Sobolevsky, Ye. I. 1996. Species composition and distribution of squids in the western Bering Sea. Pp. 135-141 *In* O.A. Mathisen and K.O. Coyle (eds.), Ecology of the Bering Sea: a review of Russian literature. Alaska Sea Grant Rept 96-01, U. Alaska, Fairbanks, AK 99775.
- Springer, A. 1993. Report of the seabird working group. pp. 14-29 *In* Is it food? Addressing marine mammal and seabird declines: a workshop summary. Alaska Sea Grant Report 93-01, Univ. Alaska, Fairbanks, AK, 99775.
- Yang, M.S. 1993. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-AFSC-22, 150 p.

D.20 Octopuses

There are at least seven species of octopuses currently identified from the Bering Sea, including one species of genus *Octopus* that has not been fully described (*Octopus* n. sp., Connors and Jorgensen 2008). The species most abundant at depths less than 200m is the giant Pacific octopus *Enteroctopus dofleini* (formerly *Octopus dofleini*). Several species are found primarily in deeper waters along the shelf break and slope, including, *Benthoctopus leioderma*, *Benthoctopus oregonensis*, *Graneledone boreopacifica*, and the cirrate octopus *Opisthoteuthis* cf. *californiana*. *Japetella diaphana* is also reported from pelagic waters of the Bering Sea. Preliminary evidence (Connors and Jorgensen 2008, Connors et al. 2004) indicates that octopuses taken as incidental catch in groundfish fisheries are primarily *Enteroctopus dofleini*. This species has been extensively studied in British Columbia and Japan, and is used as the primary indicator for the assemblage. Species identification of octopuses in the Bering Sea and Gulf of Alaska (GOA) has changed since the previous EFH review and is still developing. The state of knowledge of octopuses in the Bering Sea and Aleutian Islands (BSAI), including the true species composition, is very limited.

D.20.1 Life History and General Distribution

Octopuses are members of the molluscan class Cephalopoda, along with squid, cuttlefish, and nautiloids. The octopuses (order Octopoda) have only eight appendages or arms and unlike other cephalopods, they lack shells, pens, and tentacles. There are two groups of Octopoda, the cirrate and the incirrate. The cirrate have cirri and are by far less common than the incirrate, which contain the more traditional forms of octopus. Octopuses are found in every ocean in the world and range in size from less than 20 cm (total length) to over 3 m (total length); the latter is a record held by *Enteroctopus dofleini*.

In the Bering Sea octopuses are found from subtidal waters to deep areas near the outer slope. The highest diversity is along the shelf break region where three to four species of octopus can be collected in approximately the same area. The highest diversity is found between 200 m and 750 m. The observed take of octopus from both commercial fisheries and Alaska Fisheries Science Center Resource Assessment and Conservation Engineering Division surveys indicates few octopus occupy federal waters of Bristol Bay and the inner front region. Some octopuses have been observed in the middle front, especially in the region south of the Pribilof Islands. The majority of observed commercial and survey hauls containing octopus are concentrated in the outer front region and along the shelf break, from the horseshoe at Unimak Pass to the northern limit of the federal regulatory area. Octopuses have been observed throughout the western GOA and Aleutian Islands chain. Of the octopus species found in shallower waters, the distribution between state waters (within three miles of shore) and federal waters remains unknown. *Enteroctopus dofleini* in Japan undergo seasonal depth migrations associated with spawning; it is unknown whether similar migrations occur in Alaskan waters.

In general, octopus life spans are either 1 to 2 years or 3 to 5 years depending on species. Life histories of six of the seven species in the Bering Sea are largely unknown. *Enteroctopus dofleini* has been studied in waters of northern Japan and western Canada, but reproductive seasons and age/size at maturity in Alaskan waters are still undocumented. General life histories of the other six species are inferred from what is known about other members of the genus.

E. dofleini is sexually mature after approximately three years. In Japan, females weigh between 10 and 15 kg at maturity while males are 7 to 17 kg (Kanamaru and Yamashita 1967). *E. dofleini* in the Bering Sea may mature at larger sizes given the more productive waters in the Bering Sea. *E. dofleini* in Japan move to deeper waters to mate during July through October and move to shallower waters to spawn during October through January. There is a two-month lag time between mating and spawning. This time may be necessary for the females to consume extra food to last the seven months required for hatching of the eggs, during which time the female guards and cleans the eggs but does not feed. *E. dofleini* is a terminal spawner, females die after the eggs hatch while males die shortly after mating. While females may have 60,000 to 100,000 eggs in their ovaries, only an average of 50,000 eggs are laid (Kanamaru 1964). Hatchlings are approximately 3.5 mm. Mottet (1975) estimated survival to 6 at 4 percent, while survival to 10 mm was estimated to be 1 percent; mortality at the 1–2 year stage was also estimated to be high (Hartwick 1983). Since the highest mortality occurs during the larval stage it is likely that ocean conditions have the largest effect on the number of *E. dofleini* in the Bering Sea and large fluctuations in numbers of *E. dofleini* should be expected. Based on larval data, *E. dofleini* is the only octopus in the Bering Sea with a planktonic larval stage.

The undescribed species *Octopus* n. sp. is a small-sized species, maximum total length less than 15 cm. Although little is known about this species, a start at estimating its life history could come from what we know of *Octopus rubescens*, another small species of *Octopus* found in the North Pacific. *O. rubescens* lives 1 to 2 years and is also a terminal spawner, likely maturing after 1 year. *O. rubescens* has a planktonic stage while the new species of *Octopus* does not. Females of the new species have approximately 80 to 120 eggs. The eggs of *Octopus* n. sp. are likely much larger as benthic larvae are often bigger; they could take up to six months or more to hatch. In the most recent groundfish survey of the East Bering Sea Slope this was the most abundant octopus collected, multiple specimens were collected in over 50 percent of the tows.

Benthoctopus leioderma is a medium-sized species, maximum total length approximately 60 cm. Its life span is unknown. It occurs from 250 to 1,400 m and is found throughout the shelf break region. It is a common octopus and often occurs in the same areas where *E. dofleini* are found. The eggs are brooded by the female but mating and spawning times are unknown. They are thought to spawn under rock ledges and crevices (Voight and Grehan 2000). The hatchlings are benthic.

Benthoctopus oregonensis is larger than *B. leioderma*, maximum total length approximately 1 m. This is the second largest octopus in the Bering Sea and based on size could be confused with *E. dofleini*. We know very little about this species of octopus. It could have a life span similar to *E. dofleini*. Other members of this genus brood their eggs, and we would assume the same for this species. The hatchlings are demersal and likely much larger than those of *E. dofleini*. The samples of *B. oregonensis* all come from deeper than 500 m. This species is the least collected incirrate octopus in the Bering Sea and may live from the shelf break to the abyssal plain and therefore often out of our sampling range.

Graneledone boreopacifica is a deep-water octopus with only a single row of suckers on each arm (the other benthic incirrate octopuses have two rows of suckers). It is most commonly collected north of the Pribilof Islands but occasionally is found in the southern portion of the shelf break region. Samples of *G. boreopacifica* all come from deeper than 650 m and therefore do not occur on the shelf.

Opisthoteuthis californiana is a cirrate octopus and has fins and cirri (on the arms). It is common in the Bering Sea but would not be confused with *E. dofleini*. It is found from 300 to 1,100 m and likely common over the abyssal plain. Other details of its life history remain unknown.

Japetella diaphana is a small pelagic octopus. Little is known about members of this family. This is not a common octopus in the Bering Sea and would not be confused with *E. dofleini*.

D.20.2 Fishery

Not currently a target of federal groundfish fisheries of BSAI or GOA. A small directed fishery in state waters around Unimak Pass and in the Aleutian Islands existed from 1988 through 1995; catches from this fishery were reportedly less than 8 mt per year (Fritz 1997). Between 1995 and 2003, all reported state harvests of octopus in the BSAI were incidental to other fisheries, primarily Pacific cod (ADF&G 2004). Catches in federal waters are incidental, chiefly in the pot fishery for Pacific cod and bottom trawl fisheries for cod and flatfish, but sometimes in the pelagic trawl pollock fishery. Total incidental catch has ranged between an estimated 200 to 400 mt in the BSAI and 80 to 300 mt in the GOA. Most of the bycatch occurs on the outer continental shelf (100 to 200 m depth), chiefly north of the Alaskan peninsula from Unimak Island to Port Moller and northwest to the Pribilof Islands; also around Kodiak Island and many of the Aleutian Islands. Increasing market prices and processing capacity have led to increased retention and sale of incidental octopus catch in 2004 through 2008; the North Pacific Fisheries Management Council is currently considering dividing the “other species” category into several subgroups for separate management; one of these subgroups would be octopus (all species).

D.20.3 Relevant Trophic Information

Octopus are eaten by pinnipeds (principally Steller sea lions, and spotted, bearded, and harbor seals) and a variety of fishes, including Pacific halibut and Pacific cod (Yang 1993). When small, octopods eat planktonic and small benthic crustaceans (mysids, amphipods, copepods). As adults, octopus eat benthic crustaceans (crabs) and molluscs (clams). Large octopuses are also able to catch and eat benthic fishes; the Seattle Aquarium has documented a giant Pacific octopus preying on a 4-foot dogfish.

D.20.4 Habitat and Biological Associations

Egg/Spawning: shelf, *E. dofleini* lays strings of eggs in cave or den in boulders or rubble, which are guarded by the female until hatching. The exact habitat needs and preferences for denning are unknown.

*Larvae: pelagic for *Enteroctopus dofleini*, demersal for other octopus species.

Young Juveniles: semi-demersal; widely dispersed on shelf, upper slope

Old Juveniles and Adults: demersal, widely dispersed on shelf and upper slope, preferentially among rocks, cobble, but also on sand/mud.

Habitat and Biological Associations: *Octopus dofleini*, *O. gilbertianus*

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	U (1–2 months?)	NA	spring–summer?	U, ICS, MCS	P*,D	R, G?	U	euhaline waters
Young juveniles	U	zooplankton	summer–fall?	U, ICS, MCS, OCS, USP	D, SD	U	U	euhaline waters
Older Juveniles and Adults	3–5 yrs for <i>E.dofleini</i> , 1–2 yrs for other species?	crustaceans, mollusks, fish	all year	ICS, MCS, OCS, USP	D	R, G, S, MS?	U	euhaline waters

D.20.5 Literature

- Akimushkin, I.I. 1963. Cephalopods of the seas of the U.S.S.R. Academy of Sciences of the U.S.S.R., Institute of Oceanology, Moscow. Translated from Russian by Israel Program for Scientific Translations, Jerusalem 1965. 223 p.
- Alaska Department of Fish and Game. 2004. Annual management report of the commercial and subsistence shellfish fisheries of the Aleutian Islands, Bering Sea, and the westward region's shellfish observer program, 2003. Regional Information Report No. 4K04-43
- Aydin, K., S. Gaichas, I. Ortiz, D. Kinzey, and N. Friday. 2008. A comparison of the Bering Sea, Gulf of Alaska, and Aleutian Islands large marine ecosystems through food web modeling. NOAA Tech Memo.
- Caddy, J.F. 1979. Preliminary analysis of mortality, immigration, and emigration on *Illex* population on the Scotian Shelf. ICNAF Res. Doc. 79/VI/120, Ser. No. 5488.
- Caddy, J.F. 1983. The cephalopods: factors relevant to their population dynamics and to the assessment and management of stocks. Pages 416-452 In J.F. Caddy, ed. Advances in assessment of world cephalopod resources. FAO Fisheries Tech. Paper 231.
- Caddy, J.F. 2004. Current usage of fisheries indicators and reference points, and their potential application to management of fisheries for marine invertebrates. Can. J Fish. Aquat. Sci. 61:1307-1324.
- Caddy, J.F. and P.G. Rodhouse. 1998. Cephalopod and groundfish landings: evidence for ecological change in global fisheries? Rev. Fish Biology and Fisheries 8:431-444.
- Charnov e.L. and D. Berrigan. 1991. Evolution of life history parameters in animals with indeterminate growth, particularly fish. Evol. Ecol. 5:63-68.
- Connors, M. E., P. Munro, and S. Neidetcher. 2004. Pacific cod pot studies 2002-2003. AFSC Processed Report 2004-04. June 2004
- Connors, M.E. and E. Jorgensen. 2005. Octopus Complex in the Bering Sea and Aleutian Islands. In: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, Anchorage, AK,
- Connors, M.E. and E. Jorgensen. 2006. Octopus Complex in the Bering Sea and Aleutian Islands. In: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, Anchorage, AK,

- Connors, M.E. and E. Jorgensen. 2007. Octopus Complex in the Bering Sea and Aleutian Islands. In: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, Anchorage, AK,
- Connors, M.E. and E. Jorgensen. 2008. Octopus Complex in the Bering Sea and Aleutian Islands. In: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, Anchorage, AK,
- Fritz, L.W. 1996. Other species In Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions as Projected for 1997. North Pacific Fishery Management Council, 605 West 4th Avenue, Suite 306, Anchorage, AK 99501.
- Fritz, L. 1997. Summary of changes in the Bering Sea Aleutian Islands squid and other species assessment. (in) Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. N. Pacific Fish. Management Council, Anchorage, AK.
- Gaichas, S. 2004. Other Species (in) Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea / Aleutian Islands regions. N. Pacific Fish. Management Council, Anchorage, AK.
- Hatanaka, H. 1979. Studies on the fisheries biology of common octopus off the northwest coast of Africa. Bull Far Seas Reserarch Lab 17:13-94.
- Hartwick, B. 1983. *Octopus dofleini*. In Cephalopod Life Cycles Vol. I. P.R. Boyle eds. 277-291.
- Hartwick, E.B., R.F. Ambrose, and S.M.C. Robinson. 1984. Dynamics of shallow-water populations of *Octopus dofleini*. Mar. Biol. 82:65-72.
- Hartwick, E.B. and I. Barriga. 1997. *Octopus dofleini*: biology and fisheries in Canada (in) Lang, M. A. and F.G. Hochberg (eds.) (1997). Proceedings of the Workshop on the Fishery and market potential of octopus in California. Smithsonian Institutions: Washington. 192 p.
- Hoenig, J.N. 1983. Empirical Use of Longevity Data to Estimate Mortality Rates. Fishery Bulletin V. 82 No. 1, pp. 898-903.
- Iverson, S.J., K.J. Frost, and S.L.C. Lang. 2002. Fat content and fatty acid composition of forage fish and invertebrates in Prince William Sound, Alaska: factors contributing to among and within species variability. Marine Ecol. Prog. Ser. 241:161-181.
- Kanamaru, S. 1964. The octopods off the coast of Rumoi and the biology of mizudako. Hokkaido Marine Research Centre Monthly Report 21(4&5):189-210.
- Kanamaru, S. and Y. Yamashita. 1967. The octopus mizudako. Part 1, Ch. 12. Investigations of the marine resources of Hokkaido and developments of the fishing industry, 1961 – 1965.
- Livingston, P.L., Aydin, K.Y., J. Boldt., S. Gaichas, J. Ianelli, J. Jurado-Molina, and I. Ortiz. 2003. Ecosystem Assessment of the Bering Sea/Aleutian Islands and Gulf of Alaska Management Regions. In: Stock assessment and fishery evaluation report for the groundfish resources or the Bering Sea/Aleutian Islands regions. North. Pac. Fish. Mgmt. Council, Anchorage, AK.
- Osako, M. and . Murata. 1983. Stock assessment of cephalopod resources in the northwestern Pacific. Pages55-144 In J.F. Caddy, ed. Advances in assessment of world cephalopod resources. FAO Fisheries Tech. Paper 231.
- Merrick, R.L., M.K. Chumbley, and G.V. Byrd, 1997. Diet diversity of Steller sea lions (*Eumetpias jubatus*) and their population decline in Alaska: a potential relationship. Can J. Fish. Aquat. Sci. 54: 1342-1348.
- Mottet, M. G. 1975. The fishery biology of *Octopus dofleini*. Washington Department of Fisheries Technical Report No. 16, 39 pp.
- National Research Council. 1998. Improving fish stock assessments. National Academy Press, Washington, D.C.
- Nesis, K.N. 1987. Cephalopods of the world. TFH Publications, Neptune City, NJ, USA. 351 pp.
- Paust, B.C. 1988. Fishing for octopus, a guide for commercial fishermen. Alaska Sea Grant Report No. 88-3, 48 pp.

- Paust, B.C. 1997. *Octopus dofleini*: Commercial fishery in Alaska (in) Lang, M. A. and F.G. Hochberg (eds.) (1997). Proceedings of the Workshop on the Fishery and market potential of octopus in California. Smithsonian Institutions: Washington. 192 p.
- Perez, M. 1990. Review of marine mammal population and prey information for Bering Sea ecosystem studies. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS F/NWC-186, 81 p.
- Perry, R.I., C.J. Walters, and J.A. Boutillier. 1999. A framework for providing scientific advice for the management of new and developing invertebrate fisheries. Rev. Fish Biology and Fisheries 9:125-150.
- Punt, A.E. 1995. The performance of a production-model management procedure. Fish. Res. 21:349-374.
- Rikhter, V.A. and V.N. Efanov, 1976. On one of the approaches to estimation of natural mortality of fish populations. ICNAF Res.Doc., 79/VI/8, 12p.
- Rooper, C.F.E., M.J. Sweeny, and C.E. Nauen. 1984. FAO Species catalogue vol. 3 cephalopods of the world. FAO Fisheries Synopsis No. 125, Vol. 3.
- Sato, R. and H. Hatanaka. 1983. A review of assessment of Japanese distant-water fisheries for cephalopods. Pages 145-203 In J.F. Caddy, ed. Advances in assessment of world cephalopod resources. FAO Fisheries Tech. Paper 231.
- Scheel, D. 2002. Characteristics of habitats used by *Enteroctopus dofleini* in Prince William Sound and Cook Inlet, Alaska. Marine Ecology 23(3):185-206.
- Sinclair, E.H. and T.K. Zeppelin. 2002. Seasonal and spatial differences in diet in the western stock of Steller sea lions (*Eumetopias jubatus*). J Mammology 83:973-990.
- Voight, J. R. and A. J. Grehan. 2000. Egg brooding by deep-sea octopuses in the North Pacific Ocean. Biological Bulletin 198: 94–100.
- Wakabayashi, K, R.G. Bakkala, and M. S. Alton. 1985. Methods of the U.S.-Japan demersal trawl surveys (in) R.G. Bakkala and K. Wakabayashi (eds.), Results of cooperative U.S. - Japan groundfish investigations in the Bering Sea during May - August 1979. International North Pacific Fisheries Commission Bulletin 44.
- Walters, G. E. Report to the fishing industry on the results of the 2004 Eastern Bering Sea Groundfish Survey. AFSC Process Report 2005-03. Feb 2005.
- Wilson, J.R. and A.H. Gorham. 1982. Alaska underutilized species Volume II: Octopus. Alaska Sea Grant Report 82-3. May 1982. 64 p.
- Yang, M.S. 1993. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-AFSC-22, 150 p.

D.21 Sharks

The species representatives for sharks are:

- | | |
|------------|--|
| Lamnidae: | Salmon shark (<i>Lamna ditropis</i>) |
| Squalidae: | Sleeper shark (<i>Somniosus pacificus</i>) |
| | Spiny dogfish (<i>Squalus acanthias</i>) |

D.21.1 Life History and General Distribution

Sharks of the order Squaliformes (which includes the two families Lamnidae and Squalidae) are the higher sharks with five gill slits and two dorsal fins. The Lamnidae are large, aplacental, viviparous (with small litters of one to four pups and embryos nourished by yolk sac, oophagy and/or intrauterine cannibalism), widely migrating sharks, which are highly aggressive predators (salmon and white sharks). The Lamnidae are partly warm-blooded; the heavy trunk muscles are warmer than water for greater power and efficiency. Salmon sharks are distributed epipelagically along the shelf (can be found in shallow waters) from

California through the Gulf of Alaska (GOA) (where they occur all year and are probably most abundant in our area), the Bering Sea and off Japan. In groundfish fishery and survey data, salmon sharks occur chiefly on outer shelf/upper slope areas in the Bering Sea, but near the coast to the outer shelf in the GOA, particularly near Kodiak Island. Salmon sharks are not commonly seen in Aleutian Islands. They are believed to eat primarily fish, including salmon, sculpins, and gadids, and can be up to 3 m in length.

The Pacific sleeper shark is distributed from California around the Pacific rim to Japan and in the Bering Sea principally on the outer shelf and upper slope (but has been observed nearshore), generally demersal (but also seen near surface). Other members of the Squalidae are aplacental viviparous, but fertilization and development of sleeper sharks are not known; adults are up to 8 m in length. They are omnivorous predators of flatfish, cephalopods, rockfish, crabs, seals, and salmon and may also prey on pinnipeds. In groundfish fishery and survey data, Pacific sleeper sharks occur chiefly on outer shelf/upper slope areas in the Bering Sea, but near coast to the outer shelf in the GOA, particularly near Kodiak Island.

Spiny dogfish are widely distributed through the Atlantic, Pacific, and Indian Oceans. In the north Pacific, spiny dogfish may be most abundant in the GOA; they also occur in the Bering Sea. Spiny dogfish are pelagic species found at the surface and to depths of 700 m but mostly at 200 m or less on the shelf and the neritic zone; they are often found in aggregations. Spiny dogfish are aplacental viviparous. Litter size is proportional to the size of the female and range from 2 to 23 pups, with 10 average. Gestation may be 22 to 24 months. Young are 24 to 30 cm at birth, with growth initially rapid, then slows dramatically. Maximum adult size is about 1.6 m and 10 kg; maximum age is 80+ years. Fifty percent of females are mature at 97 cm and 35 years old; 50 percent of males are mature at 74 cm and 21 years old. Females give birth in shallow coastal waters, usually in September through January. Spiny dogfish eat a wide variety of foods, including fish (smelts, herring, sand lance, and other small schooling fish), crustaceans (crabs, euphausiids, shrimp), and cephalopods (octopus). Tagging experiments indicate local indigenous populations in some areas and widely migrating groups in others. They may move inshore in summer and offshore in winter.

The approximate upper size limit of juvenile fish is unknown for salmon sharks and sleeper sharks; for spiny dogfish, it is 94 cm for females and 72 cm for males.

D.21.2 Fishery

Sharks are not a target of groundfish fisheries of the Bering Sea and Aleutian Islands (BSAI) or GOA. Shark bycatch has ranged from 187 to 1,603 mt per year in the BSAI from 1997 to 2008 and 409 to 1,603 mt per year in the GOA principally by pelagic trawl fishery for pollock, longline fisheries for Pacific cod and sablefish, and bottom trawl fisheries for pollock, flatfish, and cod. Almost all discarded. Little is known of shark biomass in the BSAI or GOA.

D.21.3 Relevant Trophic Information

Sharks are top level predators in the GOA. The only likely predator would be larger fish preying on young/small sharks. Spiny dogfish tend to be opportunistic and generalist feeders (Tribuzio et al. 2010), feeding more on invertebrates (such as shrimp and hermit crabs) when young and having a more varied diet when older, including fish species (forage fish, rockfish, and some salmon). Salmon shark feed primarily on squid and larger fish species (e.g. pollock and salmon). Pacific sleeper shark diet is less well known, a study by Sigler et al. (2006) found squid to be a major component, but also found flesh from grey whale and harbor seal in the stomachs. However, results were inconclusive as to whether the prey was scavenged or hunted.

D.21.4 Habitat and Biological Associations

Egg/Spawning: Salmon sharks and spiny dogfish are aplacental viviparous; reproductive strategy of sleeper sharks is not known. Spiny dogfish give birth in shallow coastal waters, while salmon sharks probably offshore and pelagic.

Juveniles and Adults: Spiny dogfish are widely dispersed throughout the water column on shelf in the GOA, and along outer shelf in the eastern Bering Sea; apparently not as commonly found in the Aleutian Islands and not commonly at depths greater than 200 m.

Salmon sharks are found throughout the GOA, but less common in the eastern Bering Sea and Aleutian Islands; epipelagic, primarily over shelf/slope waters in GOA, and outer shelf in the eastern Bering Sea.

Sleeper sharks are widely dispersed on shelf/upper slope in the GOA, and along outer shelf/upper slope only in the eastern Bering Sea; generally demersal, and may be less commonly found in the Aleutian Islands.

Habitat and Biological Associations: Sharks

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs								
Larvae								
Juveniles and Adults								
Salmon shark	U	fish (salmon, sculpins, and gadids)	all year	ICS, MCS, OCS, USP in GOA; OCS, USP in BSAI	P	NA	U	
Sleeper shark	U	omnivorous; flatfish, cephalopods, rockfish, crabs, seals, salmon, pinnipeds	all year	ICS, MCS, OCS, USP in GOA; OCS, USP in BSAI	D	U	U	
Spiny dogfish	80+ years	fish (smelts, herring, sand lance, and other small schooling fish), crustaceans (crabs, euphausiids, shrimp), and cephalopods (octopus)	all year	ICS, MCS, OCS in GOA; OCS in BSAI give birth ICS in fall/winter?	P	U	U	euhaline 4–16°C

D.21.5 Literature

- Allen, M.J., and G.B. Smith. 1988. Atlas and zoogeography of common fishes in the Bering Sea and Northeastern Pacific. U.S. Dep. Commerce, NOAA Tech. Rept. NMFS 66, 151 p.
- Eschmeyer, W.N., and E.S. Herald. 1983. A field guide to Pacific coast fishes, North America. Houghton Mifflin Co., Boston. 336 p.
- Fritz, L.W. 1996. Other species *In* Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions as Projected for 1997. North Pacific Fishery Management Council, 605 West 4th Avenue, Suite 306, Anchorage, AK 99501.
- Hart, J.L. 1973. Pacific fishes of Canada. Fisheries Res. Bd. Canada Bull. 180. Ottawa. 740 p.
- Sigler M.F., L. Hulbert, C. R. Lunsford, N. Thompson, K. Burek, G. Corry-Crowe, and A. Hiron. 2006. Diet of Pacific sleeper shark, a potential Steller sea lion predator, in the north-east Pacific Ocean. Fish Biol. 69:392-405.
- Tribuzio, C.A., K. Echave, C. Rodgveller, J. Heifetz, and K.J. Goldman. 2010. Assessment of the shark stocks in the Bering Sea. *In* Stock Assessment and Fishery Evaluation Report for the groundfish resources of the Eastern

Bering Sea and Aleutian Islands. Compiled by the Plan Team for the fishery resources of the Bering Sea and Aleutian Islands. North Pacific Fisheries Management Council, Anchorage, AK.

D.22 Sculpins (Cottidae)

The species representatives for sculpins are:

Yellow Irish lord (*Hemilepidotus jordani*)
Warty (*Myoxocephalus verrucosus*)
Bigmouth sculpin (*Hemitripterus bolini*)
Great sculpin (*Myoxocephalus polyacanthocephalus*)
Plain sculpin (*Myoxocephalus jaok*)

D.22.1 Life History and General Distribution

The Cottidae (sculpins) is a large circumboreal family of demersal fishes inhabiting a wide range of habitats in the north Pacific Ocean and Bering Sea. Most species live in shallow water or in tidepools, but some inhabit the deeper waters (to 1,000 m) of the continental shelf and slope. Most species do not attain a large size (generally 10 to 15 cm), but those that live on the continental shelf and are caught by fisheries can be 30 to 50 cm; the cabezon is the largest sculpin and can be as long as 100 cm. Most sculpins spawn in the winter. All species lay eggs, but in some genera, fertilization is internal. The female commonly lays demersal eggs amongst rocks where they are guarded by males. Egg incubation duration is unknown; larvae were found across broad areas of the shelf and slope, and were found all year-round, in ichthyoplankton collections from the southeast Bering Sea and Gulf of Alaska (GOA). Larvae exhibit diel vertical migration (near surface at night and at depth during the day). Sculpins generally eat small invertebrates (e.g., crabs, barnacles, mussels), but fish are included in the diet of larger species; larvae eat copepods.

Yellow Irish lords: distributed from subtidal areas near shore to the edge of the continental shelf (down to 200 m) throughout the Bering Sea, Aleutian Islands, and eastward into the GOA as far as Sitka, Alaska; up to 40 cm in length. 12 to 26 mm larvae collected in spring on the western GOA shelf.

Warty: distributed from rocky, intertidal areas to about 100 m depth on the middle continental shelf (most shallower than 50 m), from California (Monterey Bay) to Kamchatka; throughout the Bering Sea and GOA; rarely over 30 cm in length. Spawns masses of pink eggs in shallow water or intertidally. Larvae were 7 to 20 mm long in spring in the western GOA.

Bigmouth sculpin: distributed in deeper waters offshore, between about 100 m and 300 m in the Bering Sea, Aleutian Islands, and throughout the GOA; up to 70 cm in length.

Great sculpin: distributed from the intertidal to 200 m, but may be most common on sand and muddy/sand bottoms in moderate depths (50 to 100 m); up to 80 cm in length. Found throughout the Bering Sea, Aleutian Islands, and GOA, but may be less common east of Prince William Sound. *Myoxocephalus* spp. larvae ranged in length from 9 to 16 mm in spring ichthyoplankton collections in the western GOA.

Plain sculpin: distributed throughout the Bering Sea and GOA (not common in the Aleutian Islands) from intertidal areas to depths of about 100 m, but most common in shallow waters (less than 50 m); up to 50 cm in length. *Myoxocephalus* spp. larvae ranged in length from 9 to 16 mm in spring ichthyoplankton collections in the western GOA.

The approximate upper size limit of juvenile fish is unknown.

D.22.2 Fishery

Sculpin species are not a target of groundfish fisheries of the Bering Sea and Aleutian Islands (BSAI), but sculpin bycatch, which comprises almost 30 percent of other species complex, has ranged from 5,400 mt to 7,600 mt per year in the BSAI from 1998 through 2007. Bycatch occurs principally in bottom trawl fisheries for yellowfin sole, Pacific cod, walleye pollock, Atka mackerel, and flathead sole and the Pacific cod longline fishery; up to 6 percent of sculpin catch has been retained. Bycatch of sculpins ranges from 2 to 7 percent of total sculpin biomass in the BSAI (Ormseth and TenBrink 2010).

D.22.3 Relevant Trophic Information

Feed on bottom invertebrates (e.g., crabs, barnacles, mussels, and other molluscs); larger species eat fish.

D.22.4 Habitat and Biological Associations

Egg/Spawning: Lay demersal eggs in nests guarded by males; many species in rocky shallow waters near shore.

Larvae: Distributed pelagically and in neuston across broad areas of shelf and slope, but predominantly on inner and middle shelf; have been found all year-round.

Juveniles and Adults: Sculpins are demersal fish, and live in a broad range of habitats from rocky intertidal pools to muddy bottoms of the continental shelf, and rocky, upper slope areas. Most commercial bycatch occurs on middle and outer shelf areas used by bottom trawlers for Pacific cod and flatfish.

Habitat and Biological Associations: Sculpins

Stage - EFH Level	Duration or Age	Diet/Prey	Season/Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	U	NA	winter?	BCH, ICS (MCS, OCS?)	D	R (others?)	U	
Larvae	U	copepods	all year?	ICS, MCS, OCS, US	N, P	NA?	U	
Juveniles and Adults	U	bottom invertebrates (crabs, molluscs, barnacles) and small fish	all year	BCH, ICS, MCS, OCS, US	D	R, S, M, SM	U	

D.22.5 Literature

Allen, M.J., and G.B. Smith. 1988. Atlas and zoogeography of common fishes in the Bering Sea and Northeastern Pacific. U.S. Dep. Commerce, NOAA Tech. Rept. NMFS 66, 151 p.

Doyle, M.J., W.C. Rugen, and R.D. Brodeur. 1995. Neustonic ichthyoplankton in the western Gulf of Alaska during spring. Fishery Bulletin 93: 231-253.

Eschmyer, W.N., and E.S. Herald. 1983. A field guide to Pacific coast fishes, North America. Houghton Mifflin Co., Boston. 336 p.

Fritz, L.W. 1996. Other species *In Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions as Projected for 1997*. North Pacific Fishery Management Council, 605 West 4th Avenue, Suite 306, Anchorage, AK 99501.

Hart, J.L. 1973. Pacific fishes of Canada. Fisheries Res. Bd. Canada Bull. 180. Ottawa. 740 p.

- Kendall, A.W., Jr., and J.R. Dunn. 1985. Ichthyoplankton of the continental shelf near Kodiak Island, Alaska. U.S. Dep. Commerce, NOAA Tech. Rept NMFS 20, 89 p.
- Kendall, A.W., Jr., J.R. Dunn, and R.J. Wolotira, Jr. 1980. Zooplankton, including ichthyoplankton and decapod larvae, of the Kodiak shelf. NWAFC Processed Rept. 80-8, AFSC-NMFS, 7600 Sand Point Way, NE, Seattle, WA 98115. 393 p.
- Ormseth, O.A. and T. TenBrink. 2010. Bering Sea and Aleutian Islands Sculpins. *In* Stock Assessments and Fishery Evaluation Report of the Bering Sea/Aleutian Islands Regions. North Pacific Fishery Management Council, Anchorage, AK.
- Rugen, W.C. 1990. Spatial and temporal distribution of larval fish in the western Gulf of Alaska, with emphasis on the period of peak abundance of walleye pollock (*Theragra chalcogramma*) larvae. NWAFC Processed Rept 90-01, AFSC-NMFS, 7600 Sand Point Way, NE, Seattle, WA 98115. 162 p.
- Waldron, K.D. 1978. Ichthyoplankton of the eastern Bering Sea, 11 February-16 March 1978. REFM Report, AFSC, NMFS, 7600 Sand Point Way, NE, Seattle, WA 98115. 33 p.
- Waldron, K.D., and B.M. Vinter. 1978. Ichthyoplankton of the eastern Bering Sea. Final Report (RU 380), Environmental Assessment of the Alaskan continental shelf, REFM, AFSC, NMFS, 7600 Sand Point Way, NE, Seattle, WA 98115. 88 p.

D.23 Skates (Rajidae)

The species representatives for skates are:

- Alaska skate (*Bathyraja parmifera*)
- Aleutian skate (*Bathyraja aleutica*)
- Bering skate (*Bathyraja interrupta*)

D.23.1 Life History and General Distribution:

Skates (Rajidae) that occur in the Bering Sea and Aleutian Islands (BSAI) and Gulf of Alaska (GOA) are grouped into two genera: *Bathyraja* sp., or soft-nosed species (rostral cartilage slender and snout soft and flexible), and *Raja* sp., or hard-nosed species (rostral cartilage is thick making the snout rigid). Skates are oviparous; fertilization is internal and eggs (one to five or more in each case) are deposited in horny cases for incubation. Adults and juveniles are demersal, and feed on bottom invertebrates and fish. Adult Alaska skate are mostly distributed at a depth of 50 to 200 m on shelf in eastern Bering Sea and Aleutian Islands, and are less common in the GOA. The Aleutian skate is distributed throughout the eastern Bering Sea and Aleutian Islands, but is less common in GOA, mostly at a depth of 100 to 350 m. The Bering Skate is found throughout the eastern Bering Sea and GOA, and is less common in the Aleutian Islands, mostly at a depth of 100 to 350 m. Little is known of their habitat requirements for growth or reproduction, nor of any seasonal movements. BSAI skate biomass estimate more than doubled between 1982 and 1996 from bottom trawl survey; may have decreased in GOA and remained stable in the Aleutian Islands in the 1980s.

The approximate upper size limit of juvenile fish is unknown.

D.23.2 Fishery

Skates are not a target of BSAI groundfish fisheries, but are caught as bycatch (18,877 mt to 23,084 mt per year in the BSAI from 2000 through 2009) principally by the longline Pacific cod and bottom trawl pollock and flatfish fisheries. Retention rates ranged from 30 to 40 percent during 2003 through 2009. It is likely that only larger skates are retained. Incidental catch of skates in the BSAI in 2008 was 5 percent of the 2008 survey biomass estimate for skates.

D.23.3 Relevant Trophic Information

Skates feed on bottom invertebrates (crustaceans, molluscs, and polychaetes) and fish.

D.23.4 Habitat and Biological Associations

Egg/Spawning: Deposit eggs in horny cases on shelf and slope.

Juveniles and Adults: After hatching, juveniles probably remain in shelf and slope waters, but distribution is unknown. Adults found across wide areas of shelf and slope; surveys found most skates at depths less than 500 m in the GOA and eastern Bering Sea, but greater than 500 m in the Aleutian Islands. In the GOA, most skates are found between 4 °C and 7 °C, but data are limited.

Habitat and Biological Associations: Skates

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	U	NA	U	MCS, OCS, USP	D	U	U	
Larvae	NA	NA	NA	NA	NA	NA	NA	
Juveniles	U	invertebrates small fish	all year	MCS, OCS, USP	D	U	U	
Adults	U	invertebrates small fish	all year	MCS, OCS, USP	D	U	U	

D.23.5 Literature

- Allen, M.J., and G.B. Smith. 1988. Atlas and zoogeography of common fishes in the Bering Sea and Northeastern Pacific. U.S. Dep. Commerce, NOAA Tech. Rept. NMFS 66, 151 p.
- Eschmeyer, W.N., and E.S. Herald. 1983. A field guide to Pacific coast fishes, North America. Houghton Mifflin Co., Boston. 336 p.
- Hart, J.L. 1973. Pacific fishes of Canada. Fisheries Res. Bd. Canada Bull. 180. Ottawa. 740 p.
- Hoff, G.R. 2006. Investigations of a skate nursery area in the eastern Bering Sea. Final report to the NPRB, project 415. March 7, 2006.
- Hoff, G.R. 2007. Reproduction of the Alaska skate (*Bathyraja parmifera*) with regard to nursery sites, embryo development and predation. Ph.D. dissertation, University of Washington, Seattle.
- Hoff, G. R. 2008. A nursery site of the Alaska skate (*Bathyraja parmifera*) in the eastern Bering Sea. Fish. Bull., U.S. 106:233-244.
- Ormseth, O.A., B. Matta, and J. Hoff. 1996. Bering Sea and Aleutian Islands Skates. In Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions. North Pacific Fishery Management Council, 605 West 4th Avenue, Suite 306, Anchorage, AK 99501.
- Stevenson, D. E., J. W. Orr, G. R. Hoff, and J. D. McEachran. 2008. Emerging patterns of species richness, diversity, population density, and distribution in the skates (Rajidae) of Alaska. Fish. Bull., U.S. 106:24-39.
- Teshima, K., and T.K. Wilderbuer. 1990. Distribution and abundance of skates in the eastern Bering Sea, Aleutian Islands region, and the Gulf of Alaska. Pp. 257-267 in H.L. Pratt, Jr., S.H. Gruber, and T. Taniuchi (eds.), Elasmobranchs as living resources: advances in the biology, ecology, systematics and the status of the fisheries. U.S. Dep. Commerce, NOAA Technical Report 90.

D.24 Capelin (Osmeridae)

The species representative for capelin is *Mallotus villosus*.

D.24.1 Life History and General Distribution

Capelin are a short-lived marine (neritic), pelagic, filter-feeding schooling fish with a circumpolar distribution that includes the entire coastline of Alaska and the Bering Sea, and south along British Columbia to the Strait of Juan de Fuca. In the North Pacific, capelin grow to a maximum of 25 cm and 5 years of age. Capelin, which are a type of smelt, spawn at ages 2 to 4 in spring and summer (May through August; earlier in south, later in north) when about 11 to 17 cm on coarse sand, fine gravel beaches, especially in Norton Sound, northern Bristol Bay, along the Alaska Peninsula, and near Kodiak. Age at 50 percent maturity is 2 years. In terms of fecundity, each female has 10,000 to 15,000 eggs. Eggs hatch in 2 to 3 weeks. Most capelin die after spawning. Larvae and juveniles are distributed on the inner mid-shelf in summer (rarely found in waters deeper than about 200 m), and juveniles and adults congregate in fall in mid-shelf waters east of the Pribilof Islands, west of St. Matthew and St. Lawrence Islands, and north into the Gulf of Anadyr. Capelin are distributed along the outer shelf and under the ice edge in winter. Larvae, juveniles, and adults have diurnal vertical migrations following scattering layers; at night they are near surface and at depth during the day. Smelts are captured during trawl surveys, but their patchy distribution both in space and time reduces the validity of biomass estimates.

The approximate upper size limit of juvenile fish is 13 cm.

D.24.2 Fishery

Capelin are not a target species in groundfish fisheries of the Bering Sea and Aleutian Islands (BSAI) or Gulf of Alaska, but are caught as bycatch (up to several hundred tons per year in the 1990s) principally by the yellowfin sole trawl fishery in Kuskokwim and Togiak Bays in spring in the BSAI; almost all are discarded. Small local coastal fisheries occur in spring and summer.

D.24.3 Relevant Trophic Information

Capelin are important prey for marine birds and mammals as well as other fish. Surface feeding (e.g., gulls and kittiwakes), as well as shallow and deep diving piscivorous birds (e.g., murres and puffins) largely consume small schooling fishes such as capelin, eulachon, herring, sand lance, and juvenile pollock (Hunt et al. 1981a). Both pinnipeds (Steller sea lions, northern fur seals, harbor seals, and ice seals) and cetaceans (such as harbor porpoise, and fin, sei, humpback, and beluga whales) feed on smelts, which may provide an important seasonal food source near the ice-edge in winter, and as they assemble nearshore in spring to spawn (Frost and Lowry 1987; Wespestad 1987). Smelts are also found in the diets of some commercially exploited fish species, such as Pacific cod, walleye pollock, arrowtooth flounder, Pacific halibut, sablefish, Greenland turbot, and salmon throughout the North Pacific Ocean and the Bering Sea (Allen 1987; Yang 1993; Livingston, in prep.).

D.24.4 Habitat and Biological Associations

Egg/Spawning: Spawn adhesive eggs (about 1 mm in diameter) on fine gravel or coarse sand (0.5 to 1 mm grain size) beaches intertidally to depths of up to 10 m in May through July in Alaska (later to the north in Norton Sound). Hatching occurs in 2 to 3 weeks. Most intense spawning when coastal water temperatures are 5 to 9 °C.

Larvae: After hatching, 4 to 5 mm larvae remain on the middle-inner shelf in summer; distributed pelagically; centers of distribution are unknown, but have been found in high concentrations north of Unimak Island, in the western Gulf of Alaska, and around Kodiak Island.

Juveniles: In fall, juveniles are distributed pelagically in mid-shelf waters (50 to 100 m depth; -2 to 3 °C), and have been found in highest concentrations east of the Pribilof Islands, west of St. Matthew and St. Lawrence Islands, and north into the Gulf of Anadyr.

Adults: Found in pelagic schools in inner-mid shelf in spring-fall, feed along semi-permanent fronts separating inner, mid, and outer shelf regions (approximately 50 and 100 m). In winter, found in concentrations under ice-edge and along mid-outer shelf.

Habitat and Biological Associations: Capelin

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	2–3 weeks to hatch	na	May–August	BCH (to 10 m)	D	S, CB		5–9 °C peak spawning
Larvae	4–8 months?	copepods phytoplankton	summer/fall/ winter	ICS, MCS	N, P	U NA?	U	
Juveniles	1.5+ yrs up to age 2	copepods euphausiids	all year	ICS, MCS	P	U NA?	U F? ice edge in winter	
Adults	2 yrs ages 2–4+	copepods euphausiids polychaetes small fish	spawning (May–August) non-spawning (Sep–Apr)	BCH (to 10 m) ICS, MCS, OCS	D, SD P	S, CB, G NA?	F ice edge in winter	-2 – 3°C peak distributions in EBS?

D.24.5 Literature

- Allen, M.J. 1987. Demersal fish predators of pelagic forage fishes in the southeastern Bering Sea. Pp. 29-32 In Forage fishes of the southeastern Bering Sea. Proceedings of a Conference, November 1986, Anchorage, AK. U.S. Dept Interior, Minerals Management Service, OCS Study MMS 87-0017.
- Allen, M.J., and G.B. Smith. 1988. Atlas and zoogeography of common fishes in the Bering Sea and Northeastern Pacific. U.S. Dep. Commerce, NOAA Tech. Rept. NMFS 66, 151 p.
- Crawford, T.W. 1981. Vertebrate prey of *Phocoenoides dalli* (Dall's porpoise), associated with the Japanese high seas salmon fishery in the North Pacific Ocean. M.S. Thesis, Univ. Washington, Seattle, 72 p.
- Doyle, M.J., W.C. Rugen, and R.D. Brodeur. 1995. Neustonic ichthyoplankton in the western Gulf of Alaska during spring. Fishery Bulletin 93: 231-253.
- Eschmyer, W.N., and E.S. Herald. 1983. A field guide to Pacific coast fishes, North America. Houghton Mifflin Co., Boston. 336 p.
- Fritz, L.W. 1996. Other species In Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions as Projected for 1997. North Pacific Fishery Management Council, 605 West 4th Avenue, Suite 306, Anchorage, AK 99501.
- Fritz, L.W., V.G. Wespestad, and J.S. Collie. 1993. Distribution and abundance trends of forage fishes in the Bering Sea and Gulf of Alaska. Pp. 30-44 In Is It Food: Addressing marine mammal and seabird declines. Workshop Summary. Alaska Sea Grant College Program Rept. No. AK-SG-93-01, Univ. Alaska, Fairbanks, AK 99775-5040.

- Frost, K.J. and L. Lowry. 1987. Marine mammals and forage fishes in the southeastern Bering Sea. Pp. 11-18 In Forage fishes of the southeastern Bering Sea. Proceedings of a Conference, November 1986, Anchorage, AK. U.S. Dept Interior, Minerals Management Service, OCS Study MMS 87-0017.
- Hart, J.L. 1973. Pacific fishes of Canada. Fisheries Res. Bd. Canada Bull. 180. Ottawa. 740 p.
- Hunt, G.L., Jr., B. Burgeson, and G.A. Sanger. 1981a. Feeding ecology of seabirds of the eastern Bering Sea. Pp 629-647 In D.W. Hood and J.A. Calder (eds.), The Eastern Bering Sea Shelf: Oceanography and Resources, Vol. II. U.S. Dept. Commerce, NOAA, OCSEAP, Office of Marine Pollution Assessment, Univ. WA Press, Seattle, WA.
- Hunt, G.L., Jr., Z. Eppley, B. Burgeson, and R. Squibb. 1981b. Reproductive ecology, foods and foraging areas of seabirds nesting on the Pribilof Islands, 1975-79. Environmental Assessment of the Alaskan Continental Shelf, Final Reports of Principal Investigators, RU-83, U.S. Dept. Commerce, NOAA, OCSEAP, Boulder, CO.
- Kawakami, T. 1980. A review of sperm whale food. Sci. Rep. Whales Res. Inst. Tokyo 32: 199-218.
- Kendall, A.W., Jr., and J.R. Dunn. 1985. Ichthyoplankton of the continental shelf near Kodiak Island, Alaska. U.S. Dep. Commerce, NOAA Tech. Rept NMFS 20, 89 p.
- Kendall, A.W., Jr., J.R. Dunn, and R.J. Wolotira, Jr. 1980. Zooplankton, including ichthyoplankton and decapod larvae, of the Kodiak shelf. NWAFC Processed Rept. 80-8, AFSC-NMFS, 7600 Sand Point Way, NE, Seattle, WA 98115. 393 p.
- Livingston, P.A. Groundfish utilization of walleye pollock (*Theragra chalcogramma*), Pacific herring (*Clupea pallasii*) and capelin (*Mallotus villosus*) resources in the Gulf of Alaska. In preparation.
- Morris, B.F., M.S. Alton, and H.W. Braham. 1983. Living marine resources of the Gulf of Alaska: a resource assessment for the Gulf of Alaska/Cook Inlet Proposed Oil and Gas Lease Sale 88. U.S. Dept. Commerce, NOAA, NMFS.
- Murphy, E.C., R.H. Day, K.L. Oakley, A.A. Hoover. 1984. Dietary changes and poor reproductive performances in glaucous-winged gulls. Auk 101: 532-541.
- Naumenko, E.A. 1996. Distribution, biological condition, and abundance of capelin (*Mallotus villosus socialis*) in the Bering Sea. Pp. 237-256 In O.A. Mathisen and K.O. Coyle (eds.), Ecology of the Bering Sea: a review of Russian literature. Alaska Sea Grant Report No. 96-01, Alaska Sea Grant College Program, U. Alaska, Fairbanks, AK 99775-5040. 306 p.
- Ormseth, O.A., Conners, L., Guttormsen M., and J. Vollenweider. 2008. Forage fishes in the Gulf of Alaska. In: Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska Region. North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage, AK 99501.
- Pahlke, K.A. 1985. Preliminary studies of capelin *Mallotus villosus* in Alaska waters. Alaska Dept. Fish Game, Info. Leaf. 250, 64 p.
- Perez, M.A. and M.A. Bigg. 1986. Diet of northern fur seals, *Callorhinus ursinus*, off western North America. Fish. Bull., U.S. 84: 957-971.
- Pitcher, K.W. 1980. Food of the harbor seal, *Phoca vitulina richardsi*, in the Gulf of Alaska. Fish. Bull., U.S. 78: 544-549.
- Rugen, W.C. 1990. Spatial and temporal distribution of larval fish in the western Gulf of Alaska, with emphasis on the period of peak abundance of walleye pollock (*Theragra chalcogramma*) larvae. NWAFC Processed Rept 90-01, AFSC-NMFS, 7600 Sand Point Way, NE, Seattle, WA 98115. 162 p.
- Sigler, M. *et al.* 2006. Survey strategies for assessment of Bering Sea forage species. NPRB final report, project 401.
- Waldron, K.D. 1978. Ichthyoplankton of the eastern Bering Sea, 11 February-16 March 1978. REFM Report, AFSC, NMFS, 7600 Sand Point Way, NE, Seattle, WA 98115. 33 p.

- Waldron, K.D., and B.M. Vinter. 1978. Ichthyoplankton of the eastern Bering Sea. Final Report (RU 380), Environmental Assessment of the Alaskan continental shelf, REFM, AFSC, NMFS, 7600 Sand Point Way, NE, Seattle, WA 98115. 88 p.
- Wespestad, V.G. 1987. Population dynamics of Pacific herring (*Clupea palasii*), capelin (*Mallotus villosus*), and other coastal pelagic fishes in the eastern Bering Sea. Pp. 55-60 In Forage fishes of the southeastern Bering Sea. Proceedings of a Conference, November 1986, Anchorage, AK. U.S. Dept Interior, Minerals Management Service, OCS Study MMS 87-0017.
- Yang, M.S. 1993. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-AFSC-22. 150 pp.

D.25 Eulachon (Osmeridae)

The species representative for eulachon is the candlefish (*Thaleichthys pacificus*).

D.25.1 Life History and General Distribution

Eulachon are a short-lived anadromous, pelagic schooling fish distributed from the Pribilof Islands in the eastern Bering Sea, throughout the Gulf of Alaska (GOA), and south to California. Eulachon, which are a type of smelt, are consistently found pelagically in Shelikof Strait (hydroacoustic surveys in late winter to spring) and between Unimak Island and the Pribilof Islands (bycatch in groundfish trawl fisheries) from the middle shelf to over the slope. In the North Pacific, eulachon grow to a maximum of 23 cm and 5 years of age. Spawn at ages 3 to 5 in spring and early summer (April through June) when about 14 to 20 cm in rivers on coarse sandy bottom. Age at 50 percent maturity is 3 years. In terms of fecundity, each female has approximately 25,000 eggs. Eggs adhere to sand grains and other substrates on river bottom. Eggs hatch in 30 to 40 days at 4 to 7 °C. Most eulachon die after first spawning. Larvae drift out of rivers and develop at sea. Smelts are captured during trawl surveys, but their patchy distribution both in space and time reduces the validity of biomass estimates.

The approximate upper size limit of juvenile fish is 14 cm.

D.25.2 Fishery

Eulachon are not a target species in groundfish fisheries of the Bering Sea and Aleutian Islands or GOA, but are caught as bycatch (up to several hundred tons per year in the 1990s) principally by midwater pollock fisheries in Shelikof Strait (GOA), on the east side of Kodiak (GOA), and between the Pribilof Islands and Unimak Island on the outer continental shelf and slope (eastern Bering Sea); almost all are discarded. Small local coastal fisheries occur in spring and summer.

D.25.3 Relevant Trophic Information

Eulachon may be important prey for marine birds and mammals as well as other fish. Surface feeding (e.g., gulls and kittiwakes), as well as shallow and deep diving piscivorous birds (e.g., murre and puffins) largely consume small schooling fishes such as capelin, eulachon, herring, sand lance, and juvenile pollock (Hunt et al. 1981a; Sanger 1983). Both pinnipeds (Steller sea lions, northern fur seals, harbor seals, and ice seals) and cetaceans (such as harbor porpoise, and fin, sei, humpback, and beluga whales) feed on smelts, which may provide an important seasonal food source near the ice-edge in winter, and as they assemble nearshore in spring to spawn (Frost and Lowry 1987; Wespestad 1987). Smelts also comprise significant portions of the diets of some commercially exploited fish species, such as Pacific cod, walleye pollock, arrowtooth flounder, Pacific halibut, sablefish, Greenland turbot, and salmon throughout the North Pacific Ocean and the Bering Sea (Allen 1987; Yang 1993; Livingston, in prep.).

D.25.4 Habitat and Biological Associations

Egg/Spawning: Anadromous; return to spawn in spring (May through June) in rivers; demersal eggs adhere to bottom substrate (e.g., sand, cobble). Hatching occurs in 30 to 40 days.

Larvae: After hatching, 5 to 7 mm larvae drift out of river and develop pelagically in coastal marine waters; centers of distribution are unknown.

Juveniles and Adults: Distributed pelagically in mid-shelf to upper slope waters (50 to 1000 m water depth), and have been found in highest concentrations between the Pribilof Islands and Unimak Island on the outer shelf, and in Shelikof Strait east of the Pribilof Islands, west of St. Matthew and St. Lawrence Islands and north into the Gulf of Anadyr.

Habitat and Biological Associations: Eulachon (Candlefish)

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	30–40 days	na	April–June	rivers, FW	D	S (CB?)		4 – 8°C for egg development
Larvae	1–2 months?	copepods phytoplankton mysids, larvae	summer/fall	ICS ?	P?	U, NA?	U	
Juveniles	2.5+ yrs up to age 3	copepods euphausiids	all year	MCS, OCS, USP	P	U, NA?	U F?	
Adults	3 yrs ages 3–5+	copepods euphausiids	spawning (May–June) non-spawning (July–Apr)	rivers, FW MCS, OCS, USP	D P	S (CB?) NA?	F?	

D.25.5 Literature

- Allen, M.J. 1987. Demersal fish predators of pelagic forage fishes in the southeastern Bering Sea. Pp. 29-32 In Forage fishes of the southeastern Bering Sea. Proceedings of a Conference, November 1986, Anchorage, AK. U.S. Dept Interior, Minerals Management Service, OCS Study MMS 87-0017.
- Crawford, T.W. 1981. Vertebrate prey of *Phocoenoides dalli* (Dall's porpoise), associated with the Japanese high seas salmon fishery in the North Pacific Ocean. M.S. Thesis, Univ. Washington, Seattle, 72 p.
- Fritz, L.W., V.G. Wespestad, and J.S. Collie. 1993. Distribution and abundance trends of forage fishes in the Bering Sea and Gulf of Alaska. Pp. 30-44 In Is It Food: Addressing marine mammal and seabird declines. Workshop Summary. Alaska Sea Grant College Program Rept. No. AK-SG-93-01, Univ. Alaska, Fairbanks, AK 99775-5040.
- Frost, K.J. and L. Lowry. 1987. Marine mammals and forage fishes in the southeastern Bering Sea. Pp. 11-18 In Forage fishes of the southeastern Bering Sea. Proceedings of a Conference, November 1986, Anchorage, AK. U.S. Dept Interior, Minerals Management Service, OCS Study MMS 87-0017.
- Hart, J.L. 1973. Pacific fishes of Canada. Fisheries Res. Bd. Canada Bull. 180. Ottawa. 740 p.
- Hunt, G.L., Jr., B. Burgeson, and G.A. Sanger. 1981a. Feeding ecology of seabirds of the eastern Bering Sea. Pp 629-647 In D.W. Hood and J.A. Calder (eds.), The Eastern Bering Sea Shelf: Oceanography and Resources, Vol. II. U.S. Dept. Commerce, NOAA, OCSEAP, Office of Marine Pollution Assessment, Univ. WA Press, Seattle, WA.

- Hunt, G.L., Jr., Z. Eppley, B. Burgeson, and R. Squibb. 1981b. Reproductive ecology, foods and foraging areas of seabirds nesting on the Pribilof Islands, 1975-79. Environmental Assessment of the Alaskan Continental Shelf, Final Reports of Principal Investigators, RU-83, U.S. Dept. Commerce, NOAA, OCSEAP, Boulder, CO.
- Kawakami, T. 1980. A review of sperm whale food. Sci. Rep. Whales Res. Inst. Tokyo 32: 199-218.
- Livingston, P.A. Groundfish utilization of walleye pollock (*Theragra chalcogramma*), Pacific herring (*Clupea pallasii*) and capelin (*Mallotus villosus*) resources in the Gulf of Alaska. In preparation.
- Morris, B.F., M.S. Alton, and H.W. Braham. 1983. Living marine resources of the Gulf of Alaska: a resource assessment for the Gulf of Alaska/Cook Inlet Proposed Oil and Gas Lease Sale 88. U.S. Dept. Commerce, NOAA, NMFS.
- Perez, M.A. and M.A. Bigg. 1986. Diet of northern fur seals, *Callorhinus ursinus*, off western North America. Fish. Bull., U.S. 84: 957-971.
- Pitcher, K.W. 1980. Food of the harbor seal, *Phoca vitulina richardsi*, in the Gulf of Alaska. Fish. Bull., U.S. 78: 544-549.
- Sanger, G.A. 1983. Diets and food web relationships of seabirds in the Gulf of Alaska and adjacent marine regions. Outer Continental Shelf Environmental Assessment Program, Final Reports of Principal Investigators 45: 631-771.
- Wespestad, V.G. 1987. Population dynamics of Pacific herring (*Clupea palasii*), capelin (*Mallotus villosus*), and other coastal pelagic fishes in the eastern Bering Sea. Pp. 55-60 In Forage fishes of the southeastern Bering Sea. Proceedings of a Conference, November 1986, Anchorage, AK. U.S. Dept Interior, Minerals Management Service, OCS Study MMS 87-0017.
- Yang, M.S. 1993. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-AFSC-22. 150 pp. December 11, 2006

Maps of Essential Fish Habitat

Maps of essential fish habitat are included in this section for the following species (life stage is indicated in parentheses):

Figures E-1 to E-3	Walleye pollock (eggs, larvae, late juveniles/adults)
Figures E-4 and E-5	Pacific cod (larvae, late juveniles/adults)
Figures E-6 and E-7	Sablefish (larvae, late juveniles/adults)
Figure E-8	Yellowfin sole (late juveniles/adults)
Figures E-9 to E-11	Greenland turbot (eggs, larvae, late juveniles/adults)
Figure E-12	Arrowtooth flounder (late juveniles/adults)
Figure E-13	Kamchatka flounder (late juveniles/adults)
Figures E-14 and E-15	Northern rock sole (larvae, late juveniles/adults)
Figures E-16 and E-17	Alaska Plaice (eggs, late juveniles/adults)
Figure E-18	Rex sole (late juveniles/adults)
Figure E-19	Dover sole (late juveniles/adults)
Figures E-20 to E-22	Flathead sole (eggs, larvae, late juveniles/adults)
Figure E-23	Rockfish (larvae)
Figure E-24	Pacific ocean perch (late juveniles/adults)
Figure E-25	Northern rockfish (adults)
Figure E-26	Shortraker rockfish (adults)
Figure E-27	Blackspotted and rougheye rockfish (late juveniles/adults)
Figure E-28	Dusky rockfish (adults)
Figure E-29	Thornyhead rockfish (late juveniles/adults)
Figures E-30 to E-32	Atka mackerel (eggs, larvae, adults)
Figure E-33	Squid species (late juveniles/adults)
Figure E-34	Sculpin (adults)
Figure E-35 and E-36	Skates (eggs, adults)

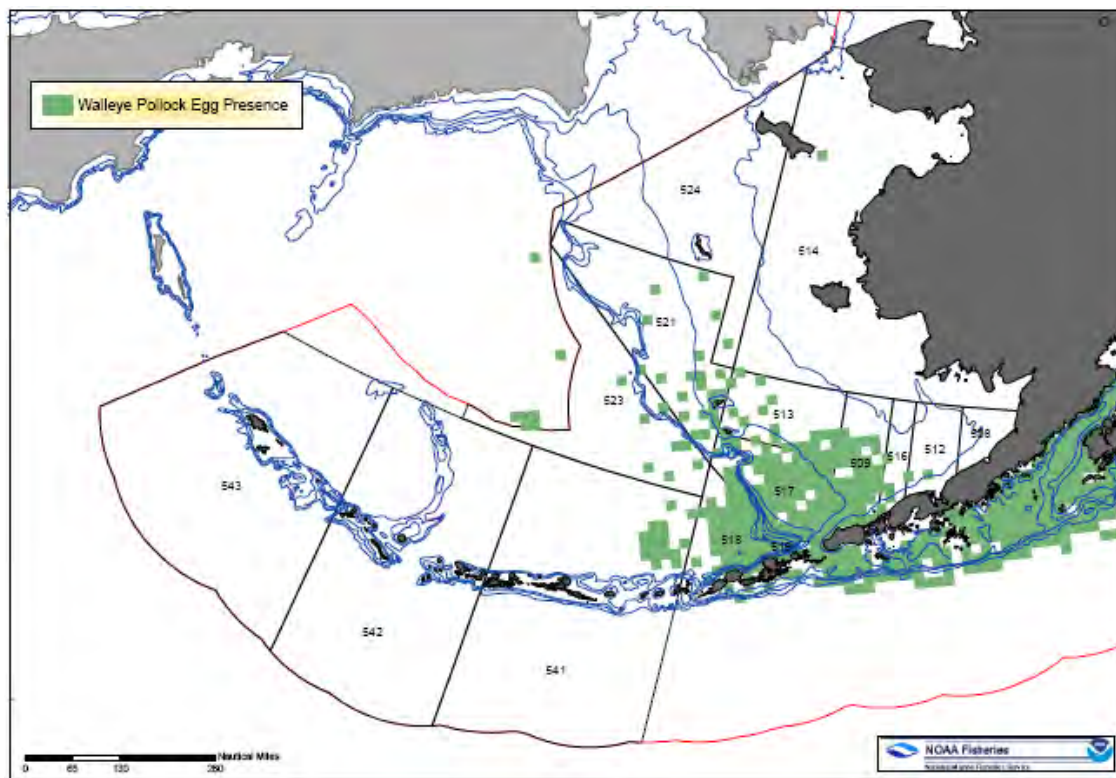
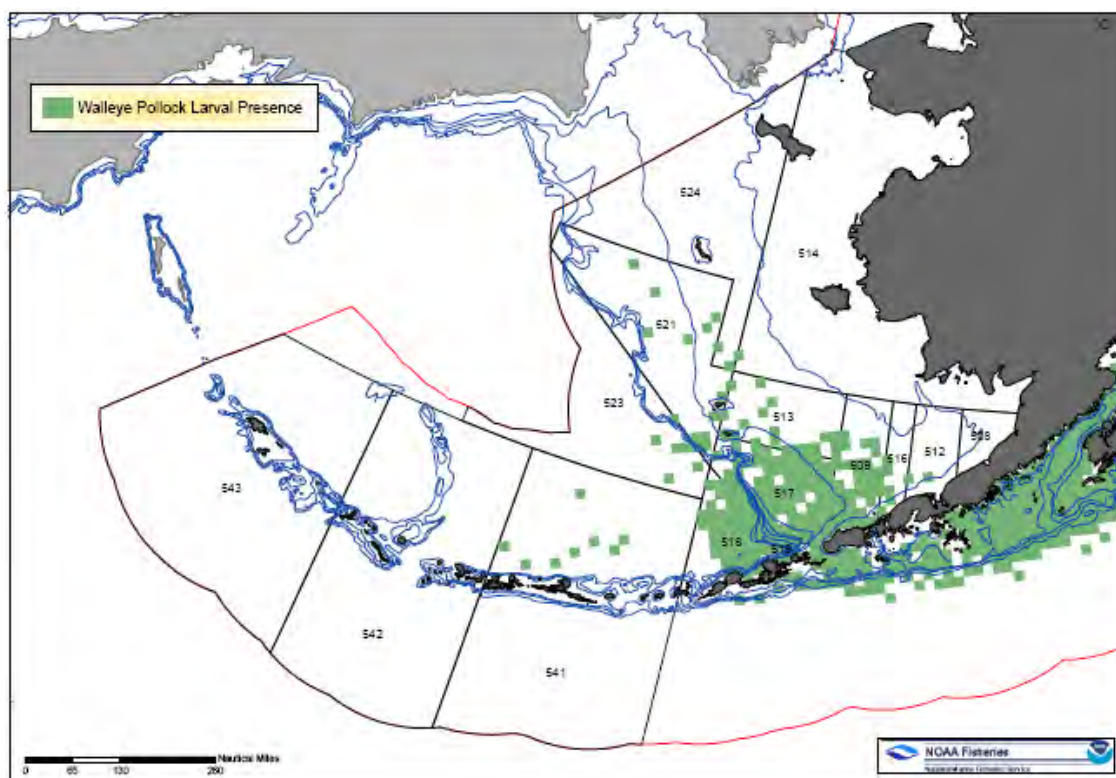
Figure 0-1 EFH Distribution - BSAI Walleye Pollock (Eggs)**Figure 0-2 EFH Distribution - BSAI Walleye Pollock (Larvae)**

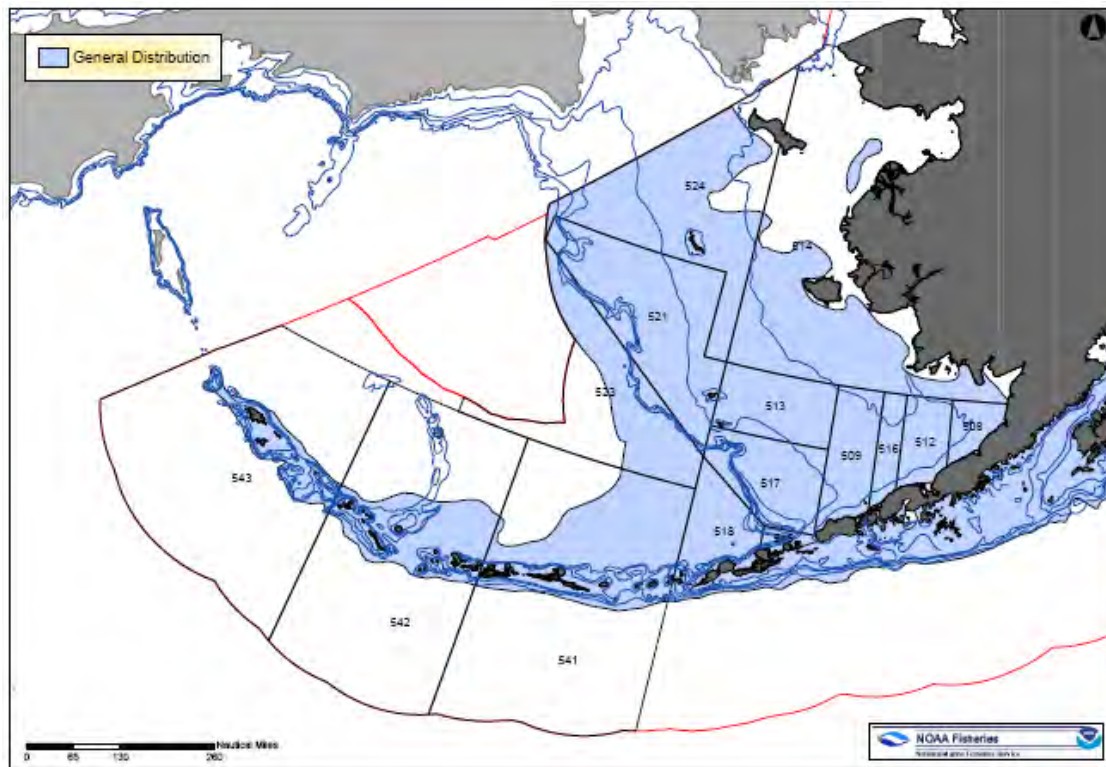
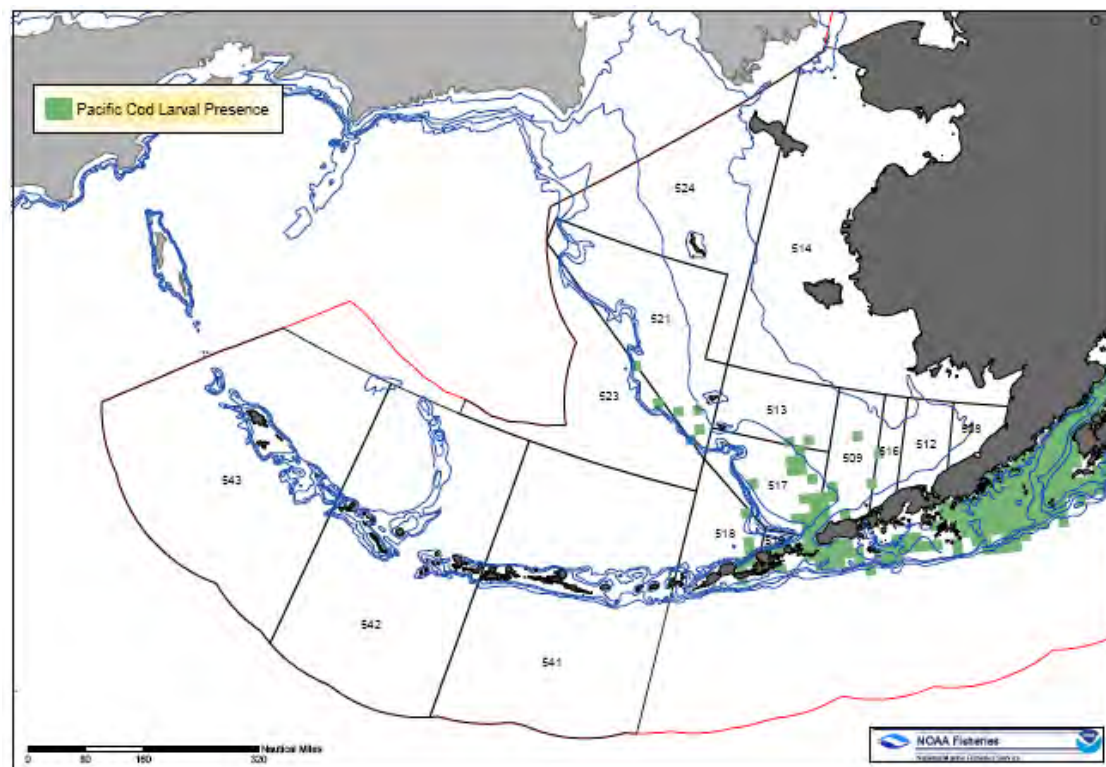
Figure 0-3 EFH Distribution - BSAI Walleye Pollock (Late Juveniles/Adults)**Figure 0-4 EFH Distribution - BSAI Pacific Cod (Larvae)**

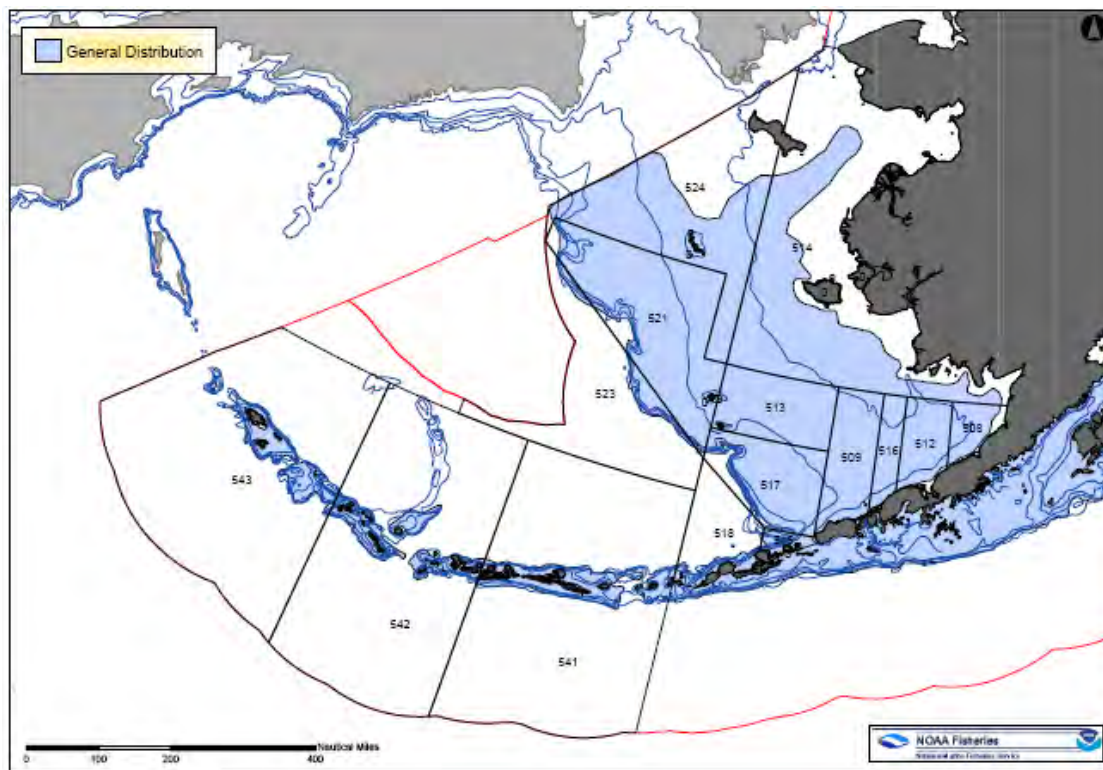
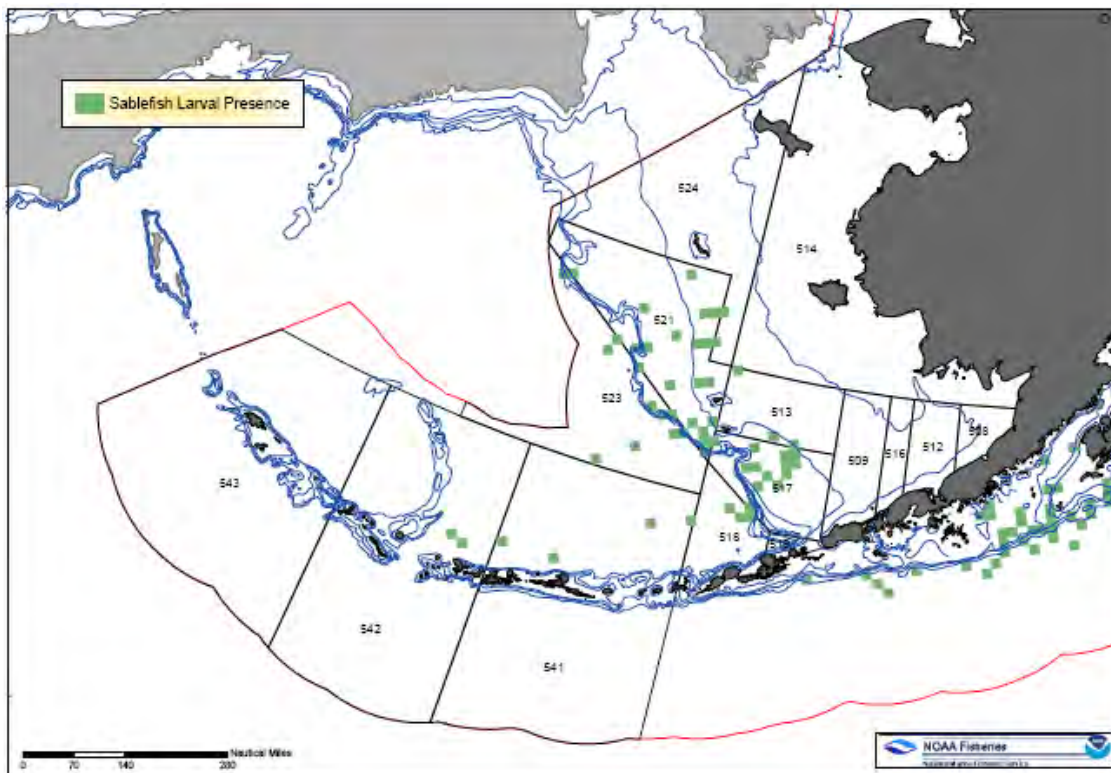
Figure 0-5 EFH Distribution - BSAI Pacific Cod (Late Juveniles/Adults)**Figure 0-6 EFH Distribution - BSAI Sablefish (Larvae)**

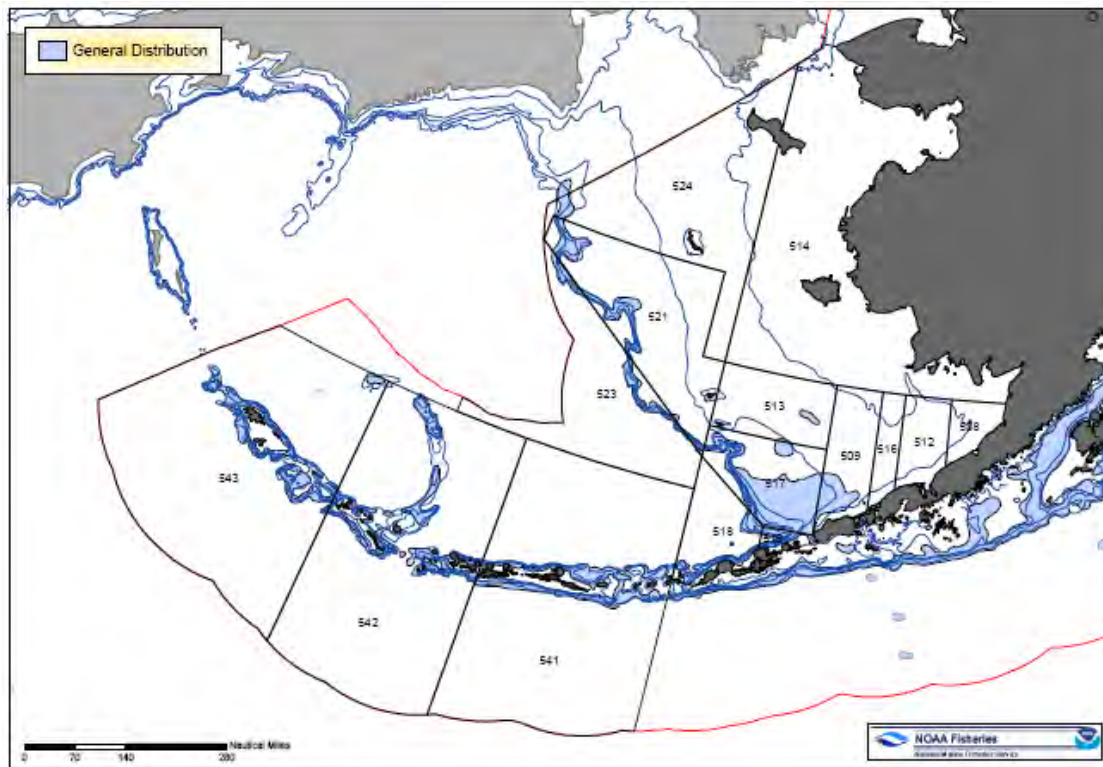
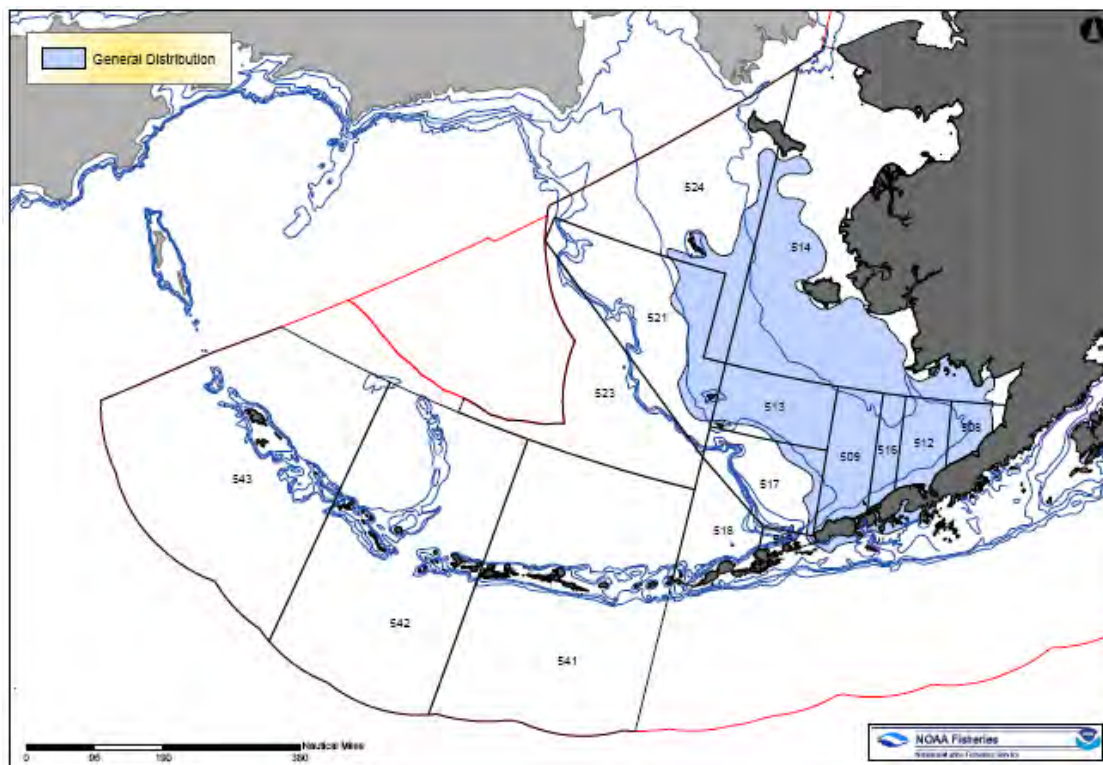
Figure 0-7 EFH Distribution - BSAI Sablefish (Late Juvenile/Adults)**Figure 0-8 EFH Distribution - BSAI Yellowfin Sole (Late Juveniles/Adults)**

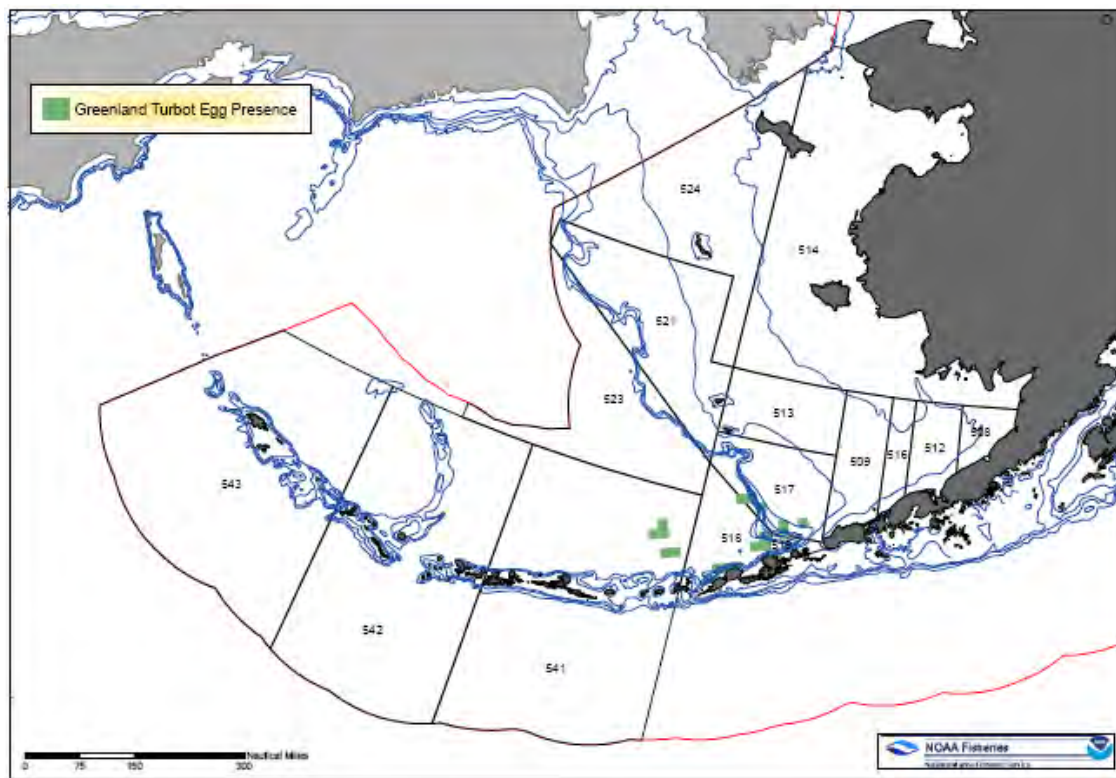
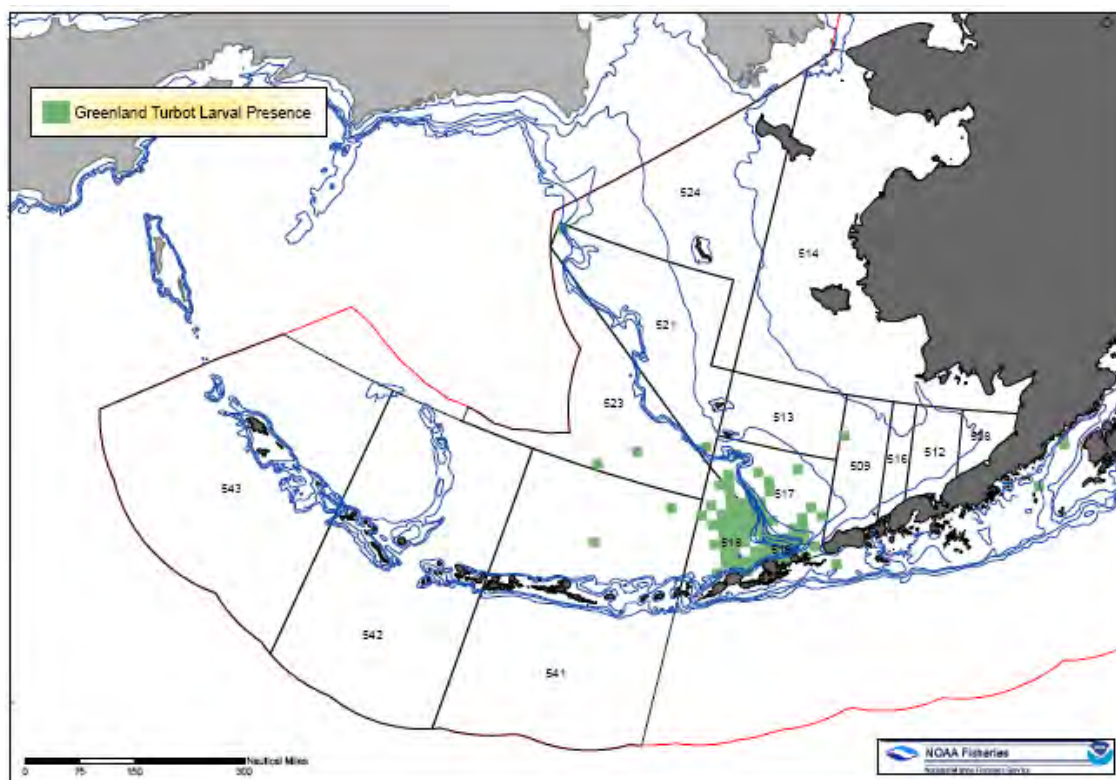
Figure 0-9 EFH Distribution - BSAI Greenland Turbot (Eggs)**Figure 0-10 EFH Distribution - BSAI Greenland Turbot (Larvae)**

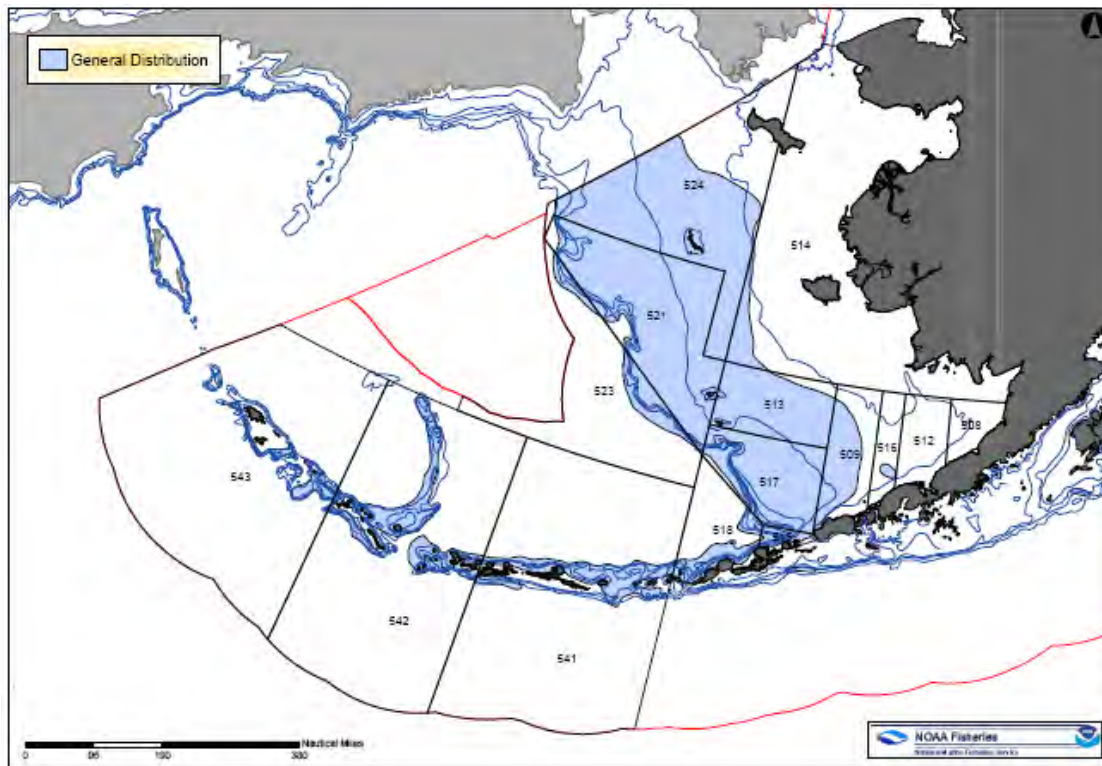
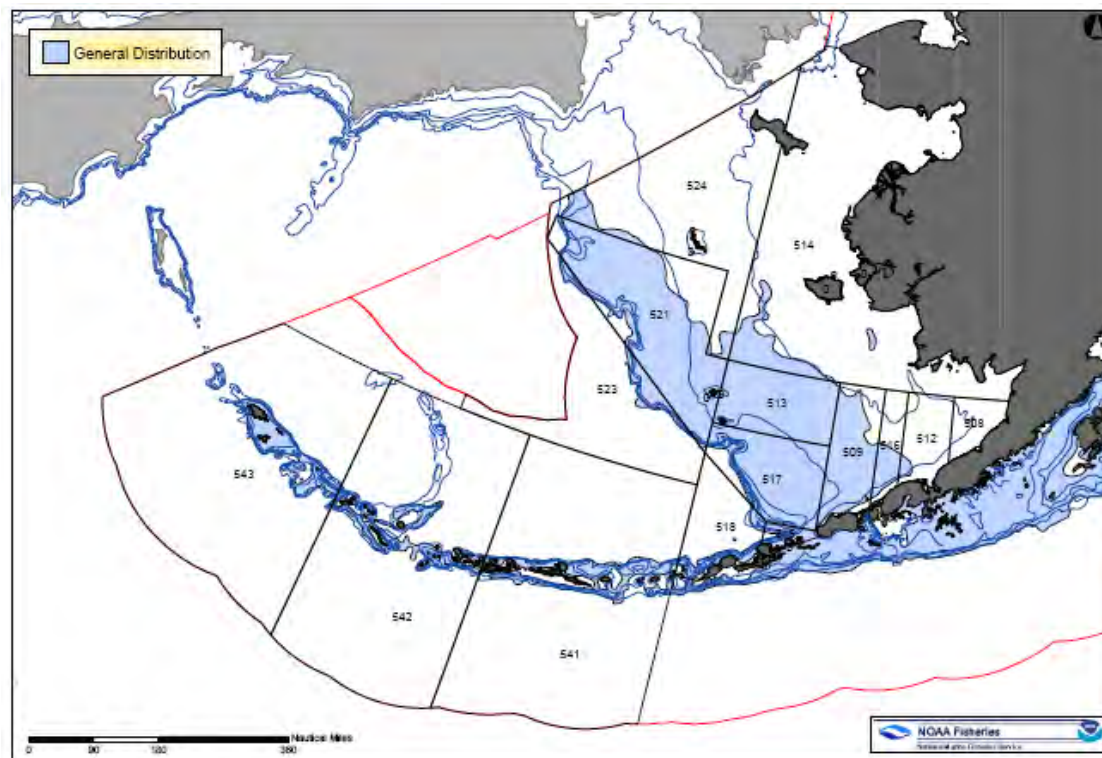
Figure 0-11 EFH Distribution - BSAI Greenland Turbot (Late Juveniles/Adults)**Figure 0-12 EFH Distribution - BSAI Arrowtooth Flounder (Late Juveniles/Adults)**

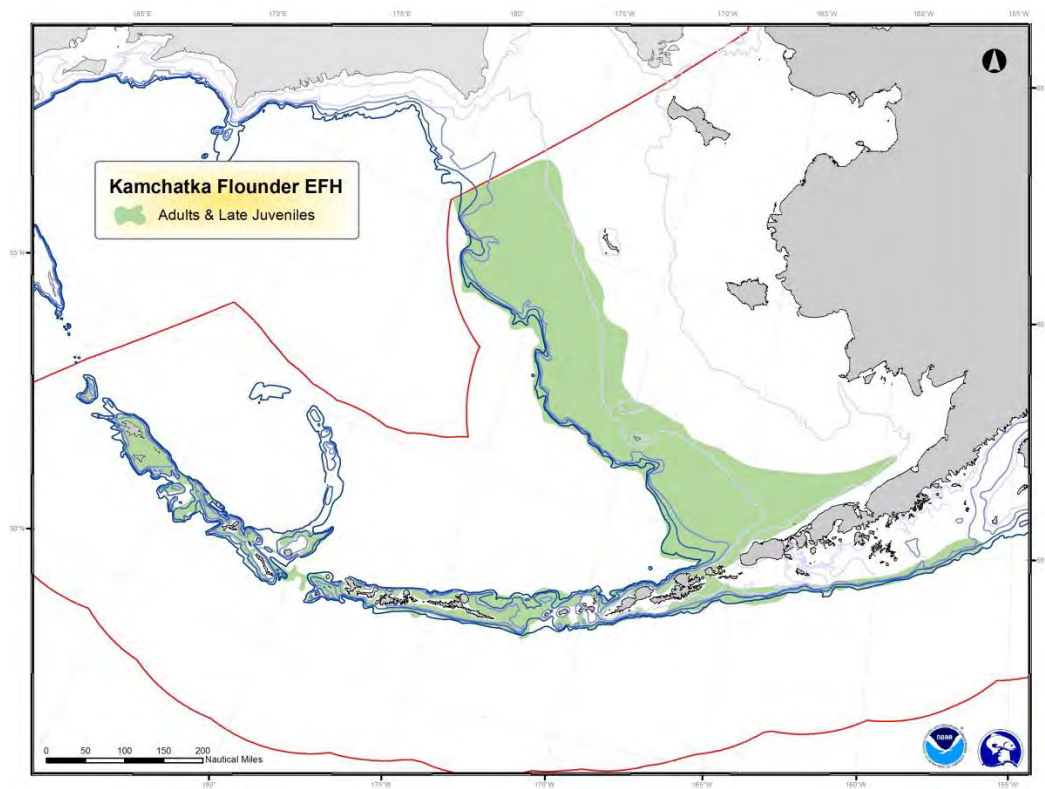
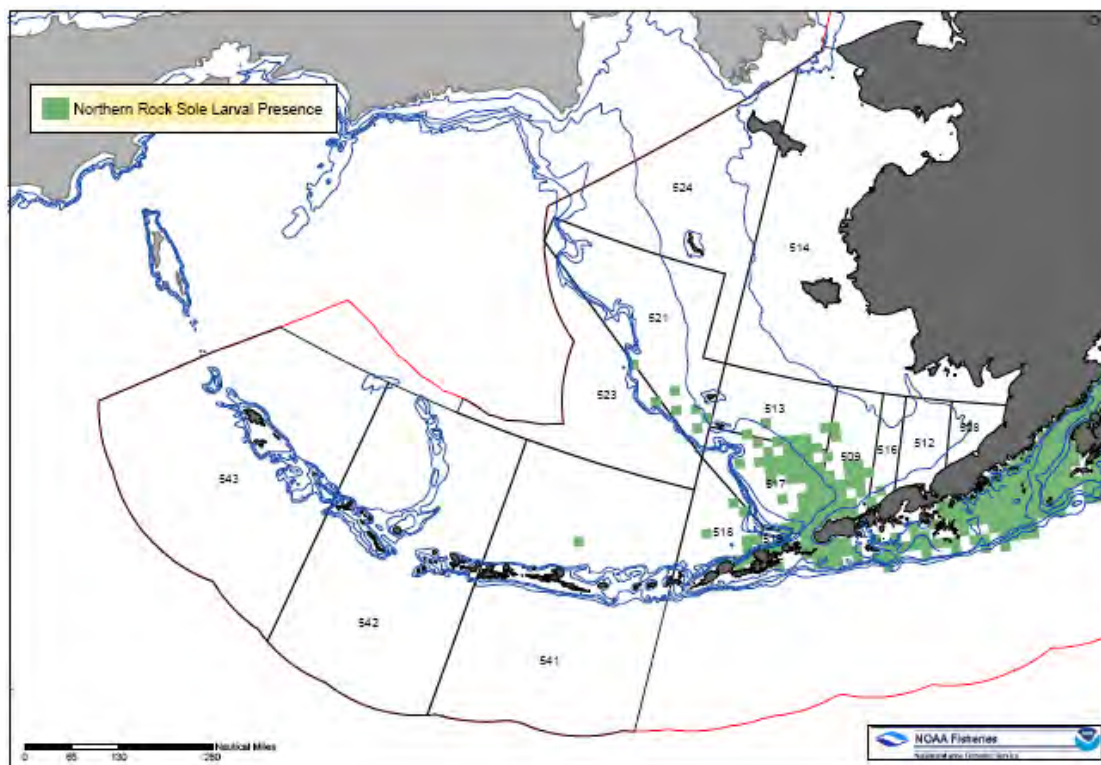
Figure 0-13 EFH Distribution - BSAI Kamchatka Flounder (Late Juveniles/Adults)**Figure 0-14 EFH Distribution - BSAI Northern Rock Sole (Larvae)**

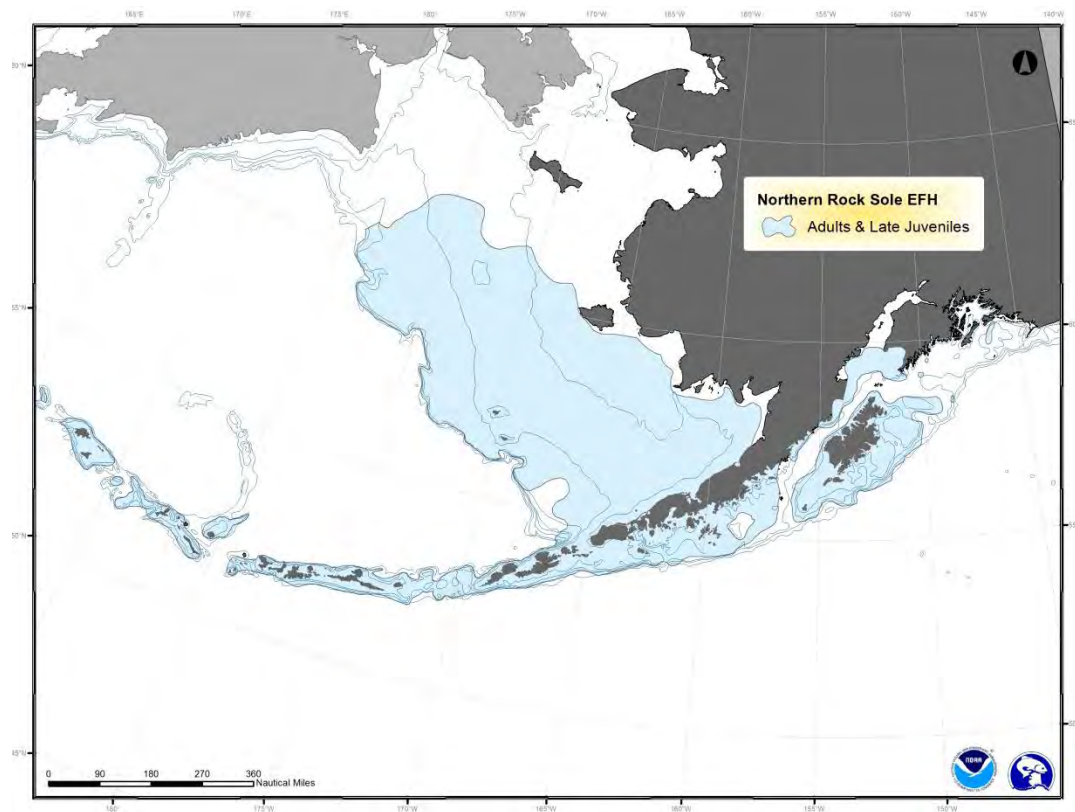
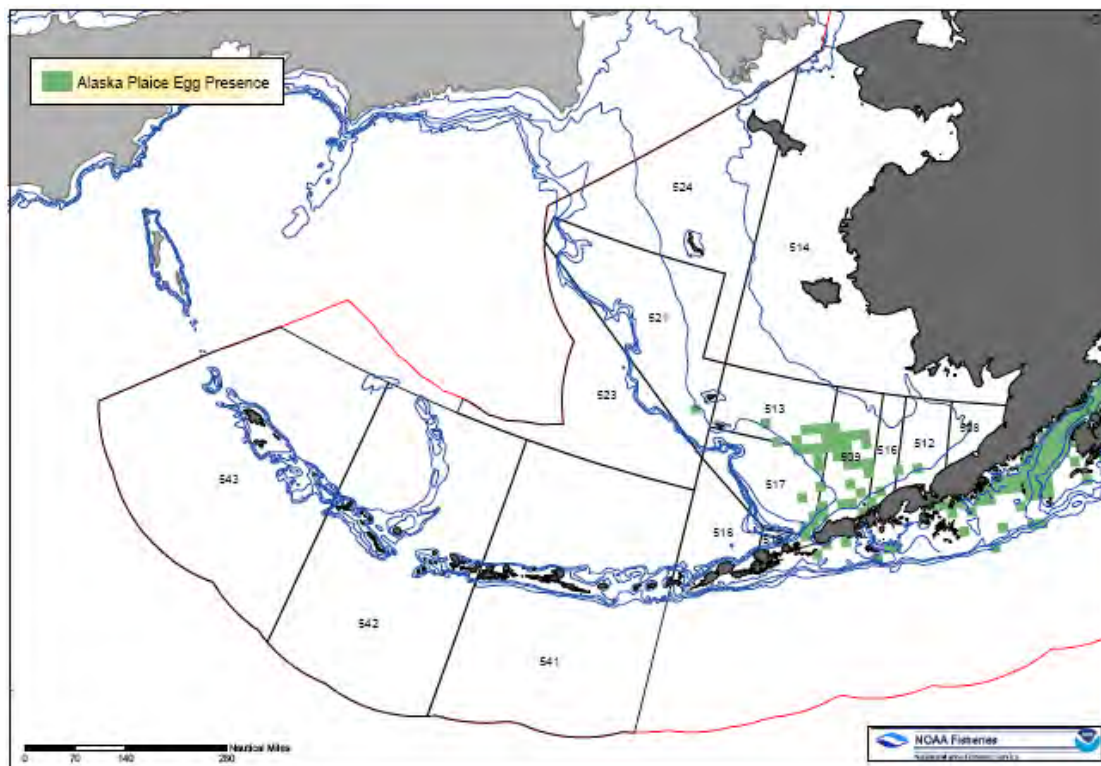
Figure 0-15 EFH Distribution - BSAI Northern Rock Sole (Late Juveniles/Adults)**Figure 0-16 EFH Distribution - BSAI Alaska Plaice (Eggs)**

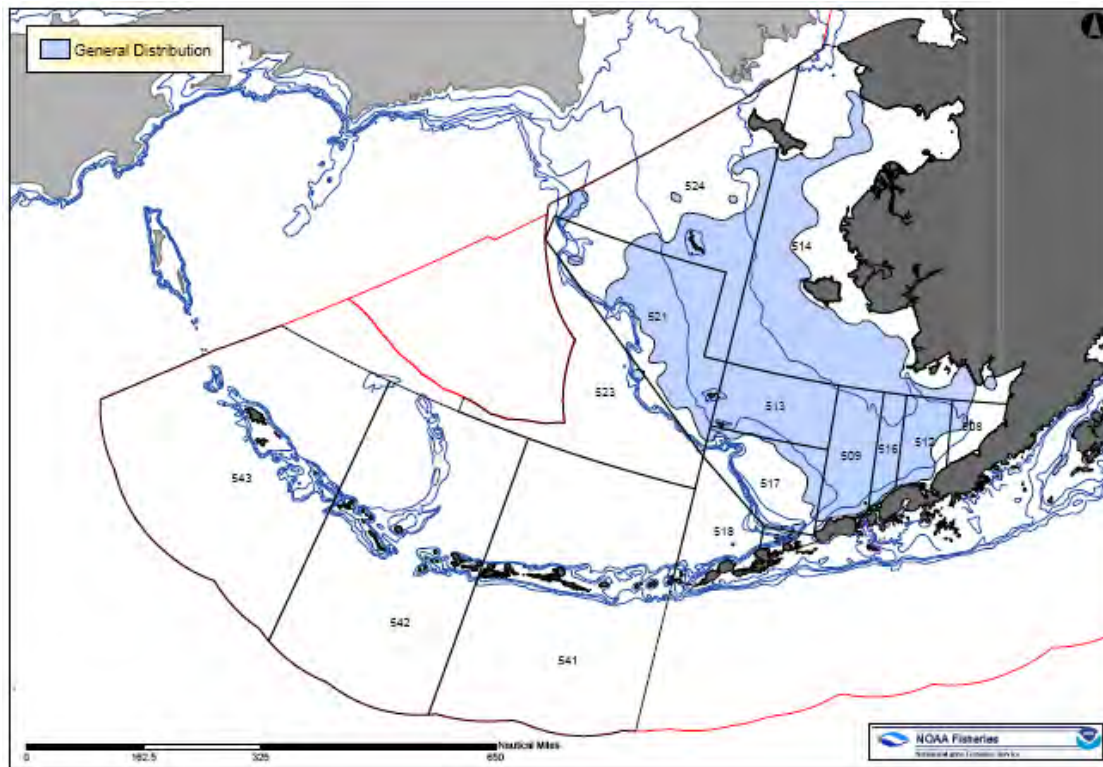
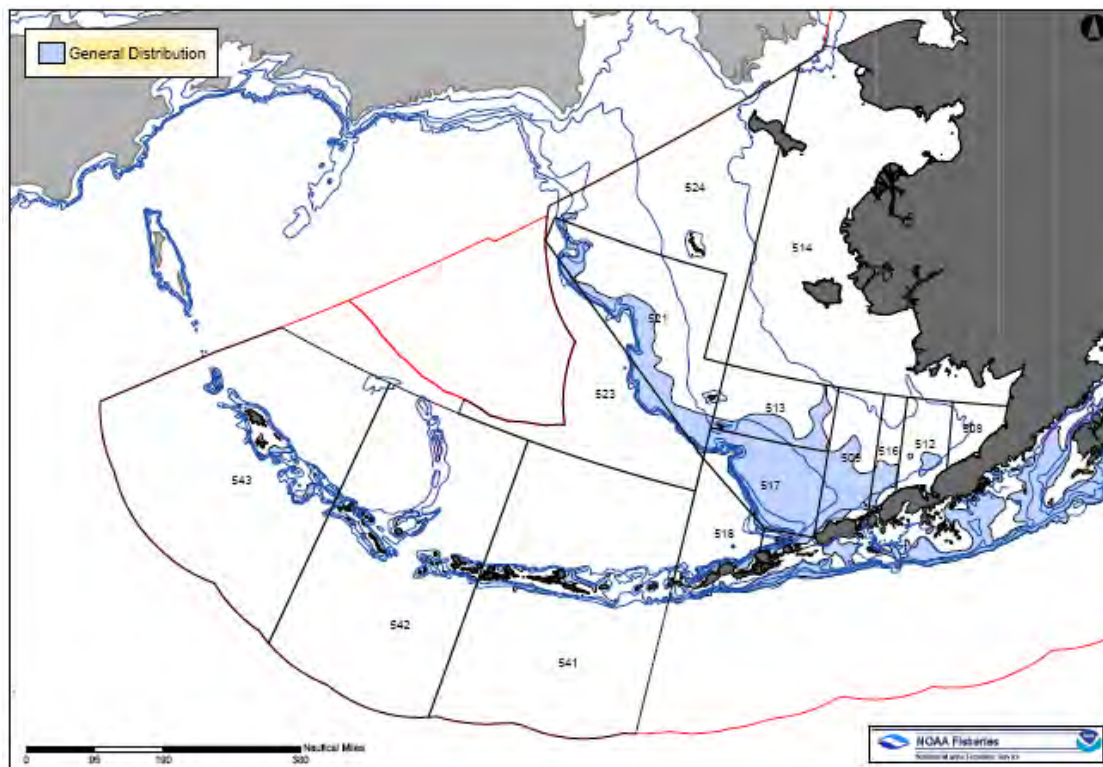
Figure 0-17 EFH Distribution - BSAI Alaska Plaice (Late Juveniles/Adults)**Figure 0-18 EFH Distribution - BSAI Rex Sole (Late Juveniles/Adults)**

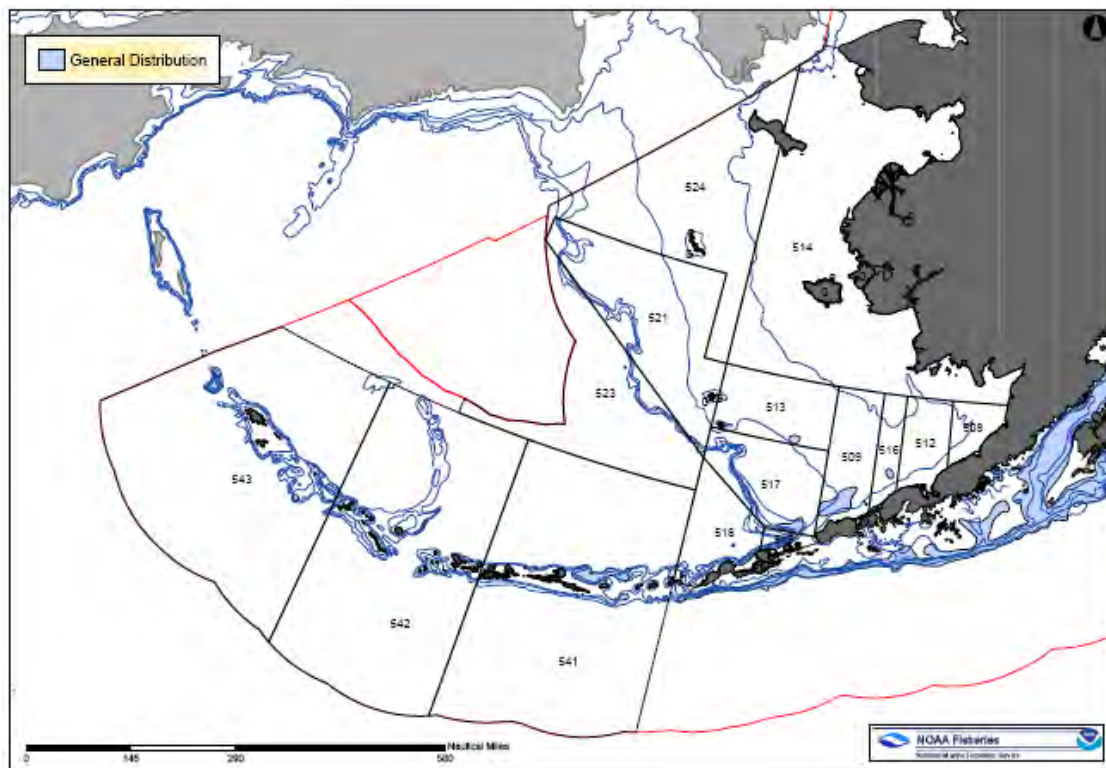
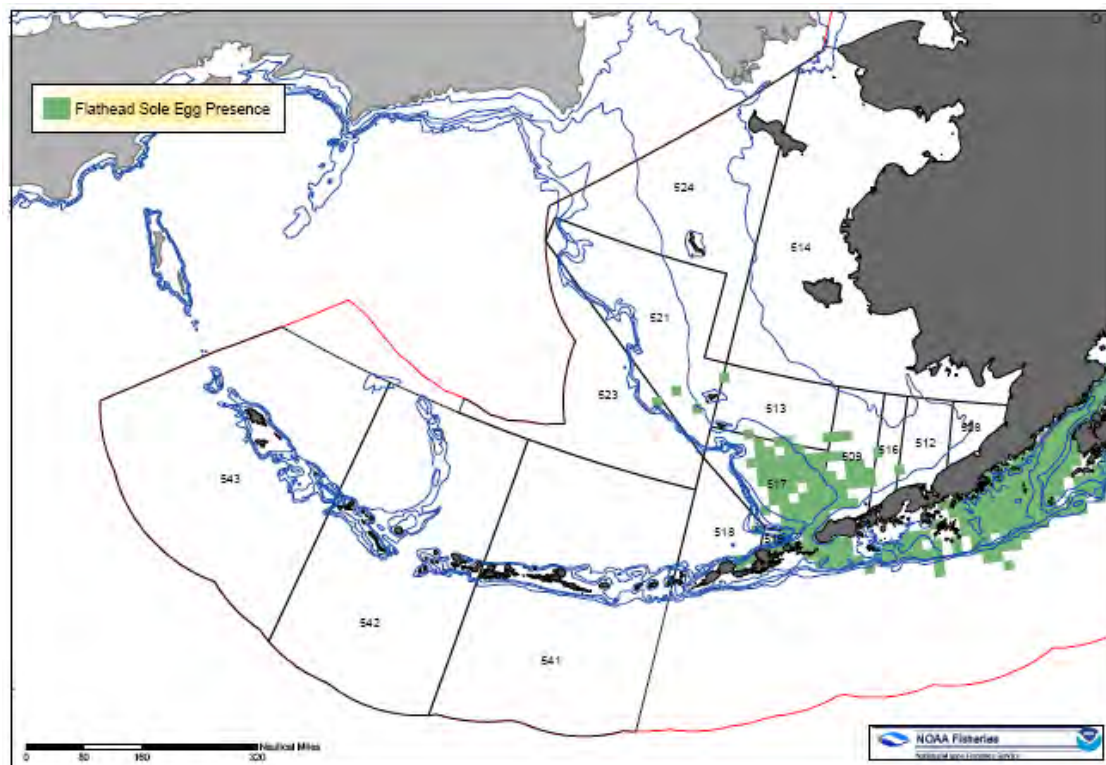
Figure 0-19 EFH Distribution - BSAI Dover Sole (Late Juveniles/Adults)**Figure 0-20 EFH Distribution - BSAI Flathead Sole (Eggs)**

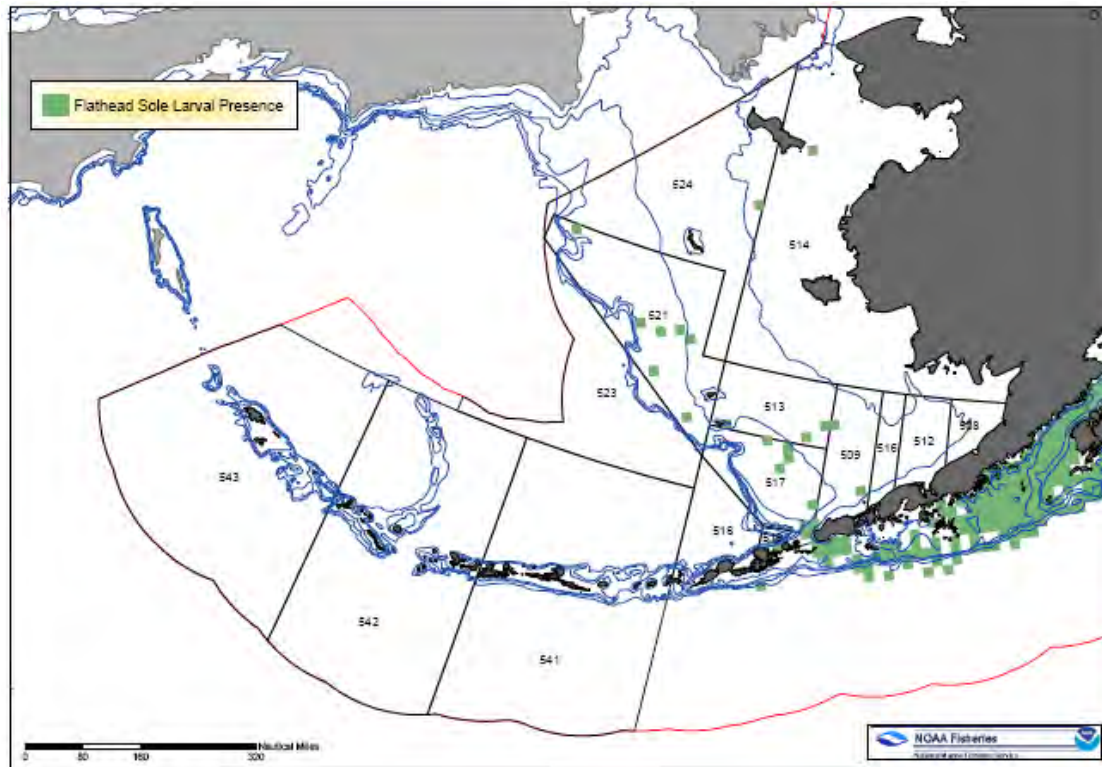
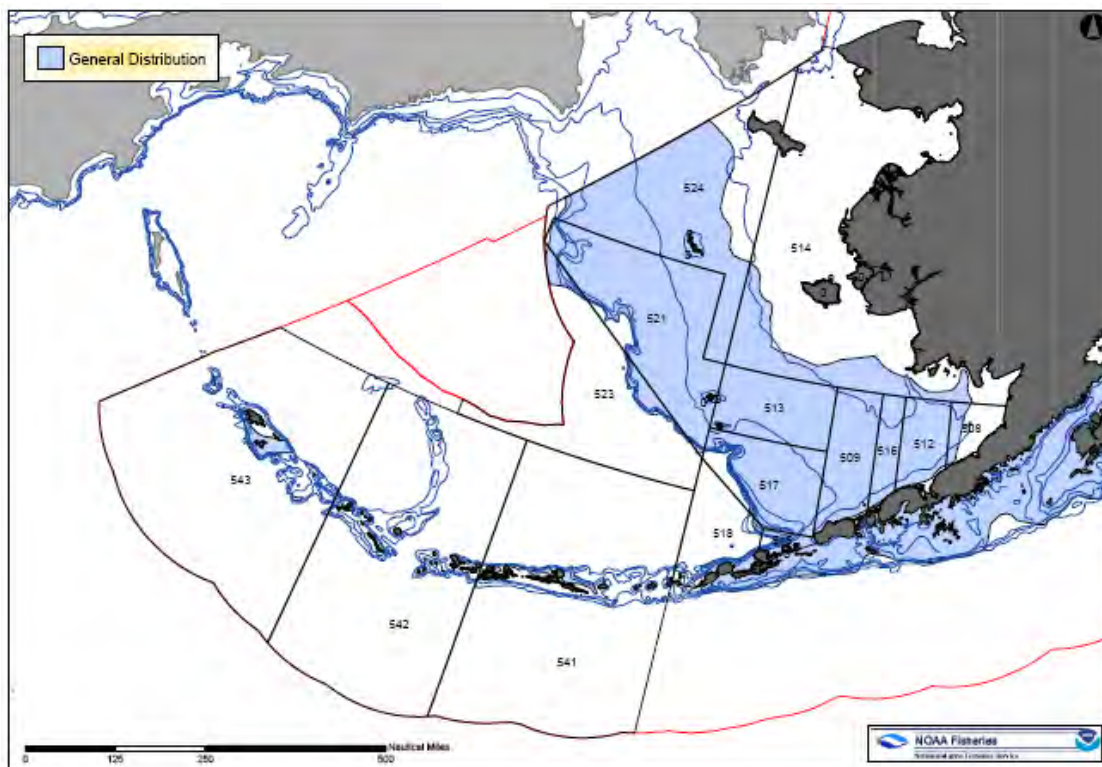
Figure 0-21 EFH Distribution - BSAI Flathead Sole (Larvae)**Figure 0-22 EFH Distribution - BSAI Flathead Sole (Late Juveniles/Adults)**

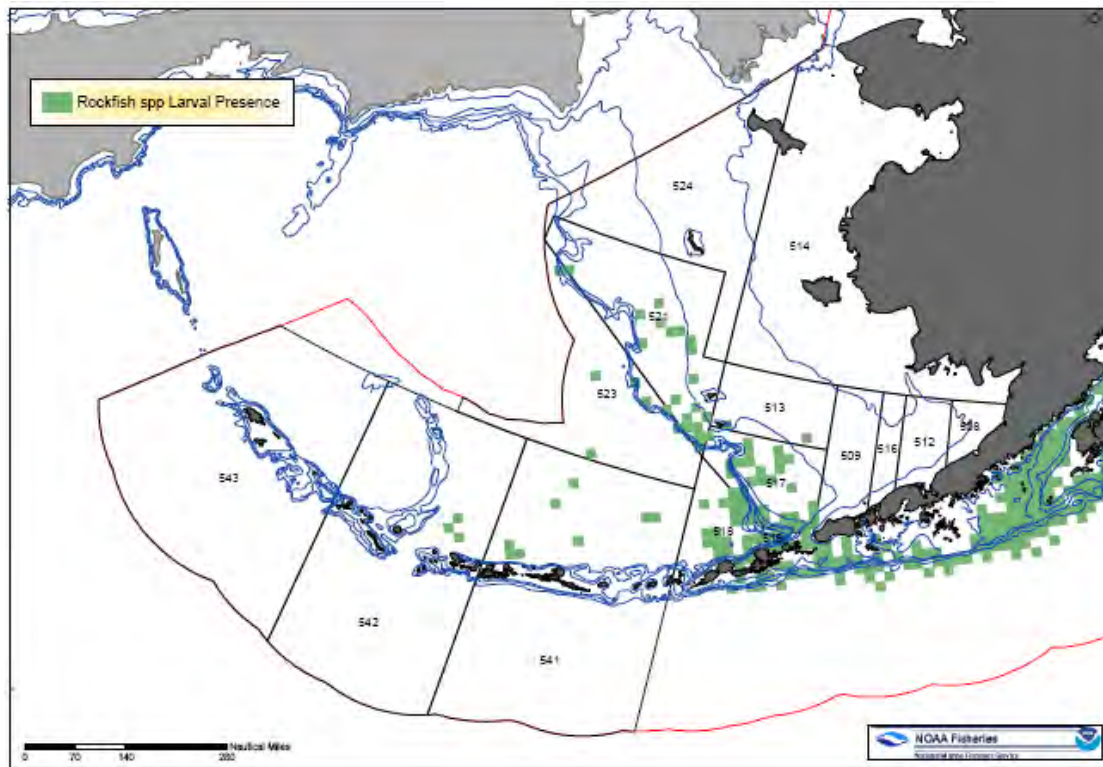
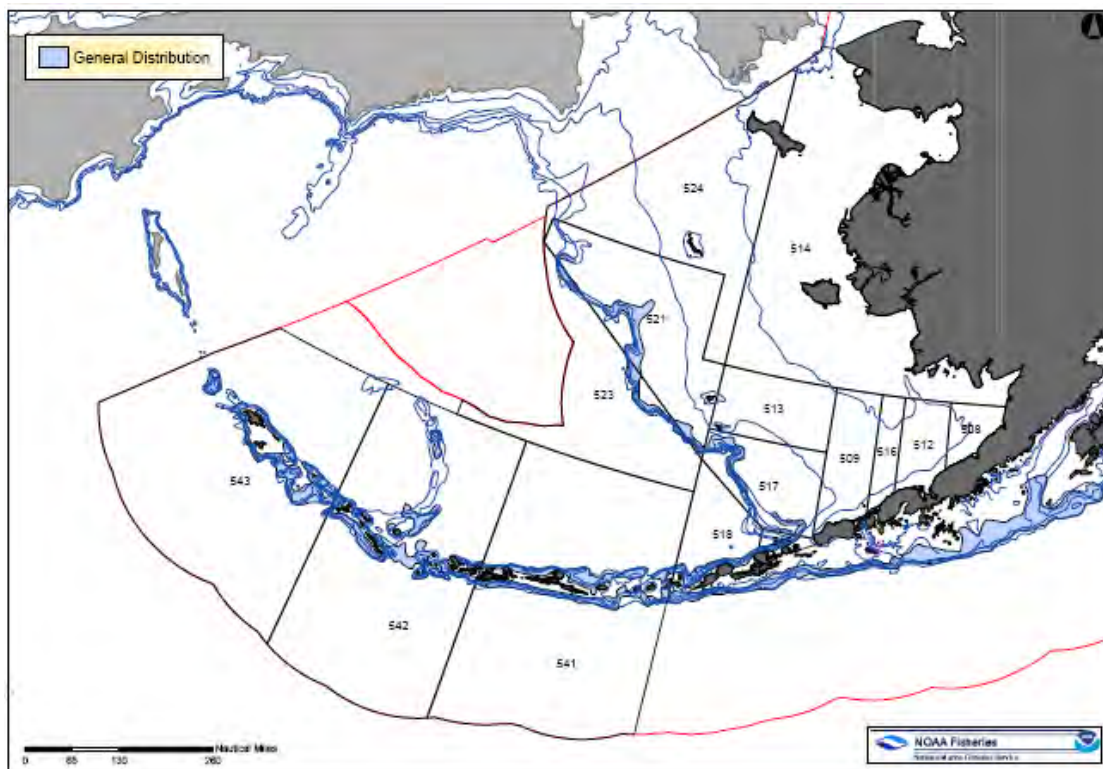
Figure 0-23 EFH Distribution - BSAI Rockfish (Larvae)**Figure 0-24 EFH Distribution - BSAI Pacific Ocean Perch (Late Juveniles/Adults)**

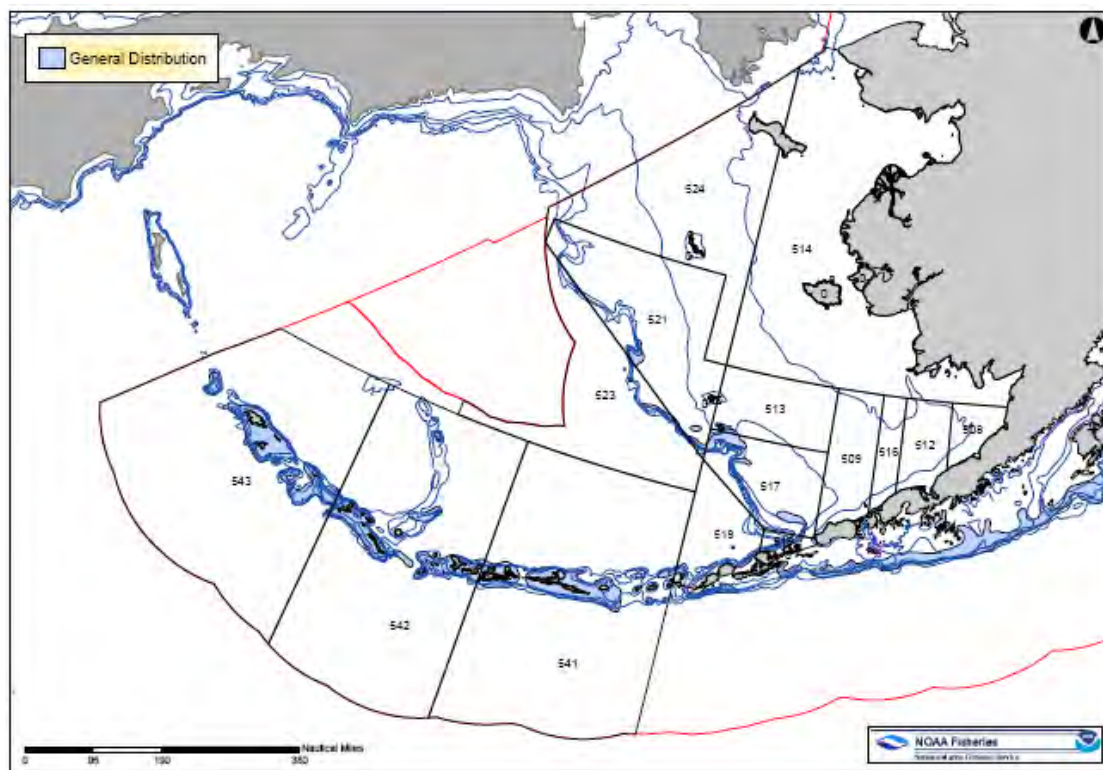
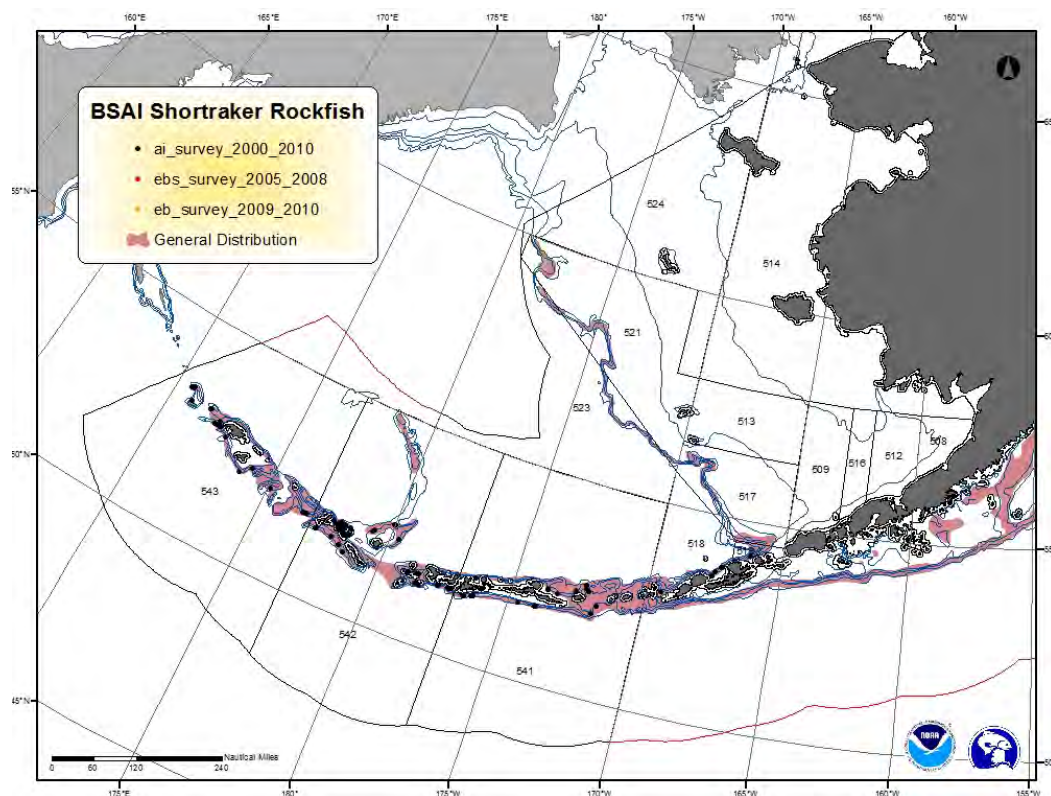
Figure 0-25 EFH Distribution - BSAI Northern Rockfish (Adults)**Figure 0-26 EFH Distribution - BSAI Shortraker Rockfish (Adults)**

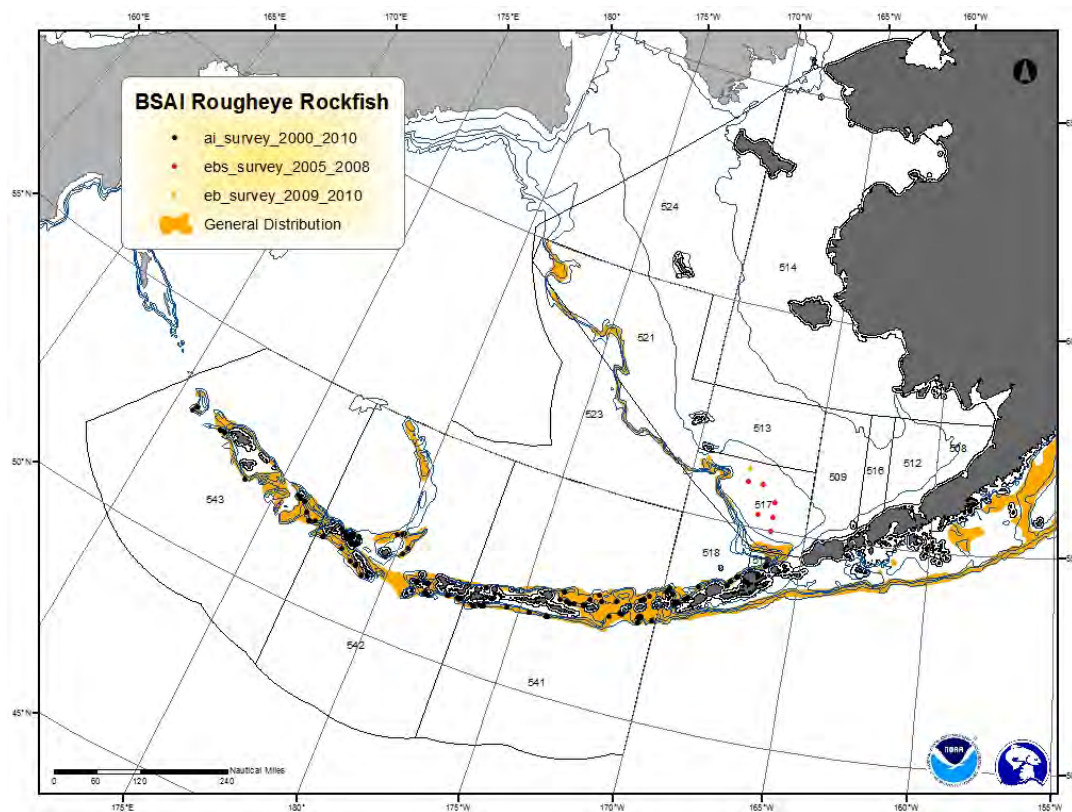
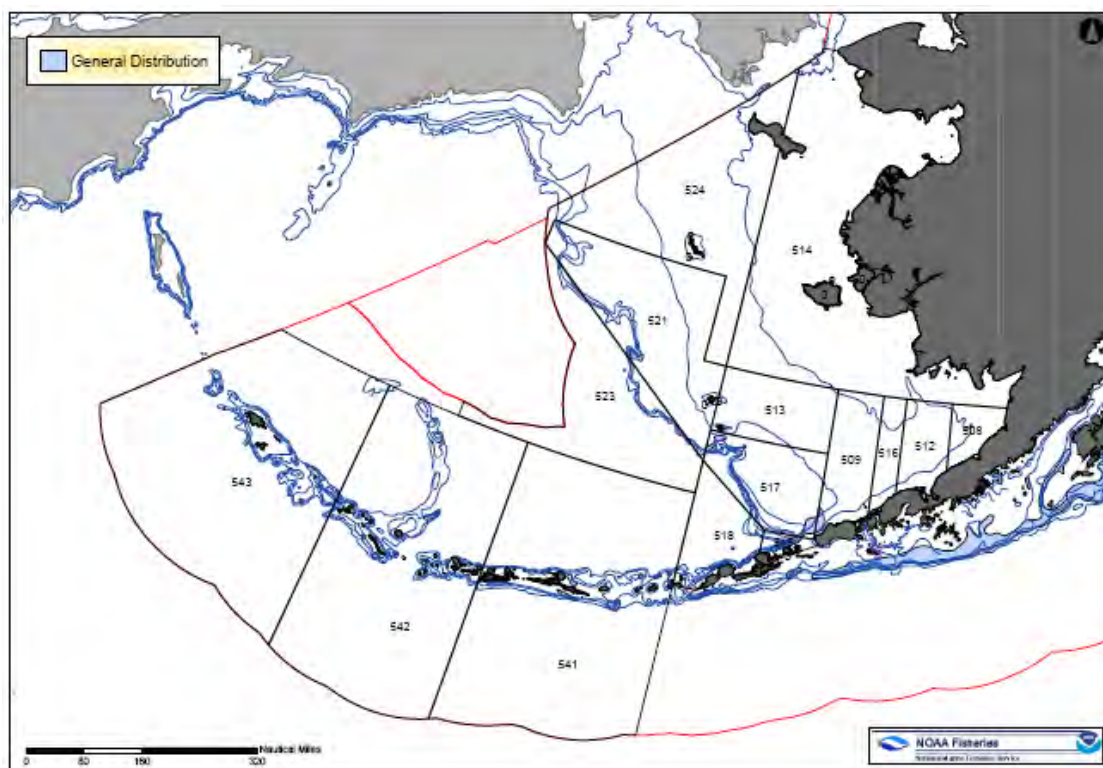
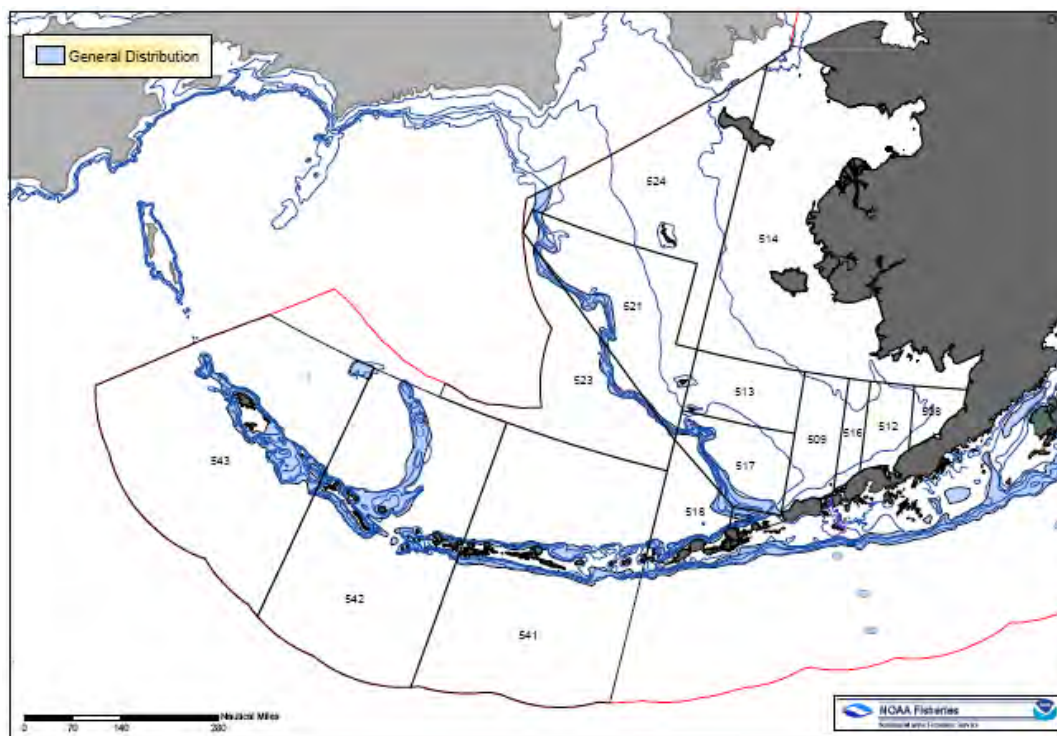
Figure 0-27 EFH Distribution - BSAI Blackspotted/Rougheye Rockfish (Late Juveniles/Adults)**Figure 0-28 EFH Distribution - BSAI Dusky Rockfish (Adults)**

Figure 0-29 EFH Distribution - BSAI Thornyhead Rockfish (Late Juveniles/Adults)**Figure 0-30 EFH Distribution - BSAI Atka Mackerel (Eggs)**

Note, map indicates known locations of Atka mackerel eggs, but is likely not all-inclusive.

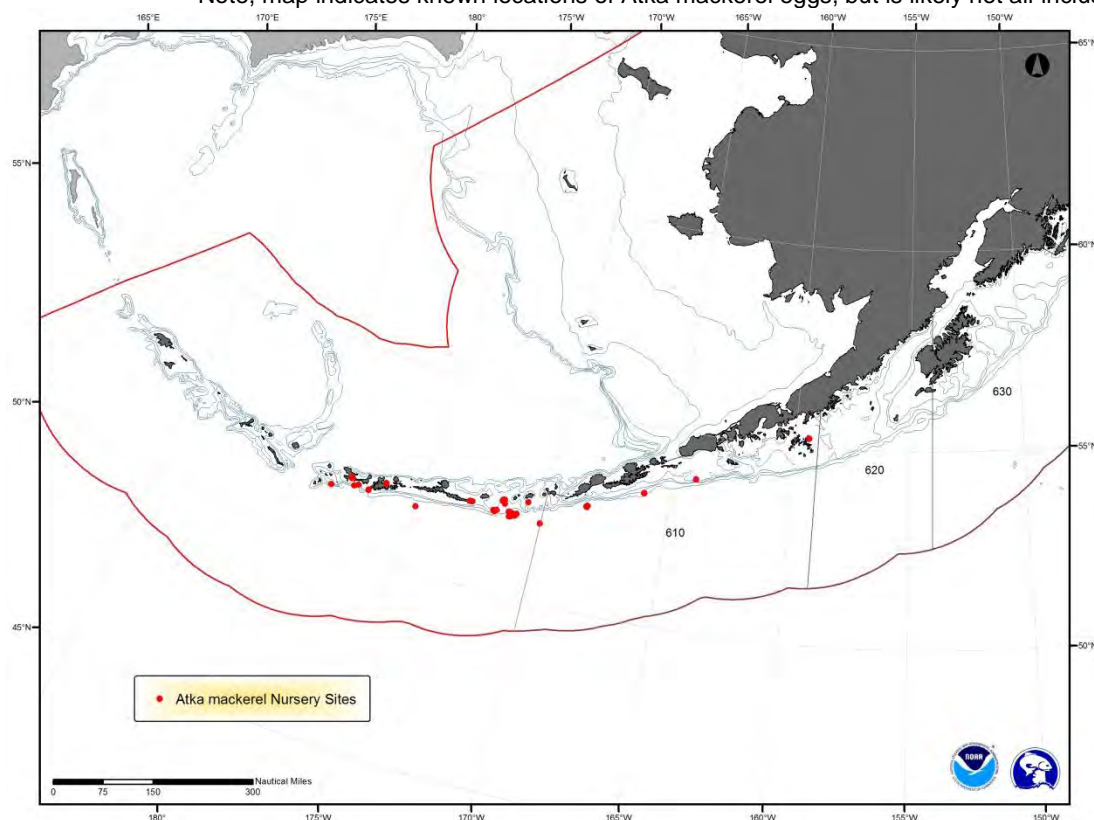


Figure 0-31 EFH Distribution - BSAI Atka Mackerel (Larvae)

Note, EFH distribution includes both green boxes and black crosses.

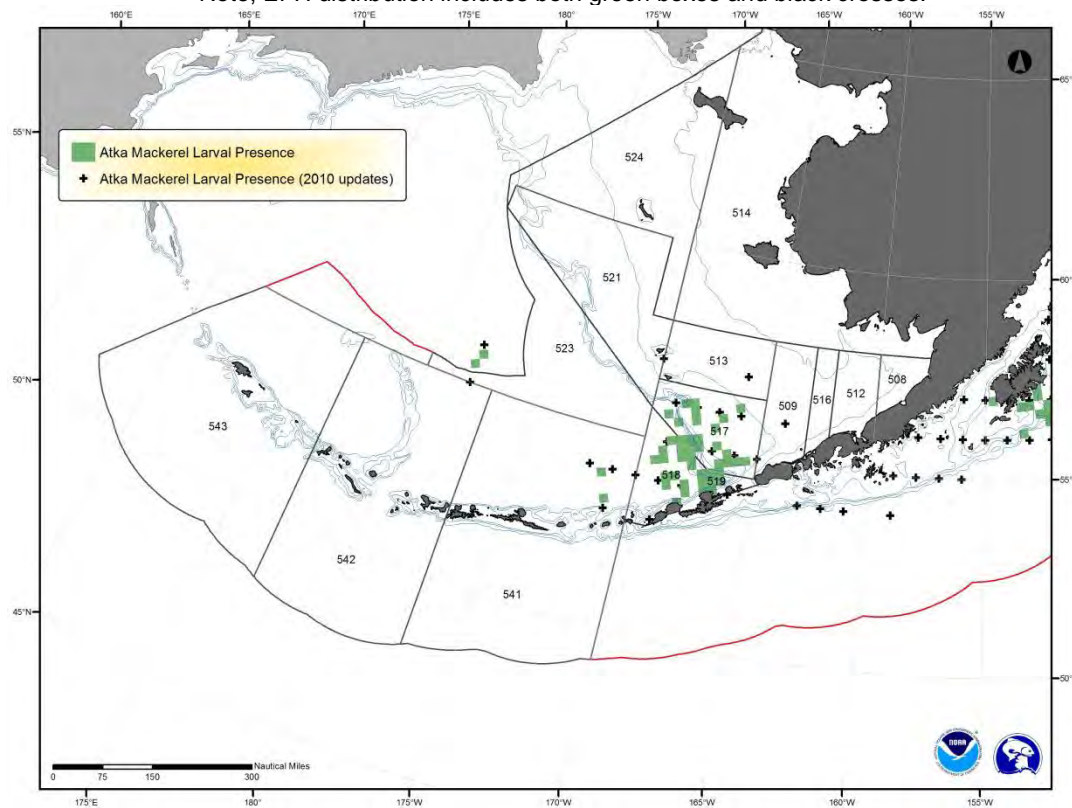
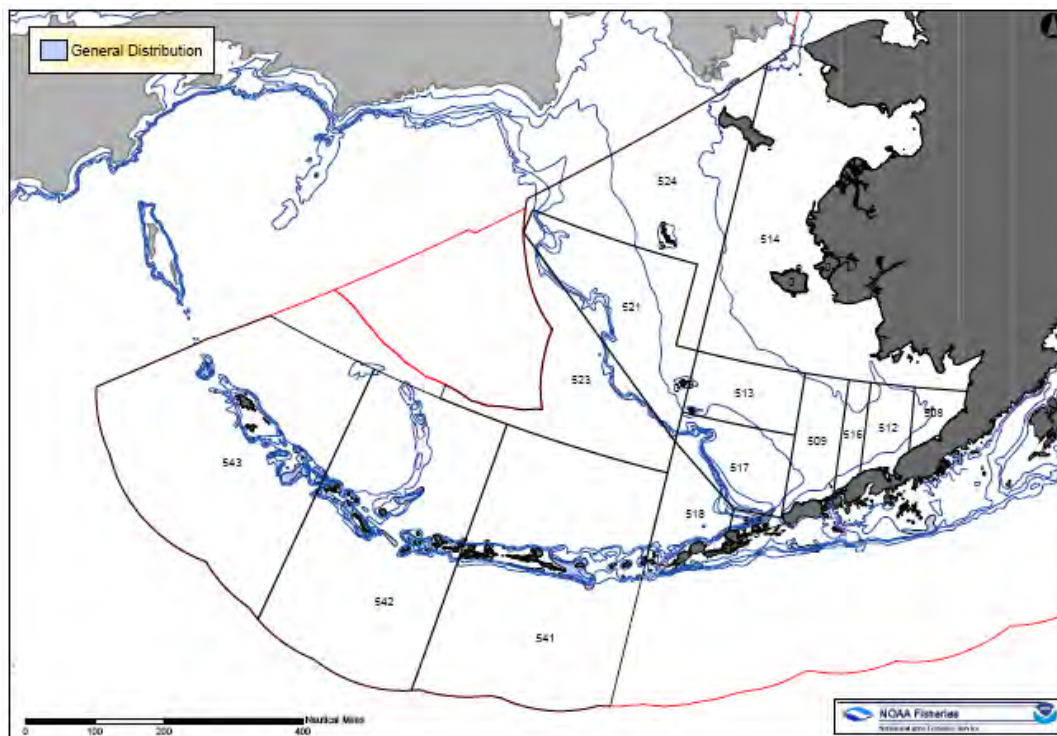
**Figure 0-32 EFH Distribution - BSAI Atka Mackerel (Adults)**

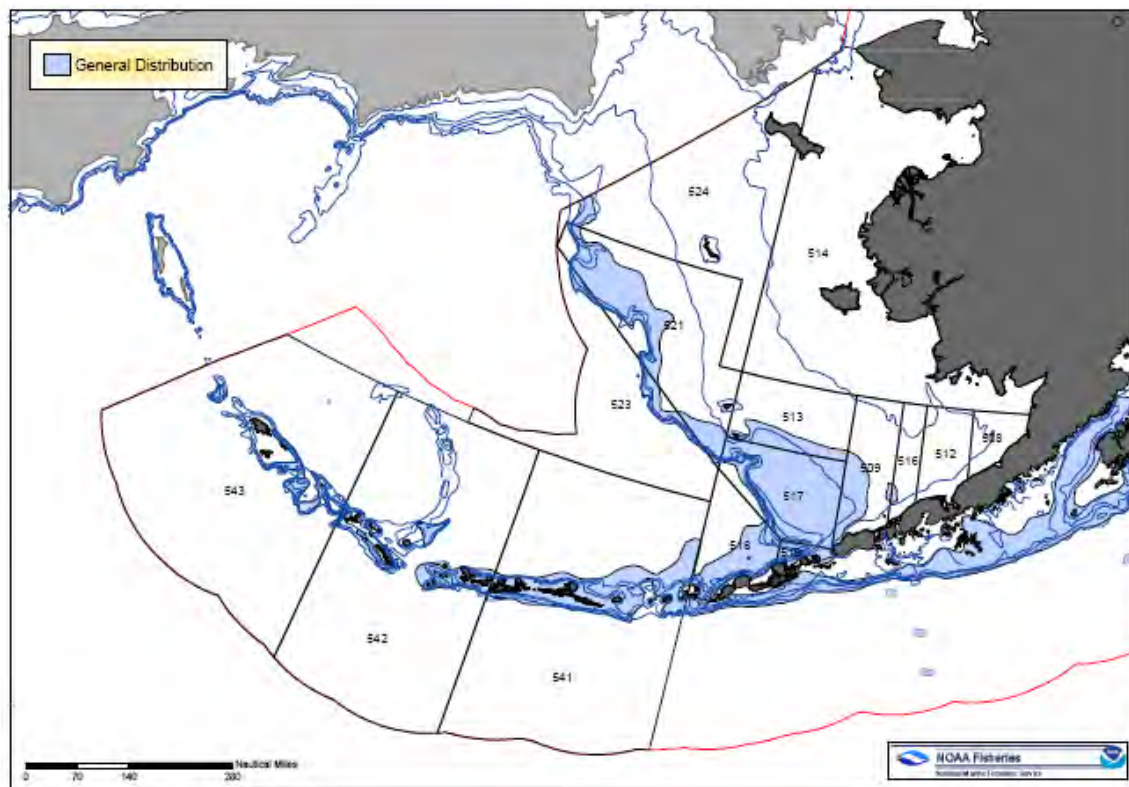
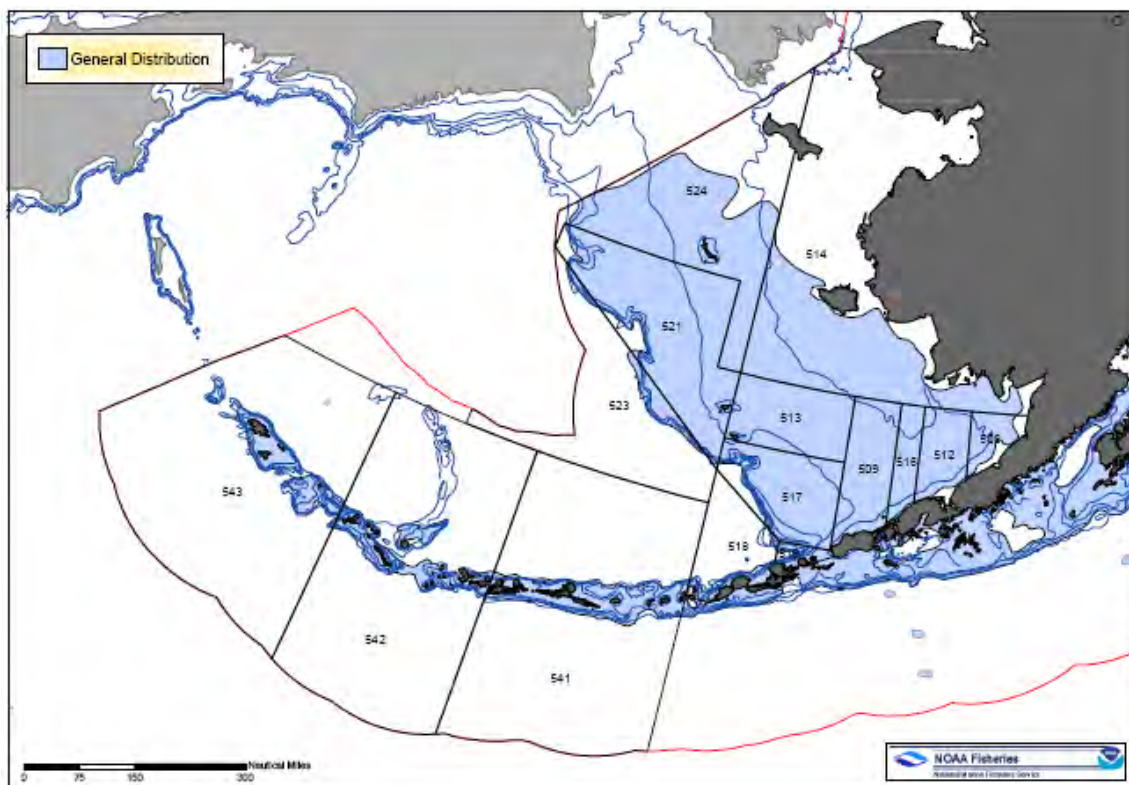
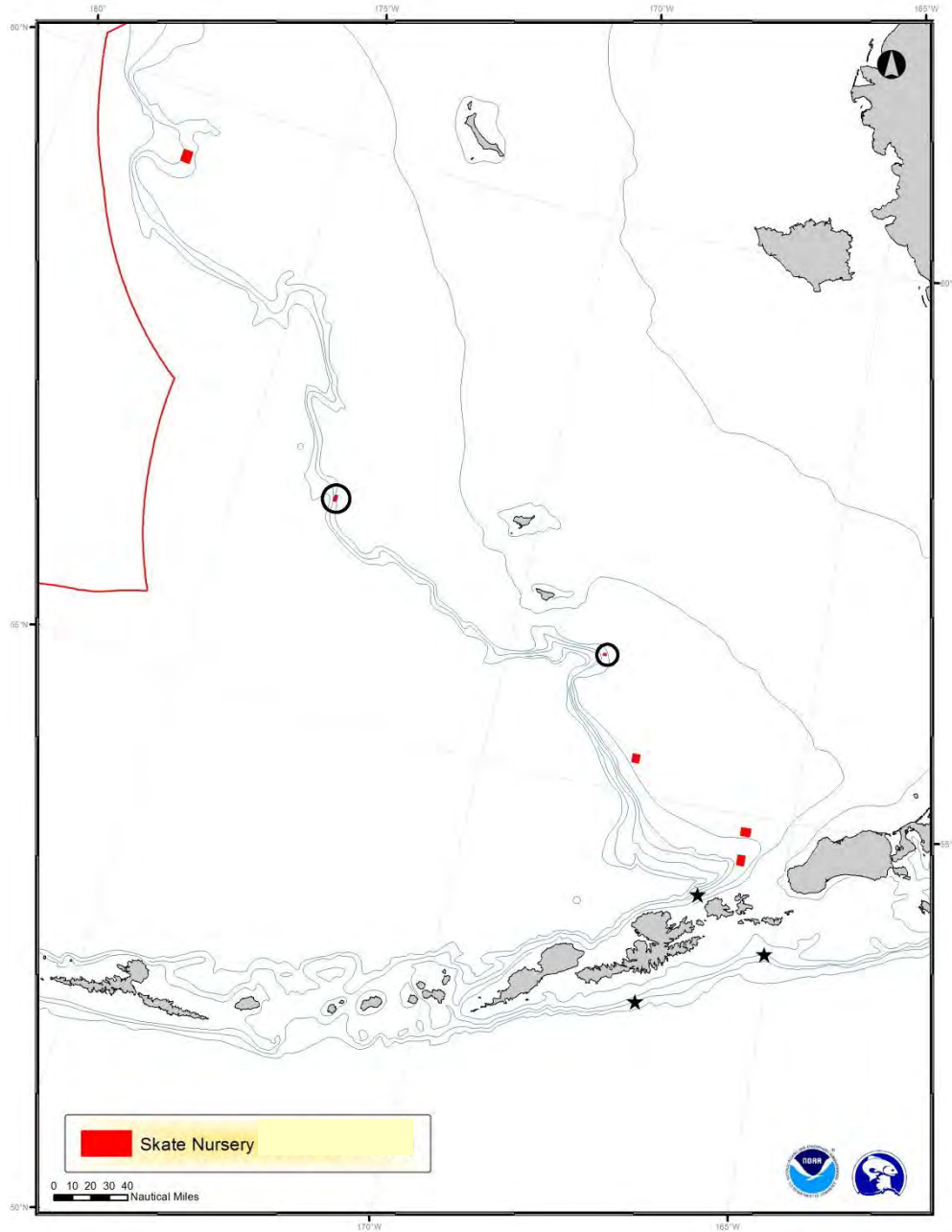
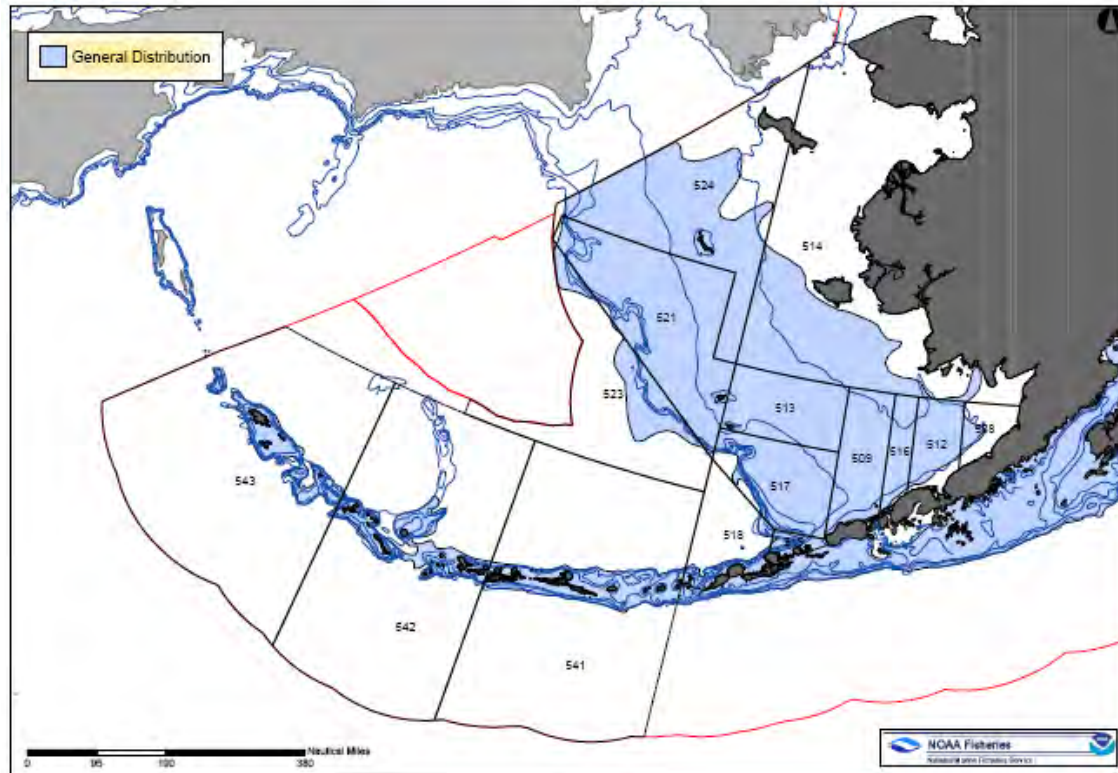
Figure 0-33 EFH Distribution – BSAI Squid (Late Juveniles/Adults)**Figure 0-34 EFH Distribution - BSAI Sculpin (Adults)**

Figure 0-35 EFH Distribution - BSAI Skate (Eggs)

Note, map indicates known locations of skate egg case concentrations, but is likely not all-inclusive.

**Figure 0-36 EFH Distribution - BSAI Skate (Adults)**



Adverse Effects on Essential Fish Habitat

F.2 Non-fishing Activities that may Adversely Affect Essential Fish Habitat

The waters and substrates that comprise EFH are susceptible to a wide array of human activities unrelated to fishing. Broad categories of such activities include, but are not limited to, mining, dredging, fill, impoundment, discharges, water diversions, thermal additions, actions that contribute to nonpoint source pollution and sedimentation, introduction of potentially hazardous materials, introduction of exotic species, and the conversion of aquatic habitat that may eliminate, diminish, or disrupt the functions of EFH. Non-fishing activities discussed in this document are subject to a variety of regulations and restrictions designed to limit environmental impacts under federal, state, and local laws. Listing all applicable environmental laws and management practices is beyond the scope of the document. Moreover, the coordination and consultation required by section 305(b) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) does not supersede the regulations, rights, interests, or jurisdictions of other federal or state agencies. NMFS may use the information in this document as a source when developing conservation recommendations for specific actions under section 305(b)(4)(A) of the MSA. NMFS will not recommend that state or federal agencies take actions beyond their statutory authority, and NMFS' EFH conservation recommendations are not binding.

Ideally, actions that are not water-dependent should not be located in EFH if such actions may have adverse impacts on EFH. Activities that may result in significant adverse effects on EFH should be avoided where less environmentally harmful alternatives are available. If there are no alternatives, the impacts of these actions should be minimized. Environmentally sound engineering and management practices should be employed for all actions that may adversely affect EFH. If avoidance or minimization is not practicable, or will not adequately protect EFH, compensatory mitigation; as defined for section 404 of the Clean Water Act (CWA) should be considered to conserve and enhance EFH.

The potential for effects from larger, less readily managed processes associated with human activity also exists, such as climate change and ocean acidification. Climate change may lead to habitat changes that prompt shifts in the distribution of managed species. Likewise, should ocean conditions warm to allow for new shipping routes, new vectors may emerge for introducing invasive species in cargo and ballast waters. Ocean acidification could also alter species distributions and complicated food web dynamics. These larger ecosystem-level effects are discussed in this document where applicable, within each activity type.

This section of the fishery management plan (FMP) synthesizes a comprehensive review of the "Impacts to Essential Fish Habitat from Non-fishing Activities in Alaska" (NMFS 2011), which is incorporated in the FMP by reference. The general purpose of that document is to identify non-fishing activities that may adversely impact EFH and provide conservation recommendations that can be implemented for specific types of activities to avoid or minimize adverse impacts to EFH. This information must be included in FMPs under section 303(a)(7) of the MSA. It is also useful to NMFS biologists reviewing proposed actions that may adversely

affect EFH, and the comprehensive document (NMFS 2011) will be utilized by federal action agencies undertaking EFH consultations with NMFS, especially in preparing EFH assessments.

The conservation recommendations for each activity category are suggestions the action agency or others can undertake to avoid, offset, or mitigate impacts to EFH. NMFS develops EFH conservation recommendations for specific activities case-by-case based on the circumstances; therefore, the recommendations in this document may or may not apply to any particular project. Because many non-fishing activities have similar adverse effects on living marine resources, some redundancy in the descriptions of impacts and the accompanying conservation recommendations between sections in this report is unavoidable.

The comprehensive non-fishing activities document (NMFS 2011) updates and builds upon a collaborative evaluation of non-fishing effects to EFH completed in 2004 by the NMFS Alaska Region, Northwest Region, and Southwest Region and the respective Fisheries Science Centers. In April 2005, NMFS completed the Final Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska (EFH EIS; NMFS 2005), and the North Pacific Fishery Management Council (Council) amended its FMPs to address the EFH requirements of the MSA. The EFH EIS contained an Appendix (Appendix G) that addressed non-fishing impacts to EFH. A 5-year review of the Council's EFH provisions, including those addressing non-fishing impacts to EFH, was completed by the Council in April 2010 (NPFMC and NMFS 2010), on the basis of which this section has been updated.

The remainder of this section addresses non-fishing activities that may adversely affect EFH. These activities are grouped into the four different systems in which they usually occur: upland, river or riverine, estuary or estuarine, and coastal or marine.

F.2.1 Upland Activities

Upland activities can impact EFH through both point source and nonpoint source pollution. Nonpoint source impacts are discussed here. Technically, the term "nonpoint source" means anything that does not meet the legal definition of point source in section 502(14) of the CWA, which refers to discernible, confined, and discrete conveyance from which pollutants are or may be discharged. Land runoff, precipitation, atmospheric deposition, seepage, and hydrologic modification, generally driven by anthropogenic development, are the major contributors to nonpoint source pollution.

Nonpoint source pollution is usually lower in intensity than an acute point source event, but may be more damaging to fish habitat in the long term. It may affect sensitive life stages and processes, is often difficult to detect, and its impacts may go unnoticed for a long time. When population impacts are detected, they may not be tied to any one event or source, and may be difficult to correct, clean up, or mitigate.

The impacts of nonpoint source pollution on EFH may not necessarily represent a serious, widespread threat to all species and life history stages. The severity of the threat of any specific pollutant to aquatic organisms depends upon the type and concentration of the pollutant and the length of exposure for a particular species and its life history stage. For example, species that spawn in areas that are relatively deep with strong currents and well-mixed water may not be as susceptible to pollution as species that inhabit shallow, inshore areas near or within enclosed

bays and estuaries. Similarly, species whose egg, larval, and juvenile life history stages utilize shallow, inshore waters and rivers may be more prone to coastal pollution than are species whose early life history stages develop in offshore, pelagic waters.

F.2.1.1 Silviculture/Timber Harvest

Recent revisions to federal and state timber harvest regulations in Alaska and best management practices (BMPs) have resulted in increased protection of EFH on federal, state, and private timber lands (United States Department of Agriculture 2008; <http://www.fs.fed.us/r10/tongass/projects/tlmp/>).

These revised regulations include forest management practices, which when fully implemented and effective, could avoid or minimize adverse effects to EFH. However, if these management practices are ineffective or not fully implemented, timber harvest could have both short and long term impacts on EFH throughout many coastal watersheds and estuaries. Historically, timber harvest in Alaska was not conducted under the current protective standards, and these past practices may have degraded EFH in some watersheds.

Potential Adverse Impacts

In both small and large watersheds there are many complex and important interactions between fish and forests (Northcote and Hartman 2004). Five major categories of silvicultural activities can adversely affect EFH if appropriate forestry practices are not followed: (1) construction of logging roads, (2) creation of fish migration barriers, (3) removal of streamside vegetation, (4) hydrologic changes and sedimentation, and (5) disturbance associated with log transfer facilities (LTFs). Possible effects to EFH include the following (Northcote and Hartman 2004):

- Removal of the dominant vegetation and conversion of mature and old-growth upland and riparian forests to tree stands or forests of early seral stage;
- Reduction of soil permeability and increase in the area of impervious surfaces;
- Increase in erosion and sedimentation due to surface runoff and mass wasting processes, also potentially affecting riparian areas;
- Impaired fish passage because of inadequate design, construction, and/or maintenance of stream crossings;
- Altered hydrologic regimes resulting in inadequate or excessive surface and stream flows, increased streambank and streambed erosion, loss of complex instream habitats;
- Changes in benthic macroinvertebrate populations,
- Loss of instream and riparian cover;
- Increased surface runoff with associated contaminants (e.g., herbicides, fertilizers, and fine sediments) and higher temperatures;
- Alterations in the supply of large woody debris (LWD) and sediment, which can have negative effects on the formation and persistence of instream habitat features; and
- Excess debris in the form of small pieces of wood and silt, which can cover benthic habitat and reduce dissolved oxygen levels.

Recommended Conservation Measures

The following recommended conservation measures for silviculture/timber harvest should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH. Additionally, management standards, guidelines, and best management practices are available from the Forest Service Region 10, the State of Alaska Division of Forestry, and forest plans for the Tongass and Chugach National Forests.

- **Stream Buffers:** For timber operations in watersheds with EFH, adhere to modern forest management practices and BMPs, including the maintenance of vegetated buffers along all streams to the extent practicable in order to reduce sedimentation and supply large wood.
- **Estuary and Beach Fringe:** For timber operations adjacent to estuaries or beaches, maintain vegetated buffers as needed to protect EFH.
- **Watershed Analysis:** A watershed analysis should be incorporated into timber and silviculture projects whenever practicable.
- **Forest Roads:** Forest roads can be a major cause of sediment into streams and road culverts can block or inhibit upstream fish passage. Roads need to be designed to minimize sediment transport problems and to avoid fish passage problems.

F.2.1.2 Pesticides

Pesticides are substances intended to prevent, destroy, control, repel, kill, or regulate the growth of undesirable biological organisms. Pesticides include the following: insecticides, herbicides, fungicides, rodenticides, repellents, bactericides, sanitizers, disinfectants, and growth regulators. More than 900 different active pesticide ingredients are currently registered for use in the United States and are formulated with a variety of other inert ingredients that may also be toxic to aquatic life. Legal mandates covering pesticides are the CWA and the Federal Insecticide, Fungicide, and Rodenticide Act. Water quality criteria for the protection of aquatic life have only been developed for a few of the currently used ingredients (EPA, Office of Pesticide Programs). While agricultural run-off is a major source of pesticide pollution in the lower 48 states, in Alaska, other human activities, such as fire suppression on forested lands, forest site preparation, noxious weed control, right-of-way maintenance (e.g., roads, railroads, power lines), algae control in lakes and irrigation canals, riparian habitat restoration, and urban and residential pest control are the most common sources of these substances.

Pesticides are frequently detected in freshwater and estuarine systems that provide EFH. Pesticides can enter the aquatic environment as single chemicals or as complex mixtures. Direct applications, surface runoff, spray drift, agricultural return flows, and groundwater intrusions are all examples of transport processes that deliver pesticides to aquatic ecosystems. Habitat alteration from pesticides is different from more conventional water quality parameters because, unlike temperature or dissolved oxygen, the presence of pesticides can be difficult to detect due to limitations in proven methodologies. This monitoring may also be expensive. As analytical methodologies have improved in recent years, the number of pesticides documented in fish and their habitats has increased. In addition, pesticides may bioaccumulate in the ecosystem by retention in sediments and detritus, which are then ingested by macroinvertebrates, and which, in

turn, are eaten by larger invertebrates and fish (Atlantic States Marine Fisheries Commission 1992).

Potential Adverse Impacts

There are three basic ways that pesticides can adversely affect EFH. These are (1) a direct, lethal or sublethal, toxicological impact on the health or performance of exposed fish; (2) an indirect impairment of aquatic ecosystem structure and function; and (3) a loss of aquatic macroinvertebrates that are prey for fish and aquatic vegetation that provides physical shelter for fish.

Recommended Conservation Measures

The following recommended conservation measures regarding pesticides (including insecticides, herbicides, fungicides, rodenticides, repellents, bactericides, sanitizers, disinfectants, and growth regulators) should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Incorporate integrated pest management and BMPs as part of the authorization or permitting process (Scott et al. 1999). If pesticides must be applied, consider area, terrain, weather, droplet size, pesticide characteristics, and other conditions to avoid or reduce effects to EFH.
- Carefully review labels and ensure that application is consistent with the product's directions.
- Avoid the use of pesticides within 500 linear feet and/or 1,000 aerial feet of anadromous fish bearing streams.
- For forestry vegetation management projects, establish a 35-foot pesticide-free buffer area from any surface or marine water body and require that pesticides not be applied within 200 feet of a public water source (Alaska Department of Environmental Conservation guidelines).
- Consider current and recent meteorological conditions. Rain events may increase pesticide runoff into adjacent water bodies. Saturated soils may inhibit pesticide penetration.
- Do not apply pesticides when wind speeds exceed 10 mph.
- Begin application of pesticide products nearest to the aquatic habitat boundary and proceed away from the aquatic habitat; do not apply towards a water body.

F.2.1.3 Urban and Suburban Development

Urban and suburban development is most likely the greatest non-fishing threat to EFH (NMFS 1998 a, 1998b). Urban and suburban development and the corresponding infrastructure result in four broad categories of impacts to aquatic ecosystems: hydrological, physical, water quality and biological (CWP 2003).

Potential Adverse Impacts

Potential impacts to EFH most directly related to general urban and suburban development discussed below are the watershed effects of land development, including stormwater runoff.

Other development-related impacts are discussed in later sections of this document, including dredging, wetland fill, and shoreline construction.

Development activities within watersheds and in coastal marine areas can impact EFH on both long and short timeframes. The Center for Watershed Protection (CWP) made a comprehensive review of the impacts associated with impervious cover and urban development and found a negative relationship between watershed development and 26 stream quality indicators (CWP 2003). The primary impacts include (1) the loss of hyporheic zones (the region beneath and next to streams where surface and groundwater mix), and riparian and shoreline habitat and vegetation; and, (2) runoff. Removal of riparian and upland vegetation has been shown to increase stream water temperatures, reduce supplies of LWD, and reduce sources of prey and nutrients to the water system. An increase in impervious surfaces in a watershed, such as the addition of new roads, buildings, bridges, and parking facilities, results in a decreased infiltration to groundwater and increased runoff volumes. This also has the potential to adversely affect water quality and the shape of the hydrograph in downstream water bodies (i.e., estuaries and coastal waters).

Recommended Conservation Measures

The following recommended conservation measures should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH where threats of impacts from urban and suburban development exist.

- Implement BMPs for sediment control during construction and maintenance operations (USEPA 1993).
- Avoid using hard engineering structures for shoreline stabilization and channelization when possible.
- Encourage comprehensive planning for watershed protection, and avoid or minimize filling and building in coastal and riparian areas affecting EFH.
- Where feasible, remove obsolete impervious surfaces from riparian and shoreline areas, and reestablish water regime, wetlands, and native vegetation.
- Protect and restore vegetated buffer zones of appropriate width along streams, lakes, and wetlands that include or influence EFH.
- Manage stormwater to replicate the natural hydrologic cycle, maintaining natural infiltration and runoff rates to the maximum extent practicable.
- Where instream flows are insufficient to maintain water quality and quantity needed for EFH, establish conservation guidelines for water use permits, and encourage the purchase or lease of water rights and the use of water to conserve or augment instream flows.
- Use the best available technologies in upgrading wastewater systems to avoid combined sewer overflow problems and chlorinated sewage discharges into rivers, estuaries, and the ocean.
- Design and install proper wastewater treatment systems.
- Where vegetated swales are not feasible, install and maintain oil/water separators to treat runoff from impervious surfaces in areas adjacent to marine or anadromous waters.

F.2.1.4 Road Building and Maintenance

Roads and trails have always been part of man's impact on his environment (Luce and Crowe 2001). Federal, state, and local transportation departments devote huge budgets to construction and upgrading of roads. As in other places, roads play an important part in access and thus are vital to the economy of Alaska (Connor 2007).

Potential Adverse Impacts

Today's road design construction and management practices have improved from the past. Roads however, still have a negative effect on the biotic integrity of both terrestrial and aquatic ecosystems (Trombulak and Frissell 2000), and the effects of roads on aquatic habitat can be profound. Potential adverse impacts to aquatic habitats resulting from existence of roads in watersheds include (1) increased surface erosion, including mass wasting events, and deposition of fine sediments; (2) changes in water temperature; (3) elimination or introduction of migration barriers such as culverts; (4) changes in streamflow; (5) introduction of invasive species; and (6) changes in channel configuration; and (7) the concentration and introduction of polycyclic aromatic hydrocarbons, heavy metals and other pollutants.

Recommended Conservation Measures

The following conservation measures should be viewed as options to avoid and minimize adverse impacts from road building and maintenance and promote the conservation, enhancement, and proper functioning of EFH.

- Roads should be sited to avoid sensitive areas such as streams, wetlands, and steep slopes to the extent practicable.
- Build bridges rather than culverts for stream crossings when possible. If culverts are to be used, they should be sized, constructed, and maintained to match the gradient and width of the stream, so as to accommodate design flood flows; they should be large enough to provide for migratory passage of adult and juvenile fishes.
- Design bridge abutments to minimize disturbances to stream banks and place abutments outside of the floodplain whenever possible.
- Specify erosion control measures in road construction plans.
- Avoid side casting of road materials on native surfaces and into streams.
- Use only native vegetation in stabilization plantings.
- Use seasonal restrictions to avoid impacts to habitat during species critical life history stages (e.g., spawning and egg development periods).
- Properly maintain roadway and associated stormwater collection systems.
- Limit roadway sanding and the use of deicing chemicals during the winter to minimize sedimentation and introduction of contaminants into nearby aquatic habitats.

F.2.2 Riverine Activities

F.2.2.1 Mining

Mining within riverine habitats may result in direct and indirect chemical, biological, and physical impacts to habitats within the mining site and surrounding areas during all stages of

operations. On site mining activities include exploration, site preparation, mining and milling, waste management, decommissioning or reclamation, and abandonment (NMFS 2004, American Fisheries Society 2000). Mining and its associated activities have the potential to cause adverse effects to EFH from exploration through post-closure. The operation of metal, coal, rock quarries, and gravel pit mines in upland and riverine areas has caused varying degrees of environmental damage in urban, suburban, and rural areas. Some of the most severe damage, however, occurs in remote areas, where some of the most productive fish habitat is often located (Sengupta 1993). In Alaska, existing regulations, promulgated and enforced by other federal and state agencies, are designed to control and manage these changes to the landscape to avoid and minimize impacts. However, while environmental regulations may avoid, limit, control, or offset many potential impacts, mining will, to some degree, always alter landscapes and environmental resources (National Research Council 1999). (Additional information on mining impacts in the marine environment is covered later in this synthesis.)

F.2.2.1.1 Mineral Mining

Mining and mineral extraction activities take many forms, such as commercial and recreational suction dredging, placer, open pit and surface mining, and contour operations. The process for mineral extraction involves exploration, mine development, mining (extraction), processing and reclamation.

Potential Adverse Impacts

The potential adverse effects of mineral mining on fish populations and EFH are well documented (Frag et al. 2003, Hansen et al. 2002, Brix et al. 2001, Goldstein et al. 1999) and depend on the type, extent, and location of the activities. Impacts associated with the extraction of material from within or near a stream or river bed may include (1) alteration in channel morphology, hydraulics, lateral migration and natural channel meander; (2) increases in channel incision and bed degradation; (3) disruption in pre-existing balance of suspended sediment transport and turbidity; (4) direct impacts to fish spawning and nesting habitats (redds), juveniles, and prey items; (5) simplification of in-channel fluvial processes and LWD deposition; (6) altered surface and ground water regimes and hydro-geomorphic and hyporheic processes; and (7) destruction of the riparian zone during extraction operations. Additional impacts may include mining-related pollution, acid mine drainage, habitat fragmentation and conversion, altered temperature regimes, reduction in oxygen concentration, the release of toxic materials (NMFS 2008), and additional impacts to wetland and riverine habitats. Many of these types of impacts have been previously introduced in the document. The additional discussion that follows is intended to round out the discussion of impacts that have not been previously introduced.

Recommended Conservation Measures

The following measures are adapted from recommendations in Spence et al. (1996), NMFS (2004), and Washington Department of Fish and Wildlife (2009). These conservation recommendations for mineral mining should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- To the extent practicable, avoid mineral mining in waters, water sources and watersheds, riparian areas, hyporheic zones, and floodplains providing habitat for federally managed species.
- Schedule necessary in-water activities when the fewest species/least vulnerable life stages of federally managed species will be present.
- Minimize spillage of dirt, fuel, oil, toxic materials, and other contaminants into EFH. Prepare a spill prevention plan if appropriate.
- Treat and test wastewater (acid neutralization, sulfide precipitation, reverse osmosis, electrochemical, or biological treatments) and recycle on site to minimize discharge to streams.
- Minimize the effects of sedimentation on fish habitat, using methods such as contouring, mulching, construction of settling ponds, and sediment curtains. Monitor turbidity during operations, and cease operations if turbidity exceeds predetermined threshold levels.
- If possible, reclaim, rather than bury, mine waste that contains heavy metals, acid materials, or other toxic compounds to limit the possibility of leachate entering groundwater.
- Restore natural contours and use native vegetation to stabilize and restore habitat function to the extent practicable. Monitor the site to evaluate performance.
- Minimize the aerial extent of ground disturbance and stabilize disturbed lands to reduce erosion.
- For large scale mining operations, stochastic models should be employed to make predictions of ground and surface hydrologic impacts and acid generating potential in mine pits and tailing impoundments.

F.2.2.1.2 Sand and Gravel Mining

In Alaska, riverine sand and gravel mining is extensive and can involve several methods: wet-pit mining (i.e., removal of material from below the water table); dry-pit mining on beaches, exposed bars, and ephemeral streambeds; and subtidal mining.

Potential Adverse Impacts

Primary impacts associated with riverine sand and gravel mining activities include (1) turbidity plumes and re-suspension of sediment and nutrients, (2) removal of spawning habitat, and (3) alteration of channel morphology. These often lead to secondary impacts including: (1) alteration of migration patterns; (2) physical and thermal barriers to upstream and downstream migration; (3) increased fluctuation in water temperature; (4) decrease in dissolved oxygen; (5) high mortality of early life stages; (6) increased susceptibility to predation; (7) loss of suitable habitat (Packer et al. 2005); (8) decreased nutrients (from loss of floodplain connection and riparian vegetation); and (9) decreased food production (loss of invertebrates) (Spence et al. 1996).

Recommended Conservation Measures

The following recommended conservation measures for sand and gravel mining are adapted from NMFS (2004) and OWRRI (1995). They should be viewed as options to avoid and minimize

adverse impacts to EFH due to sand and gravel mining and promote the conservation, enhancement, and proper functioning of EFH.

- To the extent practicable, avoid sand/gravel mining in waters, water sources and watersheds, riparian areas, hyporheic zones and floodplains providing habitat for federally managed species.
- Identify upland or off-channel (where the channel will not be captured) gravel extraction sites as alternatives to gravel mining in or adjacent to EFH, if possible.
- If operations in EFH cannot be avoided, design, manage, and monitor sand and gravel mining operations to minimize potential direct and indirect impacts to living marine resources and habitat. For example, minimize the areal extent and depth of extraction.
- Include restoration, mitigation, and monitoring plans, as appropriate, in sand/gravel extraction plans.
- Implement seasonal restrictions to avoid impacts to habitat during species critical life history stages.

F.2.2.2 Organic and Inorganic Debris

Organic and inorganic debris, and its impacts to EFH, extend beyond riverine systems into estuarine coastal and marine systems. To reduce duplication, impacts to other systems are also addressed here.

Natural occurring flotsam, such as LWD and macrophyte wrack (i.e., kelp), plays an important role in aquatic ecosystems, including EFH. LWD and wrack promote habitat complexity and provide structure to various aquatic and shoreline habitats.

The natural deposition of LWD creates habitat complexity by altering local hydrologic conditions, nutrient availability, sediment deposition, turbidity, and other structural habitat conditions. In riverine systems, the physical structure of LWD provides cover for managed species, creates habitats and microhabitats (e.g., pools, riffles, undercut banks, and side channels), retains gravels, and helps maintain underlying channel structure (Abbe and Montgomery 1996, Montgomery et al. 1995, Ralph et al. 1994, Spence et al. 1996). LWD also plays similar role in salt marsh habitats (Maser and Sedell 1994). In benthic ocean habitats, LWD enriches local nutrient availability as deep-sea wood borers convert the wood to fecal matter, providing terrestrially-based carbon to the ocean food chain (Maser and Sedell 1994). When deposited on coastal shorelines, macrophyte wrack creates microhabitats and provides a food source for aquatic and terrestrial organisms such as isopods and amphipods, which play an important role in marine food webs.

Conversely, inorganic flotsam and jetsam debris can negatively impact EFH. Inorganic marine debris is a problem along much of the coastal United States, where it litters shorelines, fouls estuaries, entangles fish and wildlife, and creates hazards in the open ocean. Marine debris consists of a wide variety of man-made materials, including general litter, plastics, hazardous wastes, and discarded or lost fishing gear. The debris enters waterbodies indirectly through rivers and storm water outfalls, as well as directly via ocean dumping and accidental release. Although laws and regulatory programs exist to prevent or control the problem, marine debris continues to affect aquatic resources.

F.2.2.2.1 Organic Debris Removal

Natural occurring flotsam, such as LWD and macrophyte wrack (i.e., kelp), is sometimes intentionally removed from streams, estuaries, and coastal shores. This debris is removed for a variety of reasons, including dam operations, aesthetic concerns, and commercial and recreational purposes (e.g., active beach log harvests, garden mulch, and fertilizer). However, the presence of organic debris is important for maintaining aquatic habitat structure and function.

Potential Adverse Impacts

The removal of organic debris from natural systems can reduce habitat function, adversely impacting habitat quality. Reductions in LWD inputs to estuaries may also affect the ecological balance of estuarine systems by altering rates and patterns of nutrient transport, sediment deposition, and availability of in-water cover for larval and juvenile fish. In rivers and streams of the Pacific Northwest, the historic practice of removing LWD to improve navigability and facilitate log transport has altered channel morphology and reduced habitat complexity, thereby negatively affecting habitat quality for spawning and rearing salmonids (Koski 1992, Sedell and Luchessa 1982).

Beach grooming and wrack removal can substantially alter the macrofaunal community structure of exposed sand beaches (Dugan et al. 2000). Species richness, abundance, and biomass of macrofauna associated with beach wrack (e.g., sand crabs, isopods, amphipods, and polychaetes) are higher on ungroomed beaches than on those that are groomed (Dugan et al. 2000). The input and maintenance of wrack can strongly influence the structure of macrofauna communities, including the abundance of sand crabs (*Emerita analoga*) (Dugan et al. 2000), an important prey species for some managed species of fish.

Recommended Conservation Measures

The recommended conservation measures for organic debris removal are listed below. They should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Encourage the preservation of LWD whenever possible, removing it only when it presents a threat to life or property.
- Encourage appropriate federal, state, and local agencies to aid in the downstream movement of LWD around dams, culverts, and bridges wherever possible, rather than removing it from the system.
- Educate landowners and recreationalists about the benefits of maintaining LWD.
- Localize beach grooming practices, and minimize them whenever possible.
- Advise gardeners to only harvest dislodged, dead kelp and leave live, growing kelp (whether dislodged or not).

F.2.2.2.2 Inorganic Debris

Inorganic debris in the marine environment is a chronic problem along much of the U.S. coast, resulting in littered shorelines and estuaries with varying degrees of negative effects to coastal ecosystems. Nationally, land-based sources of marine debris account for about 80 percent of the marine debris on beaches and in U.S. waters. Debris can originate from combined sewer

overflows and storm drains, stormwater runoff, landfills, solid waste disposal, poorly maintained garbage bins, floating structures, and general littering of beaches, rivers, and open waters. It generally enters waterways indirectly through rivers and storm drains or by direct ocean dumping. Ocean-based sources of debris also create problems for managed species. These include discarded or lost fishing gear (NMFS 2008), and galley waste and trash from commercial merchant, fishing, military, and other vessels.

Potential Adverse Impacts

Land and ocean sourced inorganic marine debris is a very diverse problem, and adverse effects to EFH are likewise varied. Floating or suspended trash can directly affect managed species that consume or are entangled in it. Toxic substances in plastics can kill or impair fish and invertebrates that use habitat polluted by these materials. The chemicals that leach from plastics can persist in the environment and can bioaccumulate through the food web.

Once floatable debris settles to the bottom of estuaries, coastal, and open ocean areas, it can continue to cause environmental problems. Plastics and other materials with a large surface area can cover and suffocate immobile animals and plants, creating large spaces devoid of life. Currents can carry suspended debris to underwater reef habitats where the debris can become snagged, damaging these sensitive habitats. The typical floatable debris from combined sewer overflows includes street litter, sewage containing viral and bacterial pathogens, pharmaceutical by-products from human excretion, and pet wastes. Pathogens can also contaminate shellfish beds and reefs.

Recommended Conservation Measures

Pollution prevention and improved waste management can occur through regulatory controls and best management practices. The recommended conservation measures for minimizing inorganic debris listed in the section below should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Encourage proper trash disposal, particularly in coastal and ocean settings, and participate in coastal cleanup activities.
- Advocate for local, state, and national legislation that rewards proper disposal of debris.
- Encourage enforcement of regulations addressing marine debris pollution and proper disposal.
- Provide resources and technical guidance for development of studies and solutions addressing the problem of marine debris.
- Educate the public on the impact of marine debris and provide guidance on how to reduce or eliminate the problem.
- Implement structural controls that collect and remove trash before it enters nearby waterways.
- Consider the use of centrifugal separation to physically separate solids and floatables from water in combined sewer outflows.
- Encourage the development of incentives and funding mechanisms to recover lost fishing gear.

- Require all existing and new commercial construction projects near the coast to develop and implement refuse disposal plans.

F.2.2.3 Dam Operation

Dams provide sources of hydropower, water storage, and flood control. Construction and operation of dams can affect basic hydrologic and geomorphic function including the alteration of physical, biological, and chemical processes that, in turn, can have effects on water quality, timing, quantity, and alter sediment transport.

Potential Adverse Impacts (adapted from NMFS 2008)

The effects of dam construction and operation on fish and aquatic habitat include (1) complete or partial upstream and downstream migratory impediment; (2) water quality and flow pattern alteration; (3) alteration to distribution and function of ice, sediment, and nutrient budgets; (4) alterations to the floodplain, including riparian and coastal wetland systems and associated functions and values; and (5) thermal impacts. Dam construction and operations can impede or block anadromous fish passage and other aquatic species migration in streams and rivers. Unless proper fish passage structures or devices are operational, dams can either prevent access to productive upstream spawning and rearing habitat or can alter downstream juvenile migration. Turbines, spillways, bypass systems, and fish ladders also affect the quality and quantity of EFH available for salmon passage in streams and rivers (Pacific Fishery Management Council [PFMC] 1999). The construction of a dam can fragment habitat, resulting in alterations to both upstream and downstream biogeochemical processes.

Recommended Conservation Measures (adapted from NMFS 2008)

The following conservation recommendations regarding dams should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Avoid construction of new dam facilities, where possible.
- Construct and design facilities with efficient and functional upstream and downstream adult and juvenile fish passage which ensures safe, effective, and timely passage.
- Operate dams within the natural flow fluctuations rates and timing and, when possible, mimic the natural hydrograph, allow for sediment and wood transport, and consider and allow for natural ice function. Monitor water flow and reservoir flow fluctuation.
- Understand longer term climatic and hydrologic patterns and how they affect habitat; plan project design and operation to minimize or mitigate for these changes.
- Use seasonal restrictions for construction, maintenance, and operation of dams to avoid impacts to habitat during species' critical life history stages.
- Develop and implement monitoring protocols for fish passage.
- Retrofit existing dams with efficient and functional upstream and downstream fish passage structures.
- Construct dam facilities with the lowest hydraulic head practicable for the project purpose. Site the project at a location where dam height can be reduced.
- Downstream passage should prevent adults and juveniles from passing through the

turbines and provide sufficient water downstream for safe passage.

- Coordinate maintenance and operations that require drawdown of the impoundment with state and federal resource agencies to minimize impacts to aquatic resources.
- Develop water and energy conservation guidelines for integration into dam operation plans and into regional and watershed-based water resource plans.
- Encourage the preservation of LWD, whenever possible.
- Develop a sediment transport and geomorphic maintenance plan to allow for peak flow mimicking that will result in sediment pulses through the reservoir/dam system and allow high flow geomorphic processes.

F.2.2.4 Commercial and Domestic Water Use

An increasing demand for potable water, combined with inefficient use of freshwater resources and natural events (e.g., droughts) have led to serious ecological damage worldwide (Deegan and Buchsbaum 2005). Because human populations are expected to continue increasing in Alaska, it is reasonable to assume that water uses, including water impoundments and diversion, will similarly increase (Gregory and Bisson 1997). Groundwater supplies 87 percent of Alaska's 3,500 public drinking water systems. Ninety percent of the private drinking water supplies are groundwater. Each day, roughly 275 million gallons of water derived from aquifers, which directly support riverine systems, are used for domestic, commercial, industrial, and agricultural purposes in Alaska (Groundwater Protection Council 2010). Surface water sources serve a large number of people from a small number of public water systems (e.g., Anchorage and several southeastern communities).

Potential Adverse Impacts

The diversion of freshwater for domestic and commercial uses can affect EFH by (1) altering natural flows and the process associated with flow rates, (2) altering riparian habitats by removing water or by submersion of riparian areas, (3) removing the amount and altering the distribution of prey bases, (4) affecting water quality, and (5) entrapping fishes. Water diversions can involve either withdrawals (reduced flow) or discharges (increased flow).

Recommended Conservation Measures

These conservation measures for commercial and domestic water use should be viewed as options to avoid and minimize adverse impacts from commercial and domestic water use and promote the conservation, enhancement, and proper functioning of EFH.

- Design water diversion and impoundment projects to create flow conditions that provide for adequate fish passage, particularly during critical life history stages. Avoid low water levels that strand juveniles and dewater redds. Incorporate juvenile and adult fish passage facilities on all water diversion projects (e.g., fish bypass systems). Install screens at water diversions on fish-bearing streams, as needed.
- Maintain water quality necessary to support fish populations by monitoring and adjusting water temperature, sediment loads, and pollution levels.
- Maintain appropriate flow velocity and water levels to support continued stream functions. Maintain and restore channel, floodplain, riparian, and estuarine conditions.

- Where practicable, ensure that mitigation is provided for unavoidable impacts to fish and their habitat.

F.2.3 Estuarine Activities

A large portion of Alaska's population resides near the state's 33,904-mile coastline (NOAA 2010). The dredging and filling of coastal wetlands for commercial and residential development, port, and harbor development directly removes important wetland habitat and alters the habitat surrounding the developed area. Physical changes from shoreline construction can result in secondary impacts such as increased suspended sediment loading, shading from piers and wharves, as well as introduction of chemical contamination from land-based human activities (Robinson and Pederson 2005). Even development projects that appear to have minimal individual impacts can have significant cumulative effects on the aquatic ecosystem (NMFS 2008).

F.2.3.1 Dredging

The construction of ports, marinas, and harbors typically involves dredging sediments from intertidal and subtidal habitats to create navigational channels, turning basins, anchorages, and berthing docks. Additionally, periodic dredging is used to maintain the required depths after sediment is deposited into these facilities. Dredging is also used to create deepwater navigable channels or to maintain existing channels that periodically fill with sediments. (Impacts from dredging from marine mining are also addressed later.)

Potential Adverse Impacts

Dredging activities can adversely affect benthic and water-column habitat. The environmental effects of dredging on managed species and their habitat can include (1) direct removal/burial of organisms; (2) turbidity and siltation, including light attenuation from turbidity; (3) contaminant release and uptake, including nutrients, metals, and organics; (4) release of oxygen consuming substances (e.g., chemicals and bacteria); (5) entrainment; (6) noise disturbances; and (7) alteration to hydrodynamic regimes and physical habitat.

Recommended Conservation Measures

The recommended conservation measures for dredging are listed in the following section. They should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Avoid new dredging in sensitive habitat areas to the maximum extent practicable.
- Reduce the area and volume of material to be dredged to the maximum extent practicable.
- Avoid dredging and placement of equipment used in conjunction with dredging operations in special aquatic sites and other high value habitat areas.
- Implement seasonal restrictions to avoid impacts to habitat during species critical life history stages (e.g., spawning season, egg, and larval development period).
- Utilize BMPs to limit and control the amount and extent of turbidity and sedimentation.

- For new dredging projects, undertake multi-season, pre-, and post-dredging biological surveys to assess the cumulative impacts to EFH and allow for implementation of adaptive management techniques.
- Prior to dredging, test sediments for contaminants as per U.S. Environmental Protection Agency (EPA) and U.S. Army Corps of Engineers (USACE) requirements.
- Provide appropriate compensation for significant impacts (short-term, long-term, and cumulative) to benthic environments resulting from dredging.
- Identify excess sedimentation in the watershed that prompts excessive maintenance dredging activities, and implement appropriate management actions, if possible.

F.2.3.2 Material Disposal and Filling Activities

Material disposal and filling activities can directly remove important habitat and alter the habitat surrounding the developed area. The discharge of dredged materials or the use of fill material in aquatic habitats can result in covering or smothering existing submerged substrates, loss of habitat function, and adverse effects on benthic communities.

F.2.3.2.1 Disposal of Dredged Material

Potential Adverse Impacts (adapted from NMFS 2008)

The disposal of dredged material can reduce the suitability of water bodies for managed species and their prey by (1) reducing floodwater retention in wetlands; (2) reducing nutrients uptake and release; (3) decreasing the amount of detrital input, an important food source for aquatic invertebrates (Mitsch and Gosselink 1993); (4) habitat conversion through alteration of water depth or substrate type; (5) removing aquatic vegetation and preventing natural revegetation; (6) impeding physiological processes to aquatic organisms (e.g., photosynthesis, respiration) caused by increased turbidity and sedimentation (Arruda et al. 1983, Cloern 1987, Dennison 1987, Barr 1993, Benfield and Minello 1996, Nightingale and Simenstad 2001a); (7) directly eliminating sessile or semi-mobile aquatic organisms via entrainment or smothering (Larson and Moehl 1990, McGraw and Armstrong 1990, Barr 1993, Newell et al. 1998); (8) altering water quality parameters (i.e., temperature, oxygen concentration, and turbidity); and (9) releasing contaminants such as petroleum products, metals, and nutrients (USEPA 2000a).

Recommended Conservation Measures

The following recommended conservation measures for dredged material disposal should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Avoid disposing dredged material in wetlands, submerged aquatic vegetation and other special aquatic sites whenever possible.
- Test sediment compatibility for open-water disposal per EPA and USACE requirements.
- Ensure that disposal sites are properly managed and monitored to minimize impacts associated with dredge material.
- Where long-term maintenance dredging is anticipated, acquire and maintain disposal sites for the entire project life.

- Encourage beneficial uses of dredged materials.

F.2.3.2.2 Fill Material

Like the discharge of dredged material, the discharge of fill material to create upland areas can remove productive habitat and eliminate important habitat functions.

Potential Adverse Impacts

Adverse impacts to EFH from the introduction of fill material include (1) loss of habitat function and (2) changes in hydrologic patterns.

Recommended Conservation Measures

The following recommended conservation measures for the discharge of fill material should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Federal, state, and local resource management and permitting agencies should address the cumulative impacts of fill operations on EFH.
- Minimize the areal extent of any fill in EFH, or avoid it entirely.
- Consider alternatives to the placement of fill into areas that support managed species.
- Fill should be sloped to maintain shallow water, photic zone productivity; allow for unrestricted fish migration; and provide refugia for juvenile fish.
- In marine areas of kelp and other aquatic vegetation, fill (including artificial structure fill reefs) should be designed to maximize kelp colonization and provide areas for juvenile fish to find shelter from higher currents and exposure to predators.
- Fill materials should be tested and be within the neutral range of 7.5 to 8.4 pH.

F.2.3.3 Vessel Operations, Transportation, and Navigation

In Alaska, the growth in coastal communities is putting demands on port districts to increase infrastructure to accommodate additional vessel operations for cargo handling and marine transportation. Port expansion has become an almost continuous process due to economic growth, competition between ports, and significant increases in vessel size. In addition, increasing boat sales have put more pressure on improving and building new harbors, an important factor in Alaska because of the limited number of roads.

Potential Adverse Impacts

Activities associated with the expansion of port facilities, vessel/ferry operations, and recreational marinas can directly and indirectly impact EFH. Impacts include (1) loss and conversion of habitat; (2) altered light regimes and loss of submerged aquatic vegetation; (3) altered temperature regimes; (4) siltation, sedimentation, and turbidity; (5) contaminant releases; and, (6) altered tidal, current, and hydrologic regimes.

Recommended Conservation Measures

The following recommended conservation measures for vessel operations, transportation infrastructure, and navigation, should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Locate marinas in areas of low biological abundance and diversity.
- Leave riparian buffers in place to help maintain water quality and nutrient input.
- Include low-wake vessel technology, appropriate routes, and BMPs for wave attenuation structures as part of the design and permit process.
- Incorporate BMPs to prevent or minimize contamination from ship bilge waters, antifouling paints, shipboard accidents, shipyard work, maintenance dredging and disposal, and nonpoint source contaminants from upland facilities related to vessel operations and navigation.
- Locate mooring buoys in water deep enough to avoid grounding and to minimize the effects of prop wash.
- Use catchment basins for collecting and storing surface runoff to remove contaminants prior to delivery to any receiving waters.
- Locate facilities in areas with enough water velocity to maintain water quality levels within acceptable ranges.
- Locate marinas where they do not interfere with natural processes so as to affect adjacent habitats.
- To facilitate movement of fish around breakwaters, breach gaps and construct shallow shelves to serve as “fish benches,” as appropriate.
- Harbor facilities should be designed to include practical measures for reducing, containing, and cleaning up petroleum spills.

F.2.3.4 Invasive Species

Introductions of invasive species into estuarine, riverine, and marine habitats have been well documented (Rosecchi et al. 1993, Kohler and Courtenay 1986, Spence et al. 1996) and can be intentional (e.g., for the purpose of stock or pest control) or unintentional (e.g., fouling organisms). Exotic fish, shellfish, pathogens, and plants can be spread via shipping, recreational boating, aquaculture, biotechnology, and aquariums. The introduction of nonindigenous organisms to new environments can have many severe impacts on habitat (Omori et al. 1994).

Invasive aquatic species that are considered high priority threats to Alaska’s marine waters include: Atlantic salmon (*Salmo salar*), green crab (*Carcinus maenas*), Chinese mitten crab (*Eriocheir sinensis*), signal crayfish (*Pacifastacus leniunculus*), zebra mussels (*Dreissena polymorpha*), New Zealand mudsnail (*Potamopyrgus antipodarum*), saltmarsh cordgrass

(*Spartina alterniflora*), purple loosestrife (*Lythrum salicaria*), and tunicates (*Botrylloides violaceus* and *Didemnum vexillum*).¹

Potential Adverse Impacts

Invasive species can create five types of negative effects on EFH: (1) habitat alteration, (2) trophic alteration, (3) gene pool alteration, (4) spatial alteration, and (5) introduction of diseases.

Recommended Conservation Measures

The following recommended conservation measures for invasive species should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Uphold fish and game regulations of the Alaska Board of Fisheries (AS 16.05.251) and Board of Game (AS 16.05.255), which prohibit and regulate the live capture, possession, transport, or release of native or exotic fish or their eggs.
- Adhere to regulations and use best management practices outlined in the State of Alaska Aquatic Nuisance Species Management Plan (Fay 2002).
- Encourage vessels to perform a ballast water exchange in marine waters to minimize the possibility of introducing invasive estuarine species into similar habitats.
- Discourage vessels that have not performed a ballast water exchange from discharging their ballast water into estuarine receiving waters.
- Require vessels brought from other areas over land via trailer to clean any surfaces that may harbor non-native plant or animal species (e.g., propellers, hulls, anchors, fenders).
- Treat effluent from public aquaria displays and laboratories and educational institutes using non-native species before discharge.
- Encourage proper disposal of seaweeds and other plant materials used for packing purposes when shipping fish or other animals.
- Undertake a thorough scientific review and risk assessment before any non-native species are introduced.

F.2.3.5 Pile Installation and Removal (From NMFS 2005)

Pilings are an integral component of many overwater and in-water structures. They provide support for the decking of piers and docks, function as fenders and dolphins to protect structures, support navigation markers, and help in the construction of breakwaters and bulkheads. Materials used in pilings include steel, concrete, wood (both treated and untreated), plastic, or a combination thereof. Piles are usually driven into the substrate by using either impact or vibratory hammers.

¹ <http://www.adfg.state.ak.us/special/invasive/invasive.ph>

F.2.3.5.1 Pile Driving

Potential Adverse Impacts

Pile driving can generate intense underwater sound pressure waves that may adversely affect EFH. These pressure waves have been shown to injure and kill fish (CalTrans 2001, Longmuir and Lively 2001, Stotz and Colby 2001, Stadler, pers. obs. 2002). Fish injuries associated directly with pile driving are poorly studied, but include rupture of the swim bladder and internal hemorrhaging (CalTrans 2001, Abbott and Bing-Sawyer 2002, Stadler pers. obs. 2002). Sound pressure levels (SPLs) 100 decibels (dB) above the threshold for hearing are thought to be sufficient to damage the auditory system in many fishes (Hastings 2002).

The type and intensity of the sounds produced during pile driving depend on a variety of factors, including the type and size of the pile, the firmness of the substrate into which the pile is being driven, the depth of water, and the type and size of the pile-driving hammer. Driving large hollow steel piles with impact hammers produces intense, sharp spikes of sound that can easily reach levels injurious to fish. Vibratory hammers, on the other hand, produce sounds of lower intensity, with a rapid repetition rate. A key difference between the sounds produced by impact hammers and those produced by vibratory hammers is the responses they evoke in fish. The differential responses to these sounds are due to the differences in the duration and frequency of the sounds.

Systems using air bubbles have been successfully designed to reduce the adverse effects of underwater SPLs on fish. Both confined (i.e., metal or fabric sleeve) and unconfined air bubble systems have been shown to attenuate underwater sound pressures (Longmuir and Lively 2001, Christopherson and Wilson 2002, Reyff and Donovan 2003).

Recommended Conservation Measures

The following recommended conservation measures for pile driving should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Install hollow steel piles with an impact hammer at a time of year when larval and juvenile stages of fish species with designated EFH are not present.

If the first measure is not possible, then the following measures regarding pile driving should be incorporated when practicable to minimize adverse effects:

- Drive piles during low tide when they are located in intertidal and shallow subtidal areas.
- Use a vibratory hammer when driving hollow steel piles.
- Implement measures to attenuate the sound should SPLs exceed the 180 dB (re: 1 μ Pa) threshold.
- Surround the pile with an air bubble curtain system or air-filled coffer dam.
- Use a smaller hammer to reduce sound pressures.
- Use a hydraulic hammer if impact driving cannot be avoided.

- Drive piles when the current is reduced in areas of strong current, to minimize the number of fish exposed to adverse levels of underwater sound.

F.2.3.5.2 Pile Removal

Potential Adverse Impacts

The primary adverse effect of removing piles is the suspension of sediments, which may result in harmful levels of turbidity and release of contaminants contained in those sediments (see earlier). Vibratory pile removal tends to cause the sediments to slough off at the mudline, resulting in relatively low levels of suspended sediments and contaminants. Breaking or cutting the pile below the mudline may suspend only small amounts of sediment, providing that the stub is left in place, and little digging is required to access the pile. Direct pull or use of a clamshell to remove broken piles may, however, suspend large amounts of sediment and contaminants. When the piling is pulled from the substrate using these two methods, sediments clinging to the piling will slough off as it is raised through the water column, producing a potentially harmful plume of turbidity and/or contaminants. The use of a clamshell may suspend additional sediment if it penetrates the substrate while grabbing the piling.

While there is a potential to adversely affect EFH during the removal of piles, many of the piles removed in Alaska are old creosote-treated timber piles. In some cases, the long-term benefits to EFH obtained by removing a chronic source of contamination may outweigh the temporary adverse effects of turbidity.

Recommended Conservation Measures

The following recommended conservation measures for pile removal should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Remove piles completely rather than cutting or breaking them off, if they are structurally sound.
- Minimize the suspension of sediments and disturbance of the substrate when removing piles. Measures to help accomplish this include, but are not limited to, the following:
 - When practicable, remove piles with a vibratory hammer.
 - Remove the pile slowly to allow sediment to slough off at, or near, the mudline.
 - The operator should first hit or vibrate the pile to break the bond between the sediment and the pile.
 - Encircle the pile, or piles, with a silt curtain that extends from the surface of the water to the substrate.
- Complete each pass of the clamshell to minimize suspension of sediment if pile stubs are removed with a clamshell.
- Place piles on a barge equipped with a basin to contain attached sediment and runoff water after removal.

- Using a pile driver, drive broken/cut stubs far enough below the mudline to prevent release of contaminants into the water column as an alternative to their removal.

F.2.3.6 Overwater Structures (from NMFS 2005)

Overwater structures include commercial and residential piers and docks, floating breakwaters, barges, rafts, booms, and mooring buoys. These structures typically are located in intertidal areas out to about 49 feet (15 meters) below the area exposed by the mean lower low tide (i.e., the shallow subtidal zone).

Potential Adverse Impacts

Overwater structures and associated developments may adversely affect EFH in a variety of ways, primarily by (1) changes in ambient light conditions, (2) alteration of the wave and current energy regime, (3) introduction of contaminants into the marine environment, and (4) activities associated with the use and operation of the facilities (Nightingale and Simenstad 2001b).

Recommended Conservation Measures

The following recommended conservation measures for overwater structures should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Use upland boat storage whenever possible to minimize need for overwater structures.
- Locate overwater structures in deep enough waters to avoid intertidal and shade impacts, minimize or preclude dredging, minimize groundings, and avoid displacement of submerged aquatic vegetation, as determined by a preconstruction survey.
- Design piers, docks, and floats to be multiuse facilities to reduce the overall number of such structures and to limit impacted nearshore habitat.
- Incorporate measures that increase the ambient light transmission under piers and docks.
 - Maximize the height and minimize the width to decrease the shade footprint.
 - Use reflective materials on the underside of the dock to reflect ambient light.
 - Use the fewest number of pilings necessary to support the structures.
 - Align piers, docks, and floats in a north-south orientation to allow the arc of the sun to cross perpendicular to the structure and to reduce the duration of light limitation.
- Use floating rather than fixed breakwaters whenever possible, and remove them during periods of low dock use. Encourage seasonal use of docks and off-season haul-out.
- Locate floats in deep water to avoid light limitation and grounding impacts to the intertidal or shallow subtidal zone.
- Maintain at least 1 foot (0.30 meter) of water between the substrate and the bottom of the float at extreme low tide.
- Conduct in-water work when managed species and prey species are least likely to be impacted.
- To the extent practicable, avoid the use of treated wood timbers or pilings.

- Mitigate for unavoidable impacts to benthic habitats.

F.2.3.7 Flood Control/Shoreline Protection (from NMFS 2005)

Structures designed to protect humans from flooding events can result in varying degrees of change in the physical, chemical, and biological characteristics of shoreline and riparian habitat. These structures also can have long-term adverse effects on tidal marsh and estuarine habitats. Tidal marshes are highly variable, but typically have freshwater vegetation at the landward side, saltwater vegetation at the seaward side, and gradients of species in between that are in equilibrium with the prevailing climatic, hydrographic, geological, and biological features of the coast. These systems normally drain through tidal creeks that empty into the bay or estuary. Freshwater entering along the upper edges of the marsh drains across the surface and enters the tidal creeks. Structures placed for coastal shoreline protection may include concrete or wood seawalls, rip-rap revetments (sloping piles of rock placed against the toe of the dune or bluff in danger of erosion from wave action), dynamic cobble revetments (natural cobble placed on an eroding beach to dissipate wave energy and prevent sand loss), vegetative plantings, and sandbags.

Potential Adverse Impacts

Dikes, levees, ditches, or other water controls at the upper end of a tidal marsh can cut off all tributaries feeding the marsh, preventing the flow of freshwater, annual renewal of sediments and nutrients, and the formation of new marshes. Water controls within the marsh can intercept and carry away freshwater drainage, thus blocking freshwater from flowing across seaward portions of the marsh, or conversely increase the speed of runoff of freshwater to the bay or estuary. This can result in lowering the water table, which may permit saltwater intrusion into the marsh, and create migration barriers for aquatic species. In deeper channels where anoxic conditions prevail, large quantities of hydrogen sulfide may be produced that are toxic to marsh grasses and other aquatic life (NMFS 2008). Acid conditions of these channels can also result in release of heavy metals from the sediments.

Long-term effects of shoreline protection structures on tidal marshes include land subsidence (sometimes even submergence), soil compaction, conversion to terrestrial vegetation, greatly reduced invertebrate populations, and general loss of productive wetland characteristics (NMFS 2005). Alteration of the hydrology of coastal salt marshes can reduce estuarine productivity, restrict suitable habitat for aquatic species, and result in salinity extremes during droughts and floods (NMFS 2008). Armoring shorelines to prevent erosion and to maintain or create shoreline real estate can reduce the amount of intertidal habitat, and affects nearshore processes and the ecology of numerous species (Williams and Thom 2001). Hydraulic effects on the shoreline include increased energy seaward of the armoring, reflected wave energy, dry beach narrowing, substrate coarsening, beach steepening, changes in sediment storage capacity, loss of organic debris, and downdrift sediment starvation (Williams and Thom 2001). Installation of breakwaters and jetties can result in community changes from burial or removal of resident biota, changes in cover and preferred prey species, and predator attraction (Williams and Thom 2001). As with armoring, breakwaters and jetties modify hydrology and nearshore sediment transport, as well as movement of larval forms of many species (Williams and Thom 2001).

Recommended Conservation Measures

The following recommended conservation measures for flood and shoreline protection should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Avoid or minimize the loss of coastal wetlands as much as possible.
- Do not dike or drain tidal marshlands or estuaries.
- Wherever possible, use soft in lieu of “hard” shoreline stabilization and modifications.
- Ensure that the hydrodynamics and sedimentation patterns are properly modeled and that the design avoids erosion to adjacent properties when “hard” shoreline stabilization is deemed necessary.
- Include efforts to preserve and enhance fishery habitat to offset impacts.
- Avoid installing new water control structures in tidal marshes and freshwater streams.
- Ensure water control structures are monitored for potential alteration of water temperature, dissolved oxygen concentration, and other parameters.
- Use seasonal restrictions to avoid impacts to habitat during critical life history stages.
- Address the cumulative impacts of development activities in the review process for flood control and shoreline protection projects.
- Use an adaptive management plan with ecological indicators to oversee monitoring and to ensure that mitigation objectives are met. Take corrective action as needed.

F.2.3.8 Log Transfer Facilities/In-Water Log Storage (from NMFS 2005)

Rivers, estuaries, and bays were historically the primary ways to transport and store logs in the Pacific Northwest, and log storage continues in some tidal areas today. Using estuaries and bays and nearby uplands for storage of logs is common in Alaska, with most log transfer facilities (LTFs) found in Southeast Alaska and a few located in Prince William Sound. LTFs are facilities that are constructed wholly or in part in waterways and used to transfer commercially harvested logs to or from a vessel or log raft, or for consolidating logs for incorporation into log rafts (USEPA 2000b). LTFs may use a crane, A-frame structure, conveyor, slide or ramp to move logs from land into the water. Logs can also be placed in the water at the site by helicopters.

Potential Adverse Impacts

Log handling and storage in the estuaries and intertidal zones can result in modification of benthic habitat and water quality degradation within the area of bark deposition (Levings and Northcote 2004). EFH may be physically impacted by activities associated with LTFs. LTFs may cause shading and other indirect effects similar in many ways to those of floating docks and other over-water structures (see earlier).

Recommended Conservation Measures

The following recommended conservation measures for log transfer and storage facilities should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

The physical, chemical, and biological impacts of LTF operations can be substantially reduced by adherence to appropriate siting and operational constraints. Adherence to the Alaska Timber Task Force (ATTF) operational and siting guidelines and BMPs in the National Pollutant Discharge Elimination System (NPDES) General Permit will reduce (1) the amount of bark and wood debris that enters the marine and coastal environment, (2) the potential for displacement or harm to aquatic species, and (3) the accumulation of bark and wood debris on the ocean floor. The following conservation measures reflect those guidelines.²

- Restrict or eliminate storage and handling of logs from waters where state and federal water quality standards cannot be met at all times outside of the authorized zone of deposition.
- Minimize potential impacts of log storage by employing effective bark and wood debris control, collection, and disposal methods at log dumps, raft building areas, and mill-side handling zones; avoiding free-fall dumping of logs; using easy let-down devices for placing logs in the water; and bundling logs before water storage (bundles should not be broken except on land and at millside).
- Do not store logs in the water if they will ground at any time or shade sensitive aquatic vegetation such as eelgrass.
- Avoid siting log-storage areas and LTFs in sensitive habitat and areas important for specified species, as required by the ATTF guidelines.
- Site log storage areas and LTFs in areas with good currents and tidal exchanges.
- Use land-based storage sites where possible.

F.2.3.9 Utility Line, Cables, and Pipeline Installation

With the continued development of coastal regions comes greater demand for the installation of cables, utility lines for power and other services, and pipelines for water, sewage, and other utilities. The installation of pipelines, utility lines, and cables can have direct and indirect impacts on the offshore, nearshore, estuarine, wetland, beach, and rocky shore coastal zone habitats. Many of the direct impacts occur during construction, such as ground disturbance in the clearing of the right-of-way, access roads, and equipment staging areas. Indirect impacts can include increased turbidity, saltwater intrusion, accelerated erosion, and introduction of urban and industrial pollutants due to ground clearing and construction.

Potential Adverse Impacts

Adverse effects on EFH from the installation of pipelines, utility lines, and cables can occur through (1) destruction of organisms and habitat; (2) turbidity impacts; (3) resuspension and

² See also http://www.fs.fed.us/r10/TLMP/F_PLAN/APPEND_G.PDF.

release of contaminants; (4) changes in hydrology; and; (5) destruction of vertically complex hard bottom habitat (e.g., hard corals and vegetated rocky reef).

Recommended Conservation Measures

The following recommended conservation measures for cable and utility line installation should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Align crossings along the least environmentally damaging route.
- Use horizontal directional drilling where cables or pipelines would cross anadromous fish streams, salt marsh, vegetated inter-tidal zones, or steep erodible bluff areas adjacent to the intertidal zone.
- Store and contain excavated material on uplands.
- Backfill excavated wetlands with either the same or comparable material capable of supporting similar wetland vegetation, and at original marsh elevations.
- Use existing rights-of-way whenever possible.
- Bury pipelines and submerged cables where possible.
- Remove inactive pipelines and submerged cables unless they are located in sensitive areas (e.g., marsh, reefs, sea grass).
- Use silt curtains or other barriers to reduce turbidity and sedimentation whenever possible.
- Limit access for equipment to the immediate project area. Tracked vehicles are preferred over wheeled vehicles.
- Limit construction equipment to the minimum size necessary to complete the work.
- Conduct construction during the time of year when it will have the least impact on sensitive habitats and species.
- Suspend transmission lines beneath existing bridges or conduct directional boring under streams to reduce the environmental impact.
- For activities on the Continental Shelf, implement the following to the extent practicable:
 - Shunt drill cuttings through a conduit and either discharge the cuttings near the sea floor, or transport them ashore.
 - Locate drilling and production structures, including pipelines, at least 1 mile (1.6 kilometers) from the base of a hard-bottom habitat.
 - Bury pipelines at least 3 feet (0.9 meter) beneath the sea floor whenever possible.
 - Locate alignments along routes that will minimize damage to marine and estuarine habitat.

F.2.3.10 Mariculture

Productive embayments are often used for commercial culturing and harvesting operations. These locations provide protected waters for geoduck, oyster, and mussel culturing. In 1988, Alaska passed the Alaska Aquatic Farming Act (AAF Act) which is designed to encourage establishment and growth of an aquatic farming industry in the state. The AAF Act establishes four criteria for issuance of an aquatic farm permit, including the requirement that the farm may not significantly affect fisheries, wildlife, or other habitats in an adverse manner. Aquatic farm permits are issued by the Alaska Department of Natural Resources (ADNR).

Potential Adverse Impacts

Shellfish aquaculture tends to have less impact on EFH than finfish aquaculture because the shellfish generally are not fed or treated with chemicals (OSPAR Commission 2009). Adverse impacts to EFH by mariculture operations include (1) risk of introducing undesirable species and disease; (2) physical disturbance of intertidal and subtidal areas; (3) impacts on estuarine food webs, including disruption of eelgrass habitat (e.g., dumping of shell on eelgrass beds, repeated mechanical raking or trampling, and impacts from predator exclusion netting, though few studies have documented impacts). Hydraulic dredges used to harvest oysters in coastal bays can cause long-term adverse impacts to eelgrass beds by reducing or eliminating the beds (Phillips 1984).

Recommended Conservation Measures

The following recommended conservation measures for mariculture facilities should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Site mariculture operations away from kelp or eelgrass beds.
- Do not enclose or impound tidally influenced wetlands for mariculture.
- Undertake a thorough scientific review and risk assessment before any non-native species are introduced.
- Encourage development of harvesting methods to minimize impacts on plant communities and the loss of food and/or habitat to fish populations during harvesting operations.
- Provide appropriate mitigation for the unavoidable, extensive, or permanent loss of plant communities.
- Ensure that mariculture facilities, spat, and related items transported from other areas are free of nonindigenous species.

F.2.4 Coastal/Marine Activities

F.2.4.1 Point-Source Discharges

Point source pollutants are generally introduced via some type of pipe, culvert, or similar outfall structure. These discharge facilities typically are associated with domestic or industrial activities, or in conjunction with collected runoff from roadways and other developed portions of the coastal landscape. Waste streams from sewage treatment facilities and watershed runoff may be combined in a single discharge. Point source discharges introduce inorganic and organic

contaminants into aquatic habitats, where they may become bioavailable to living marine resources.

Potential Adverse Impacts (adopted from NMFS 2008)

The Clean Water Act (CWA) includes important provisions to address acute or chronic water pollution emanating from point source discharges. Under the NPDES program, most point-source discharges are regulated by the state or EPA. While the NPDES program has led to ecological improvements in U.S. waters, point sources continue to introduce pollutants into the aquatic environment, albeit at reduced levels.

Determining the fate and effect of natural and synthetic contaminants in the environment requires an interdisciplinary approach to identify and evaluate all processes sensitive to pollutants. This is critical as adverse effects may be manifested at the biochemical level in organisms (Luoma 1996) in a manner particular to the species or life stage exposed. Exposure to pollutants can inhibit (1) basic detoxification mechanisms, e.g., production of metallothioneins or antioxidant enzymes; (2) disease resistance; (3) the ability of individuals or populations to counteract pollutant-induced metabolic stress; (4) reproductive processes including gamete development and embryonic viability; (5) growth and successful development through early life stages; (6) normal processes including feeding rate, respiration, osmoregulation; and (7) overall Darwinian fitness (Capuzzo and Sassner 1977; Widdows et al. 1990; Nelson et al. 1991; Stiles et al. 1991; Luoma 1996; Thurberg and Gould 2005).

Recommended Conservation Measures

The following recommended conservation measures for point source discharges should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Locate discharge points in coastal waters well away from shellfish beds, sea grass beds, corals, and other similar fragile and productive habitats.
- Reduce potentially high velocities by diffusing effluent to acceptable velocities.
- Determine baseline benthic productivity by sampling before any construction activity.
- Provide for mitigation when degradation or loss of habitat occurs.
- Institute source-control programs that effectively reduce noxious materials.
- Ensure compliance with pollutant discharge permits, which set effluent limitations and/or specify operation procedures, performance standards, or BMPs.
- Treat discharges to the maximum extent practicable.
- Use land-treatment and upland disposal/storage techniques where possible.
- Avoid siting pipelines and treatment facilities in wetlands and streams.

F.2.4.2 Seafood Processing Waste—Shoreside and Vessel Operation

Seafood processing is conducted throughout much of coastal Alaska. Processing facilities may be vessel-based or located onshore (ADEC 2010a). Seafood processing facilities generally consist of mechanisms to offload the harvest from fishing boats; tanks to hold the seafood until

the processing lines are ready to accept them; processing lines, process water, and waste collection systems; treatment and discharge facilities; processed seafood storage areas; and necessary support facilities such as electrical generators, boilers, retorts, water desalinators, offices, and living quarters. In addition, recreational fish cleaning at marinas and small harbors can produce a large quantity of fish waste.

Pollutants of concern from seafood processing wastewater are primarily components of the biological wastes generated by processing raw seafood into a marketable form, chemicals used to maintain sanitary conditions for processing equipment and fish containment structures, and refrigerants (ammonia and freon) that may leak from refrigeration systems used to preserve seafood (ADEC 2010b). Biological wastes include fish parts (e.g., heads, fins, bones, entrails); and chemicals, which are primarily disinfectants that must be used in accordance with EPA specifications.

Potential Adverse Impacts

Seafood processing operations have the potential to adversely affect EFH through the discharge of nutrients, chemicals, fish byproducts, and “stickwater” (water and entrained organics originating from the draining or pressing of steam-cooked fish products). Seafood processing discharges influence nutrient loading, eutrophication, and anoxic and hypoxic conditions significantly influencing marine species diversity and water quality (Theriault et al. 2006, Roy Consultants 2003, Lotze et al. 2003). Although fish waste is biodegradable, fish parts that are ground to fine particles may remain suspended for some time, thereby overburdening habitats from particle suspension (NMFS 2005). Scum and foam from seafood waste deposits can also occur on the water surface and/or increase turbidity. Turbidity decreases light penetration into the water column, reducing primary production. In addition, stickwater takes the form of a fine gel or slime that can concentrate on surface waters and move onshore to cover intertidal areas.

Recommended Conservation Measures

The following recommended conservation measures for fish processing waste should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- To the maximum extent practicable, base effluent limitations on site-specific water quality concerns.
- Encourage the use of secondary or wastewater treatment systems where possible.
- Do not allow designation of new zones of deposit for fish processing waste and instead seek disposal options that avoid an accumulation of waste.
- Promote sound recreational fish waste management through a combination of fish-cleaning restrictions, public education, and proper disposal of fish waste.
- Encourage alternative uses of fish processing wastes.
- Explore options for additional research.
- Monitor biological and chemical changes to the site of processing waste discharges.

F.2.4.3 Water Intake Structures/Discharge Plumes

Withdrawals of riverine, estuarine, and marine waters are common for a variety of uses such as to cool power-generating stations and create temporary ice roads and ice ponds. In the case of power plants, the subsequent discharge of heated and/or chemically treated discharge water can also occur.

Potential Adverse Impacts

Water intake structures and effluent discharges can interfere with or disrupt EFH functions in the source or receiving waters by (1) entrainment, (2) impingement, (3) degrading water quality, (4) operation and maintenance, and (5) construction-related impacts.

Recommended Conservation Measures

The following recommended conservation measures for water intakes and discharges should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Locate facilities that rely on surface waters for cooling in areas other than estuaries, inlets, heads of submarine canyons, rock reefs, or small coastal embayments where managed species or their prey concentrate.
- Design intake structures to minimize entrainment or impingement.
- Design power plant cooling structures to meet the best technology available requirements as developed pursuant to section 316(b) of the CWA.
- Regulate discharge temperatures so they do not appreciably alter the ambient temperature to an extent that could cause a change in species assemblages and ecosystem function in the receiving waters.
- Avoid the use of biocides (e.g., chlorine) to prevent fouling where possible.
- Treat all discharge water from outfall structures to meet state water quality standards at the terminus of the pipe.

F.2.4.4 Oil and Gas Exploration, Development, and Production

Two agencies, the Bureau of Ocean Energy Management and the Bureau of Safety and Environmental Enforcement are responsible for regulating oil and gas operations on the Outer Continental Shelf (OCS). The ADNRR Division of Oil and Gas exercises similar authority over State waters (ADNRR 1999). Offshore petroleum exploration, development, and production activities have been conducted in Alaska waters or on the Alaska OCS since the 1960s (Kenai Peninsula Borough 2004). As demand for energy resources grows, the debate over trying to balance the development of oil and gas resources and the protection of the environment will also continue.

Potential Adverse Impacts

Offshore oil and gas operations can be classified into exploration, development, and production activities (which includes transportation). These activities occur at different depths in a variety of habitats, and can cause an assortment of physical, chemical, and biological disturbances

(NMFS 2005, Helvey 2002). (Some of these disturbances are listed below; however, not all of the potential disturbances in this list apply to every type of activity.)

- Noise from seismic surveys, vessel traffic, and construction of drilling platforms or islands
- Physical alterations to habitat from the construction, presence, and eventual decommissioning and removal of facilities such as islands or platforms, storage and production facilities, and pipelines to onshore common carrier pipelines, storage facilities, or refineries
- Waste discharges, including well drilling fluids, produced waters, surface runoff and deck drainage, domestic waste waters generated from the offshore facility, solid waste from wells (drilling muds and cuttings), and other trash and debris from human activities associated with the facility
- Oil spills
- Platform storage and pipeline decommissioning

The potential disturbances and associated adverse impacts on the marine environment have been reduced through operating procedures required by regulatory agencies and, in many cases, self-imposed by facilities operators. Most of the activities associated with oil and gas operations are conducted under permits and regulations that require companies to minimize impacts or avoid construction in sensitive marine habitats. New technological advances in operating procedures also reduce the potential for impacts.

Recommended Conservation Measures

The following recommended conservation measures for oil and gas exploration and development should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH:

- Avoid the discharge of produced waters into marine waters and estuaries.
- Avoid discharge of muds and cuttings into the marine and estuarine environment.
- To the extent practicable, avoid the placement of fill to support construction of causeways or structures in the nearshore marine environment.
- As required by federal and state regulatory agencies, encourage the use of geographic response strategies that identify EFH and environmentally sensitive areas.
- Evaluate potential impacts to EFH that may result from activities carried out during the decommissioning phase of oil and gas facilities.
- Vessel operations and shipping activities should be familiar with Alaska Geographic Response Strategies which detail environmentally sensitive areas of Alaska's coastline.

F.2.4.5 Habitat Restoration and Enhancement

Habitat loss and degradation are major, long-term threats to the sustainability of fishery resources (NMFS 2002). Viable coastal and estuarine habitats are important to maintaining healthy fish stocks. Good water quality and quantity, appropriate substrate, ample food sources,

and adequate shelter from predators are needed to sustain fisheries. Restoration and/or enhancement of coastal and riverine habitat that supports managed fisheries and their prey will assist in sustaining and rebuilding fish stocks by increasing or improving ecological structure and functions. Habitat restoration and enhancement may include, but is not limited to, improvement of coastal wetland tidal exchange or reestablishment of natural hydrology; dam or berm removal; fish passage barrier removal or modification; road-related sediment source reduction; natural or artificial reef, substrate, or habitat creation; establishment or repair of riparian buffer zones; improvement of freshwater habitats that support anadromous fishes; planting of native coastal wetland and submerged aquatic vegetation; and improvements to feeding, shade or refuge, spawning, and rearing areas that are essential to fisheries.

Potential Adverse Impacts

The implementation of restoration and enhancement activities may have localized and temporary adverse impacts on EFH. Possible impacts can include (1) localized nonpoint source pollution such as influx of sediment or nutrients, (2) interference with spawning and migration periods, (3) temporary removal feeding opportunities, (4) indirect effects from construction phase of the activity (5) direct disturbance or removal of native species, and (6) temporary or permanent habitat disturbance.

Recommended Conservation Measures

The following recommended conservation measures for habitat restoration and enhancement should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Use BMPs to minimize and avoid potential impacts to EFH during restoration activities.
 - Use turbidity curtains, hay bales, and erosion mats.
 - Plan staging areas in advance, and keep them to a minimum size.
 - Establish buffer areas around sensitive resources.
 - Remove invasive plant and animal species from the proposed action area before starting work. Plant only native plant species.
 - Establish temporary access pathways before restoration activities.
- Avoid restoration work during critical life stages for fish such as spawning, nursery, and migration.
- Provide adequate training and education for volunteers and project contractors to ensure minimal impact to the restoration site.
- Conduct monitoring before, during, and after project implementation.
- To the extent practicable, mitigate any unavoidable damage to EFH.
- Remove and, if necessary, restore any temporary access pathways and staging areas used.
- Determine benthic productivity by sampling before any construction activity in the case of subtidal enhancement (e.g., artificial reefs). Avoid areas of high productivity to the maximum extent possible.

F.2.4.6 Marine Mining

Mining activities, which are also described in Sections 3.1.1 and 3.1.2 of the EFH EIS (NMFS 2005), can lead to the direct loss or degradation of EFH for certain species. Offshore mining, such as the extraction of gravel and gold in the Bering Sea, can increase turbidity, and resuspension of organic materials could impact eggs and recently hatched larvae in the area. Mining large quantities of beach gravel can also impact turbidity, and may significantly affect the transport and deposition of sand and gravel along the shore, both at the mining site and down-current (NMFS 2005).

Potential Adverse Impacts

Impacts from mining on EFH include both physical impacts (i.e., intertidal dredging) and chemical impacts (i.e., additives such as flocculants) (NMFS 2005). Physical impacts may include the removal of substrates that serve as habitat for fish and invertebrates; habitat creation or conversion in less productive or uninhabitable sites, such as anoxic holes or silt bottom; burial of productive habitats, such as in near-shore disposal sites (as in beach nourishment); release of harmful or toxic materials either in association with actual mining, or in connection with machinery and materials used for mining; creation of harmful turbidity levels; and adverse modification of hydrologic conditions so as to cause erosion of desirable habitats. Submarine disposal of mine tailings can also alter the behavior of marine organisms.

Recommended Conservation Measures

The following recommended conservation measures for marine mining should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- To the extent practicable, avoid mining in waters containing sensitive marine benthic habitat, including EFH (e.g., spawning, migrating, and feeding sites).
- Minimize the areal extent and depth of extraction to reduce recolonization times.
- Monitor turbidity during operations, and cease operations if turbidity exceeds predetermined threshold levels.
- Monitor individual mining operations to avoid and minimize cumulative impacts.
- Use seasonal restrictions as appropriate to avoid and minimize impacts to EFH during critical life history stages of managed species (e.g., migration and spawning).
- Deposit tailings within as small an area as possible.

F.2.5 References

- Abbe, T.B. and D.R. Montgomery. 1996. "Large woody debris jams, channel hydraulics, and habitat formation in large rivers." *Regulated Rivers: Research and Management*. 12:201-221.
<http://www.cems.uvm.edu/ce361/papers/abbe1996.pdf>
- Abbott, R. and E. Bing-Sawyer. 2002. Assessment of pile driving impacts on the Sacramento blackfish (*Othodon microlepidotus*). Draft report prepared for Caltrans District 4. October 10, 2002.

- Alaska Department of Environmental Conservation (ADEC). 2010a. Ocean Discharge Criteria Evaluation Alaska Offshore Seafood Processors APDES General Permit AKG523000. Prepared by Tetra Tech, 10306 Eaton Place Suite 340, Fairfax, VA 22030. 152 pp.
- ADEC. 2010b. Wastewater Discharge Authorization Program, 555 Cordova Street, Anchorage, AK 99501. Fact Sheet Alaska Offshore Seafood Processors General Permit AKG523000. 43 pp.
- Alaska Department of Natural Resources (ADNR). 1999. Cook Inlet Areawide 1999 Oil and Gas Lease Sale, Final Finding of the Director. Volume II. Appendix B: "Laws and Regulations Pertaining to Oil and Gas Exploration, Development, Production, and Transportation."
- American Fisheries Society (AFS). 2000. AFS Policy Statement #13: Effects of Surface Mining on Aquatic Resources in North America (Revised). (Abbreviated) http://www.fisheries.org/afs/docs/policy_13f.pdf
- Arruda, J.A., G.R. Marzolf, R.T. Faulk. 1983. The role of suspended sediments in the nutrition of zooplankton in turbid reservoirs. *Ecology* 64(5):1225-35.
- Atlantic States Marine Fisheries Commission. 1992. Fishery management plan for inshore stocks of winter flounder. Washington (DC): ASMFC. FMR No. 21. 138 p.
- Barr B.W. 1993. Environmental impacts of small boat navigation: vessel/sediment interactions and management implications. In: Magoon OT, editor. Coastal Zone '93: proceedings of the eighth Symposium on Coastal and Ocean Management; 1993 Jul 19-23; New Orleans, LA. American Shore and Beach Preservation Association. p 1756-70.
- Benfield, M.C. and T. J. Minello. 1996. "Relative effects of turbidity and light intensity on reactive distance and feeding of an estuarine fish." *Environmental Biology of Fishes*. 46:211-216.
- Brix, K.V., D.K. DeForest, and W.J. Adams 2001. Assessing acute and chronic copper risks to freshwater aquatic life using species sensitivity distributions for different taxonomic groups. *Environmental Toxicology and Chemistry*. 20(8): 1846-1856.
- CalTrans. 2001. Fisheries Impact Assessment, Pile Installation Demonstration Project for the San Francisco - Oakland Bay Bridge, East Span Seismic Safety Project, August 2001. 59 pp.
- Capuzzo J.M., and J.J. Sassner Jr. 1977. The effect of chromium on filtration rates and metabolic activity of *Mytilus edulis* L. and *Mya arenaria* L. In: Vernberg FJ, and others, editors. Physiological responses of marine biota to pollutants. San Diego (CA): Academic Press. p 225-37.
- Center for Watershed Protection (CWP). 2003. Impacts of Impervious Cover on Aquatic Systems. Elliott City, MD, www.cwp.org. 141 pp.
- Christopherson, A. and J. Wilson. 2002. Technical Letter Report Regarding the San Francisco-Oakland Bay Bridge East Span Project Noise Energy Attenuation Mitigation. Peratrovich, Nottingham & Drage, Inc. Anchorage, Alaska. 27 pp.
- Cloern, J.E. 1987. "Turbidity as a control on phytoplankton biomass and productivity in estuaries." *Continental Shelf Research*. 7:1367-1381.
- Conner, Billy, Director Alaska University Transportation Center. University of Alaska, Fairbanks PO Box 755900. 2007 Interview in Building Alaska. http://www.buildingalaskamovie.com/interviews_billy.html
- Deegan, L.A. and R.N. Buchsbaum. 2005. The effect of habitat loss and degradation on fisheries. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline on fisheries resources in New England: evaluating the

- impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 67-96.
- Dennison, W.C. 1987. "Effect of light on seagrass photosynthesis, growth and depth distribution." *Aquatic Botany*. 27:15-26.
- Dugan, J.E., D.M. Hubbard, D.L. Martin, J.M. Engle, D.M. Richards, G.E. Davis, K.D. Lafferty, and R.F. Ambrose. 2000. Macrofauna communities of exposed sandy beaches on the Southern California mainland and Channel Islands. pp 339-346. In Brown, D.R., K.L. Mitchell, and H.W. Chang, eds. Proceedings of the Fifth California Islands Symposium. Minerals Management Service Publication # 99-0038.
- Farag, A.M., D.A. Skaar, E. Nimick, C. MacConnell, and C. Hogstrand. 2003. Characterizing aquatic health using salmonids mortality, physiology, and biomass estimates in streams with elevated concentrations of arsenic, cadmium, copper, lead, and zinc in the Boulder River Watershed, Montana. *Transaction of the American Fisheries Society* 132(3): 450-457.
- Fay, V. 2002. Alaska Aquatic Nuisance Species Management Plan. Alaska Department of Fish and Game Publication. Juneau, AK. http://www.adfg.state.ak.us/special/invasive/ak_ansmp.pdf.
- Goldstein, J.N., D.F. Woodward, and A.M. Farag. 1999. Movement of adult Chinook salmon during spawning migration in a metals-contaminated system, Coeur d'Alene River, Idaho. *Transactions of the American Fisheries Society* 128:121-129.
- Gregory, S.V. and P.A. Bisson. 1997. Degradation and loss of anadromous salmonid habitat in the Pacific Northwest. In Stouder, J.D., P.A. Bisson, and R.J. Naiman, eds. *Pacific Salmon and Their Ecosystems: Status and Future Options*, pp. 277-314. Chapman and Hall, New York.
- Groundwater Protection Council. 2010. State Groundwater Fact Sheets. http://www.gwpc.org/e-library/documents/state_fact_sheets/alaska.pdf. Ground Water Protection Council, 13308 N. MacArthur Blvd., Oklahoma City, OK 73142.
- Hansen, J.A., Lipton J., and Welsh P.G. 2002. *Environmental toxicology and chemistry*. 21 (3): 633-639
- Hastings, M.C. 2002. Clarification of the meaning of sound pressure levels and the known effects of sound on fish. Document in support of Biological Assessment for San Francisco-Oakland Bay Bridge East Span Seismic Safety Project. August 26, 2002. Revised August 27, 2002. 8 pp.
- Helvey, M. 2002. "Are southern California oil and gas platforms essential fish habitat?" *ICES Journal of Marine Science*. 59:S266-S271.
- Kenai Peninsula Borough. 2004. Cook Inlet Oil and Gas, Kenai Peninsula Borough Oil and Gas History. <http://www.cookinletoilandgas.org/kpb/history.htm>
- Kohler, C.C. and W.R. Courtenay, Jr. 1986. "Introduction of aquatic species." *Fisheries*. 11(2):39-42. Proceedings of the Seventh International Zebra Mussel and Aquatic Nuisance Species Conference. 1997.
- Koski, K.V. 1992. Restoring stream habitats affected by logging activities. Pages 343-404 in G. W. Thayer (editor) *Restoring the nation's marine environment*. Publication UM-SG-TS-92-06. Maryland Sea Grant College, College Park, MD.
- Larson, K. and C. Moehl. 1990. Entrainment of anadromous fish by hopper dredge at the mouth of the Columbia River. In C.A. Simenstad, ed. *Effects of dredging on anadromous Pacific coast fishes*. University of Washington Sea Grant. pp. 102-112.

- Levings, C.D. and T. G. Northcote. 2004. Effects of forestry on estuarine ecosystems supporting fishes. *In* T.G. Northcote and G.F.Hartman, editors, *Fishes and Forestry Worldwide Watershed Interactions and Management*, Blackwell Publishing, pp 320 -335.
- Longmuir, C. and T. Lively. 2001. Bubble curtain systems for use during marine pile driving. Report by Fraser River Pile & Dredge Ltd., New Westminster, British Columbia. 9 pp.
- Lotze, H., I. Milewski, B. Worm, and Z. Koller. 2003 Nutrient Pollution: A Eutrophication Survey of Eelgrass Beds in Estuaries and Coastal Bays in Northern and Eastern New Brunswick. Conservation Council of New Brunswick Inc.
- Luce, A. and M.Crowe. 2001. "Invertebrate terrestrial diversity along a gravel road on Barrie Island, Ontario, Canada." *Great Lakes Entomologist*. 34(1):55-60 SPR-SUM.
- Luoma, S.N. 1996. The developing framework of marine ecotoxicology: pollutants as a variable in marine ecosystems. *Journal of Experimental Marine Biology and Ecology* 200:29-55.
- Maser, C. and J.R. Sedell. 1994. *From the Forest to the Sea: the Ecology of Wood in Streams, Estuaries and Oceans*. St. Lucie Press, Delray Beach, FL. 200 pp.
- McGraw, K. and D. Armstrong. 1990. Fish entrainment by dredges in Grays Harbor, Washington. *In* C.A. Simenstad, ed. *Effects of dredging on anadromous Pacific coast fishes*. University of Washington Sea Grant. pp. 113-131.
- Mitsch W.J., Gosselink JG. 1993. *Wetlands*. 2nd ed. New York (NY): Van Nostrand Reinhold. 722 pp.
- Montgomery, D.R., R.D. Smith, K.M. Schmidt, and G.R. Pess. 1995. "Pool Spacing in Forest Channels." *Water Resources Research*. 31:1097-1105.
- National Marine Fisheries Service (NMFS). 2011. *Impacts to Essential Fish Habitat from Non-fishing Activities in Alaska*. National Marine Fisheries Service, Alaska Region. Juneau, Alaska. November, 2011.
- NMFS. 2008. *Impacts to Marine Fisheries Habitat from Nonfishing Activities in the Northeastern United States*. Northeast Regional Office Gloucester, Massachusetts NOAA Technical Memorandum NMFS-NE-209.
- NMFS. 2005. *Final Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska, Appendix G Non-fishing Impacts to Essential Fish Habitat and Recommended Conservation Measures*.
- NMFS. 2004. *Draft National Gravel Extraction Policy*. 1335 East-West Highway, Silver Spring, MD 20910. <http://www.nmfs.noaa.gov/habitat/habitatprotection/pdf/gravelguidance.pdf>
- NMFS. 2002. *Environmental Assessment, NMFS' Restoration Plan for the Community-Based Restoration Program*. Prepared by the NOAA Restoration Center, Office of Habitat Conservation. Silver Spring, MD.
- NMFS. 1998a. *Draft document - Non-fishing threats and water quality: A reference for EFH consultation*
- NMFS. 1998b. *Final recommendations: Essential Fish Habitat for Pacific Coast Groundfish*. Prepared by: The Core Team for EFH for Pacific Coast Groundfish June 3, 1998. 2725 Montlake Blvd. E. Seattle, WA 98112. http://www.psmfc.org/efh/groundfish_desc.pdf.
- National Oceanic and Atmospheric Agency (NOAA). 2010. *Office of Ocean and Coastal Resource Management. Ocean and Coastal Management in Alaska*. <http://coastalmanagement.noaa.gov/mystate/ak.html>.

- National Research Council. 1999. Committee on Hardrock Mining. Hardrock Mining on Federal Lands. Appendix B. Potential Environmental Impacts of Hardrock Mining. (http://www.nap.edu/html/hardrock_fed_land/appB.html).
- Nelson D, Miller J, Rusanowsky D, Greig R, Sennefelder G, Mercaldo-Allen R, Kuropat C, Gould E, Thurberg F, Calabrese A. 1991. Comparative reproductive success of winter flounder in Long Island Sound: a three-year study (biology, biochemistry, and chemistry). *Estuaries* 14(3):318-31.
- Newell, R.C., L.J. Seiderer, and D.R. Hitchcock. 1998. "The impact of dredging on biological resources of the sea bed." *Oceanography and Marine Biology Annual Review*. 36:127-178.
- Nightingale, B. and C.A. Simenstad. 2001a. Dredging activities: Marine issues. Washington State Transportation Center, University of Washington, Seattle, WA 98105. (Document available through the National Technical Information Service, Springfield, VA 22616).
- Nightingale, B. and C.A. Simenstad. 2001b. Overwater Structures: Marine Issues. White paper submitted to Washington Department of Fish and Wildlife, Washington Department of Ecology and Washington Department of Transportation. www.wa.gov/wdfw/hab. 133 pp.
- North Pacific Fishery Management Council and NMFS. 2010. Essential Fish Habitat (EFH) 5-year Review for 2010 Summary Report: Final. April 2010. <http://www.alaskafisheries.noaa.gov/habitat/efh/review.htm>.
- Northcote, T.G. and G.F. Hartman. 2004. Fishes and Forestry - Worldwide Watershed Interactions and Management, Blackwell Publishing, Oxford, UK, 789 pp.
- Omori, M., S. Van der Spoel, C.P. Norman. 1994. Impact of human activities on pelagic biogeography. *Progress in Oceanography* 34 (2-3):211-219.
- Oregon Water Resource Research Institute (OWRRI). 1995. Gravel disturbance impacts on salmon habitat and stream health, volume 1. Summary report. Oregon State University, Corvallis, Oregon. (Also available Vol. II: Technical background report). Available from Oregon Division of State Lands, Salem, Oregon, 503-378-3805.
- OSPAR Commission. 2009. Assessment of Impacts of Mariculture . Publication Number: 442/2009. London, UK
- Pacific Fishery Management Council (PFMC). 1999. Appendix A: Identification and description of essential fish habitat, adverse impacts, and recommended conservation measures for salmon. Amendment 14 to the Pacific Coast Salmon Plan. Portland, OR. 146 pp.
- Packer, D.B., Griffin K., McGlynn K.E. 2005. National Marine Fisheries Service national gravel extraction guidance. Washington (DC): US Department of Commerce. NOAA Technical Memorandum NMFS-F/SPO-70. [cited 2008 Jul 15]. 27 p. Available from: <http://www.nmfs.noaa.gov/habitat/habitatprotection/anadfish/gravel.htm>.
- Phillips, R.C. 1984. The ecology of eelgrass meadows in the Pacific Northwest: a community profile. U.S. Fish and Wildlife Service. FWS/OBS-84/24. 85 pp.
- Ralph, S., G. Poole, L. Conquest, and R. Naiman. 1994. "Stream channel morphology and woody debris in logged and unlogged basins in western Washington." *Can. J. Fish. Aquatic Sciences*. 51:37-51.
- Reyff, J.A and P. Donovan. 2003. Benicia-Martinez Bridge Bubble Curtain Test - Underwater Sound Measurement Data. Memo to Caltrans dated January 31, 2003. 3 pp.
- Robinson W.E., and Pederson J. 2005. Contamination, habitat degradation, overfishing - An "either-or" debate? In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England:

- evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 1-10.
- Rosecchi, E., A.J. Crivelli, G. Catsadorakis. 1993. The establishment and impact of *Pseudorabiosa parva*, an exotic fish species introduced into lake Mikri Prespa (northwestern Greece). *Aquatic Conservation: Marine and Freshwater Ecosystems* 3:223-231.
- Roy Consultants Ltd., NATECH Environmental Services Inc. and OCL Group. Environmental Management Consultants. 2003. Lamèque Bay environmental management study. Report No. 133-01.
- Scott G.I., M.H. Fulton, D.W. Moore, E.F. Wirth, G.T. Chandler, P.B. Key, J.W. Daugomah, E.D. Strozier, J. Devane, J.R. Clark, M.A. Lewis, D.B. Finley, W. Ellenberg, and K.J. Karnaky. 1999. "Assessment of risk reduction strategies for the management of agricultural nonpoint source pesticide runoff in estuarine ecosystems." *Toxicology and Industrial Health*. 15:200-213.
- Sedell, J.R., and K.J. Luchessa. 1982. Using the historical record as an aid to salmonid habitat enhancement. In Armantrout, N.B. (ed.), *Acquisition and utilization of aquatic habitat inventory information*, p. 210-222. American Fisheries Society, Western Division, Bethesda, MD.
- Sengupta, M. 1993. *Environmental Impacts of Mining: Monitoring, Restoration, and Control*. CRC Press, Inc. 2000 Corporate Blvd., N.W. Boca Raton, FL. 33431. p.1.
- Spence, B.C., G.A. Lomnický, R.M. Hughes, and R.P. Novitzki. 1996. An ecosystem approach to salmonid conservation. TR-4501-96-6057. ManTech Environmental Research Services Corp., Corvallis, OR. 356 pp. (Available from the NMFS Habitat Branch, Portland, OR).
- Stadler, J.H. 2002. Personal observation of fish-kill occurring during pile driving activity at the Winslow Ferry Terminal, Winslow, WA. October 7, 2002. Fish Biologist, DOC/NOAA/National Marine Fisheries Service/HCD, Lacey, WA.
- Stiles, S., J. Choromanski, D. Nelson, J. Miller, R. Grieg, and G. Sennefelder. 1991. Early reproductive success of the hard clam (*Mercenaria mercenaria*) from five sites in Long Island Sound. *Estuaries* 14(3):332-42.
- Stotz, T. and J. Colby. 2001. January 2001 dive report for Mukilteo wingwall replacement project. Washington State Ferries Memorandum. 5 pp. + appendices.
- Theriault, M.H., S.C. Courtenay, C. Godin and W.B. Ritchie. 2006. Evaluation of the Community Aquatic Monitoring Program (CAMP) to assess the health of four coastal areas within the southern Gulf of St. Lawrence with special reference to the impacts of effluent from seafood processing plants. *Can. Tech. Rep. Fish. Aquat. Sci.* 2649: vii + 60 p.
- Thurberg, F.P., and E. Gould. 2005. Pollutant effects upon cod, haddock, pollock, and flounder of the inshore fisheries of Massachusetts and Cape Cod Bays. In: Buchsbaum R, Pederson J, Robinson WE, editors. *The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation*. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 43-66.
- Trombulak, S.C. and C.A. Frissell. 2000. "Review of ecological effects of roads on terrestrial and aquatic communities." *Conservation Biology*. 14(10):18-30. February.
- United States Department of Agriculture Forest Service. 2008. Tongass Monitoring and Evaluation Report – Appendix B http://www.fs.fed.us/r10/tongass/projects/tlmp/2008_monitoring_report/index2008.shtml
- United States Environmental Protection Agency (USEPA). 2000a. Environmental Screening Checklist and Workbook for the Water Transportation Industry. August 2000.

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- USEPA, Region 10. 2000b. Authorization to discharge under the National Pollutant Discharge Elimination System (NPDES) for Section 402 modifications of Section 404 permits for log Transfer Facilities which received a Section 404 permit prior to October 22, 1985. NPDES Permit Number AK-G70-0000. March 2000. 1200 Sixth Avenue, OW-130 Seattle, Washington 98101.
- USEPA. 1993. Guidance for specifying management measures for sources of nonpoint pollution in coastal waters. EPA Office of Water. 840-B-92-002. 500+ pp.
- Washington Department of Fish and Wildlife. 2009. Gold and fish. Rules for mineral prospecting and placer mining. 2nd edition. April 2009. Olympia, WA.
- Widdows J, Burns K.A., Menon N.R., Page D., Soria S. 1990. Measurement of physiological energetics (scope for growth) and chemical contaminants in mussel (*Arca zebra*) 220 transplanted along a contamination gradient in Bermuda. *Journal of Experimental Marine Biology and Ecology* 138:99-117.
- Williams, G.D. and R.M. Thom. 2001. Marine and estuarine shoreline modification issues. White paper submitted to Washington Department of Fish and Wildlife, Washington Department of Ecology and Washington Department of Transportation. www.wa.gov/wdfw/hab/ahg. 99 pp.

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Appendix 2 GOA Groundfish FMP Amendment 90 - amendment text for updating EFH description and non-fishing impacts to EFH, changing HAPC timeline, and updating EFH research objectives (EFH Omnibus Amendment)

Make the following changes to Sections 3, 4, and 6, Appendix A, Appendix D, Appendix E, Appendix F, and Appendix H of the Fishery Management Plan for Groundfish of the Bering Sea / Aleutian Islands Management Area. When edits to existing sections are proposed, words indicated with ~~strikeout~~ (e.g., ~~strikeout~~) should be deleted from the FMP, and words that are underlined (e.g., underlined) should be inserted into the FMP. Instructions are italicized and highlighted. Note, instructions reference three supplemental files: Appendix D, Appendix E, and Appendix F.2.

1. In Section 3.10.2, Schedule for Review, revise the second paragraph under the subheading “Essential Fish Habitat Components” as follows:

Additionally, the Council may ~~use the FMP amendment cycle every three years to~~ solicit proposals for habitat areas of particular concern (HAPC) and/or conservation and enhancement measures to minimize the potential adverse effects of fishing. Those proposals that the Council endorses would be implemented through FMP amendments. HAPC proposals may be solicited every 5-years, coinciding with the EFH 5-year review, or may be initiated at any time by the Council.

2. In Section 4.2.2, make the following edits to the existing text:

4.2.2 Essential Fish Habitat Definitions

EFH is defined in the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act) as “those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity.” EFH for groundfish species is determined to be the general distribution of a species described by life stage. General distribution is a subset of a species’ total population distribution, and is identified as the distribution of 95 percent of the species population, for a particular life stage, if life history data are available for the species. Where information is insufficient and a suitable proxy cannot be inferred, EFH is not described. General distribution is used to describe EFH for all stock conditions whether or not higher levels of information exist, because the available higher level data are not sufficiently comprehensive to account for changes in stock distribution (and thus habitat use) over time.

EFH is described for FMP-managed species by life stage as general distribution using ~~new~~ guidance from the EFH Final Rule (50 CFR 600.815), such as including the updated EFH Level of Information definitions. New analytical tools are used and recent scientific information is incorporated for each life history stage from updated scientific habitat assessment reports (see Appendix F to ~~the~~ NMFS 2005, and NPFMC and NMFS 2010). EFH descriptions include both text (Section 4.2.2.2) and maps (Section 4.2.2.3 and Appendix E), if information is available for a species’ particular life stage. These descriptions are risk averse, supported by scientific rationale, and accounts for changing oceanographic conditions, regime shifts, and the seasonality of migrating fish stocks.

EFH descriptions are interpretations of the best scientific information. In support of this information, a thorough review of FMP species is contained in the Environmental Impact Statement for Essential Fish Habitat Identification and Conservation (NMFS 2005) (EFH EIS) ~~is contained~~ in Section 3.2.1, Biology, Habitat Usage, and Status of Magnuson-Stevens Act Managed Species and detailed by life history stage in Appendix F: EFH Habitat Assessment Reports. This EIS was supplemented in 2010 by a 5-year

review, which re-evaluated EFH descriptions and fishing and non-fishing impacts on EFH in light of new information (NPFMC and NMFS 2010).

3. In Section 4.2.2.1, replace Table 4-13 and the associated table notes with the following revised table and table notes:

Table 4-13 Levels of essential fish habitat information currently available for GOA groundfish, by life history stage.

Species	Eggs	Larvae	Early Juveniles	Late Juveniles	Adults
Walleye pollock	1	1	x	1	1
Pacific cod	1	1	x	1	1
Sablefish	1	1	x	1	1
Yellowfin sole	1	1	x	1	1
Northern rock sole	x	1	x	1	1
Southern rock sole	x	1	x	1	1
Alaska plaice	1	1	x	1	1
Dover sole	1	1	x	1	1
Rex sole	1	1	x	1	1
Arrowtooth flounder	x	1	x	1	1
Flathead sole	1	1	x	1	1
Pacific ocean perch	x	1	x	1	1
Northern rockfish	x	x	x	x	1
Shortraker rockfish	x	x	x	x	1
Blackspotted/rougheye rockfish	x	x	x	x	1
Dusky rockfish	x	1	x	x	1
Yelloweye rockfish	x	1	1	1	1
Thornyhead rockfish	x	1	1	1	1
Atka mackerel	1	1	x	x	1
Skates	X	x	x	x	1
Octopuses	x	x	x	x	x
Sharks	x	x	x	x	x
Sculpins	x	x	x	1	1
Squids	x	x	x	1	1
Forage fish complex	x	x	x	x	x

Juveniles were subdivided into early and late juvenile stages based on survey selectivity curves.

Note: "1" indicates general distribution data are available for some or all portions of the geographic range of the species; "x" indicates insufficient information is available to describe EFH.

4. In Section 4.2.2.2.1, make the following edits to the early juvenile, late juvenile, and adult descriptions for pollock:

Early Juveniles: No EFH ~~d~~Description ~~d~~Determined. ~~Limited information exists to describe walleye pollock early juvenile larval general distribution; however, the data cannot be analyzed in the same manner as directed by the approach for Alternative 3. Information is insufficient due to these ages (primarily age 2) being unavailable to bottom-trawl survey gear and partially available to echo-integrated mid-water trawl surveys.~~

Late Juveniles: EFH for late juvenile walleye pollock is the general distribution area for this life stage, located in the lower and middle portion of the water column along the inner (0 to 50 m), middle (50 to 100 m), and outer (100 to 200 m) shelf throughout the GOA, as depicted in Figure E-3. ~~No known preference for s~~Substrate preferences, if they exist, are unknown.

Adults: EFH for adult walleye pollock is the general distribution area for this life stage, located in the lower and middle portion of the water column along the entire shelf (~10 to 200

m) and slope (200 to 1,000 m) throughout the GOA, as depicted in Figure E-3. ~~No known preference for substrates exist. Substrate preferences, if they exist, are unknown.~~

5. In Section 4.2.2.2.3, replace references to “Figure E-26”, “Figure E-27”, and “Figure E-28” with “Figure E-7”, “Figure E-8”, and “Figure E-9”, respectively. Make the following edits to the early juvenile description for sablefish:

Early Juveniles: No EFH ~~d~~Description ~~d~~Determined. ~~Insufficient information is available. Generally, have been observed in inshore water, bays, and passes, and on shallow shelf pelagic and demersal habitat. Information is limited.~~

6. In Section 4.2.2.2.4, Yellowfin Sole, replace references to “Figure E-7”, “Figure E-8”, and “Figure E-9” with “Figure E-10”, “Figure E-11”, and “Figure E-12”, respectively.

7. In Section 4.2.2.2.5, change the title from “Rock Sole” to “Northern Rock Sole”. Make the following edits to the larvae, late juvenile, and adult descriptions for northern rock sole:

Larvae: EFH for larval northern rock sole is the general distribution area for this life stage, located in pelagic waters along the entire shelf (0 to 200 m) and upper slope (200 to 1,000 m) throughout the GOA, as depicted in Figure E-12~~13~~.

Late Juveniles: EFH for late juvenile northern rock sole is the general distribution area for this life stage, located in the lower portion of the water column along the inner (0 to 50 m), middle (50 to 100 m), and outer (100 to 200 m) shelf throughout the GOA~~BSA~~ wherever there are softer substrates consisting of sand, gravel, and cobble, as depicted in Figure E-13~~14~~.

Adults: EFH for adult northern rock sole is the general distribution area for this life stage, located in the lower portion of the water column along the inner (0 to 50 m), middle (50 to 100 m), and outer (100 to 200 m) shelf throughout the GOA wherever there are softer substrates consisting of sand, gravel, and cobble, as depicted in Figure E-13~~14~~.

8. In Section 4.2.2.2.6, Alaska Plaice, replace references to “Figure E-14”, “Figure E-15”, and “Figure E-16” with “Figure E-16”, “Figure E-17”, and “Figure E-18”, respectively.

9. In Section 4.2.2.2.7, Rex Sole, replace references to “Figure E-17”, “Figure E-18”, and “Figure E-19” with “Figure E-19”, “Figure E-20”, and “Figure E-21”, respectively.

10. In Section 4.2.2.2.8, Dover Sole, replace references to “Figure E-20”, “Figure E-21”, and “Figure E-22” with “Figure E-22”, “Figure E-23”, and “Figure E-24”, respectively.

11. In Section 4.2.2.2.9, Flathead Sole, replace references to “Figure E-23”, “Figure E-24”, and “Figure E-25” with “Figure E-25”, “Figure E-26”, and “Figure E-27”, respectively.

12. In Section 4.2.2.2.10, Arrowtooth Flounder, replace references to “Figure E-10” and “Figure E-11” with “Figure E-28” and “Figure E-29”, respectively.

13. In Section 4.2.2.2.11, Pacific Ocean perch and “Other Slope” Rockfish, replace references to “Figure E-29” and “Figure E-30” with “Figure E-30” and “Figure E-31”, respectively.

14. In Section 4.2.2.2.12, Northern rockfish, make the following edits to the egg, larvae, and adult descriptions for northern rockfish:

- Eggs:** ~~No EFH Description Determined. Insufficient information is available. Eggs develop internally, so EFH description is not applicable.~~
- Larvae:** ~~No EFH description determined. Insufficient information is available. EFH for larval northern rockfish is the general distribution area for this life stage, located in pelagic waters along the entire shelf (0 to 200 m) and slope (200 to 3,000 m) throughout the GOA, as depicted in Figure E-29, General Distribution of Rockfish Larvae.~~
- Adults:** ~~EFH for adult northern rockfish is the general distribution area for this life stage, located in the middle and lower portions of the water column along the outer continental shelf slope (75-100 to 200 m) and upper slope (200 to 3500 m) in the central and western throughout the GOA wherever there are substrates of cobble and rock, as depicted in Figure E-32.~~

15. In Section 4.2.2.2.13, retile the section as “Shortraker Rockfish”, make the following edits to the egg, larvae, and adult descriptions:

- Eggs:** ~~No EFH Description Determined. Insufficient information is available. Eggs develop internally, so EFH description is not applicable.~~
- Larvae:** ~~No EFH description determined. Insufficient information is available. EFH for larval shortraker and rougheye rockfish is the general distribution area for this life stage, located in pelagic waters along the entire shelf (0 to 200 m) and slope (200 to 3,000 m) throughout the GOA, as depicted in Figure E-29, General Distribution of Rockfish Larvae.~~
- Adults:** ~~EFH for adult shortraker and rougheye rockfish is the general distribution area for this life stage, located in the lower portion of the water column along the outer shelf (100 to 200 m) and upper slope (200 to 500 m) regions throughout the GOA wherever there are substrates consisting of mud, sand, sandy mud, muddy sand, rock, cobble, and gravel, as depicted in Figure E-2633. Adults are especially found on steep slopes with frequent boulders.~~

16. In Section 4.2.2.2.14, Dusky Rockfish, replace references to “Figure E-29” with “Figure E-30”.

17. In Section 4.2.2.2.15, Yelloweye Rockfish, replace references to “Figure E-29” and “Figure E-34” with “Figure E-30” and “Figure E-36”, respectively. Replace the existing early juvenile description with the following:

- Early Juveniles:** EFH for early juvenile yelloweye rockfish is the general distribution area for this life stage, located in the lower portion of the water column within bays and island passages and along the inner (0 to 50 m), middle (50 to 100 m), and outer shelf (100 to 200 m) throughout the GOA wherever there are substrates of rock and in areas of vertical relief, such as crevices, overhangs, vertical walls, coral, and larger sponges, as depicted in Figure E-36.

18. In Section 4.2.2.2.16, Thornyhead Rockfish, replace references to “Figure E-29” and “Figure E-33” with “Figure E-30” and “Figure E-37”, respectively. Replace the existing early juvenile description with the following:

Early Juveniles: EFH for early juvenile thornyhead rockfish is the general distribution area for this life stage, located in pelagic waters along the entire shelf (0 to 200 m) and slope (200 to 3,000 m) throughout the GOA, as depicted in Figure E-30, General Distribution of Rockfish Larvae.

19. In Section 4.2.2.2.17, Atka Mackerel, replace reference to “Figure E-36” with “Figure E-39”. Replace reference to “Figure E-37” with “Figure E-40”. Replace the existing egg description for Atka mackerel with the following:

Eggs: Several nesting sites in the GOA have been identified. There are general distribution data available, but it is not complete for the entire GOA, as depicted in Figure E-38.

20. In Section 4.2.2.2.18, Skates, replace reference to “Figure E-39” with “Figure E-41”.

21. In Section 4.2.2.2.19, Squid, replace references to “Figure E-40” with “Figure E-42”.

22. In Section 4.2.2.2.20, Sculpins, replace references to “Figure E-38” with “Figure E-43”.

23. Insert a new section after Section 4.2.2.2.5 “Northern Rock Sole”, titled Section 4.2.2.2.6 “Southern Rock Sole”, and renumber all subsequent subsections up to and including the subsection titled “Shortraker Rockfish”. Insert the following text descriptions for the new Section 4.2.2.2.6:

Eggs: No EFH description determined. Insufficient information is available.

Larvae: EFH for larval southern rock sole is the general distribution area for this life stage, located in pelagic waters along the entire shelf (0 to 200 m) and upper slope (200 to 1,000 m) throughout the GOA, as depicted in Figure E-13.

Early Juveniles: No EFH description determined. Insufficient information is available; settlement patterns are unknown.

Late Juveniles: EFH for late juvenile southern rock sole is the general distribution area for this life stage, located in the lower portion of the water column along the inner (0 to 50 m), middle (50 to 100 m), and outer (100 to 200 m) shelf throughout the GOA wherever there are softer substrates consisting of sand, gravel, and cobble, as depicted in Figure E-15.

Adults: EFH for adult southern rock sole is the general distribution area for this life stage, located in the lower portion of the water column along the inner (0 to 50 m), middle (50 to 100 m), and outer (100 to 200 m) shelf throughout the GOA wherever there are softer substrates consisting of sand, gravel, and cobble, as depicted in Figure E-15.

24. Insert a new subsection in Section 4.2.2.2, to follow the subsection titled “Shortraker Rockfish”, titled “Rougheye and Blackspotted Rockfish”, and number it and renumber all subsequent subsections in 4.2.2.2 accordingly. Insert the following text descriptions for the new subsection:

- Eggs:** Eggs develop internally, so this category is not applicable.
- Larvae:** No EFH description determined. Insufficient information is available. The larval stage is pelagic, but larval studies are hindered because the larvae at present can only be positively identified by genetic analysis, which is expensive and labor-intensive.
- Early Juveniles:** No EFH description determined. Insufficient information is available. The post-larvae and early young-of-the-year stages also appear to be pelagic. Genetic techniques have been used recently to identify a few post-larval rougheye rockfish from samples collected in epipelagic waters far offshore in the GOA. This is the only documentation of habitat preference for this life stage.
- Late Juveniles:** No EFH description determined. Insufficient information is available.
- Adults:** EFH for adult rougheye and blackspotted rockfish is the general distribution area for this life stage, located in the lower portion of the water column along the outer shelf (100 to 200 m) and upper slope (200 to 500 m) regions throughout the GOA wherever there are substrates consisting of mud, sand, sandy mud, muddy sand, rock, cobble, and gravel, as depicted in Figure E-34.

25. In Section 4.2.2.3, make the following edit to the existing text:

Figures E-1 through E-4043 in Appendix E show EFH distribution for the GOA groundfish species.

26. In Section 4.2.3, delete the second paragraph and associated bullets, as follows:

~~HAPCs are those areas of special importance that may require additional protection from adverse effects. Regulations at 50 CFR 600.815(a)(8) provide the following:~~

~~FMPs should identify specific types or areas of habitat within EFH as habitat areas of particular concern based on one or more of the following considerations:~~

- ~~(i) The importance of the ecological function provided by the habitat.~~
- ~~(ii) The extent to which the habitat is sensitive to human induced environmental degradation.~~
- ~~(iii) Whether, and to what extent, development activities are, or will be, stressing the habitat type.~~
- ~~(iv) The rarity of the habitat type.~~

27. In Section 4.2.3.1, revise the existing final two paragraphs, as follows:

The Council will initiate the HAPC process by setting priorities and issuing a request for HAPC proposals. Any member of the public may submit a HAPC proposal. HAPC proposals may be solicited every 3 years or on a schedule established by the Council 5 years, to coincide with the EFH 5-year review, or may be initiated at any time by the Council. The Council will establish a process to review the proposals. The Council may periodically review existing HAPCs for efficacy and considerations based on new scientific research.

Criteria to evaluate the HAPC proposals will be reviewed by the Council and the Scientific and Statistical Committee prior to the request for proposals. The Council will establish a process to review the proposals and may establish HAPCs and conservation measures (NPFMC 2005).

28. In Section 6.1.3.2, insert the following new paragraph at the end of the section:

In 2009–2010, the Council undertook a 5-year review of EFH for the Council’s managed species, which was documented in the Final EFH 5-year Review Summary Report published in April 2010 (NPFMC and NMFS 2010). The review evaluated new information on EFH, including EFH descriptions and identification, and fishing and non-fishing activities that may adversely affect EFH. The review also assessed information gaps and research needs, and identified whether any revisions to EFH are needed or suggested. The Council identified various elements of the EFH descriptions meriting revision, and approved omnibus amendments 98/90/40/15/11 to the BSAI Groundfish FMP, the GOA Groundfish FMP, the BSAI King and Tanner Crab FMP, the Scallop FMP, and the Salmon FMP, respectively, in 2011.

29. In Section 6.3, insert the following reference for NPFMC and NMFS 2010 alphabetically, and delete reference for NPFMC 2005 (in strikeout).

NPFMC and NMFS. 2010. Essential Fish Habitat (EFH) 5-year Review for 2010 Summary Report: Final. April 2010. <http://www.alaskafisheries.noaa.gov/habitat/efh/review.htm>

~~NPFMC. 2005. Environmental Assessment/Regulatory Impact Review/Regulatory Flexibility Analysis for Amendments 65/65/12/7/8 to the BSAI Groundfish FMP (#65), GOA Groundfish FMP (#65), BSAI Crab FMP (#12), Scallop FMP (#7) and the Salmon FMP (# 8) and regulatory amendments to provide Habitat Areas of Particular Concern. March 2005. NPFMC 605 West 4th St. Ste. 306, Anchorage, AK 99501-2252. 248pp.~~

30. In Appendix A, insert the following description of this amendment in sequential order, and include the effective date of the approved amendment.

Amendment 90, implemented on _____ (insert effective date)_____, revised Amendment 73:

1. Revise EFH description and identification by species, and update life history, distribution, and habitat association information, based on the 2010 EFH 5-year review.
2. Update description of EFH impacts from non-fishing activities, and EFH conservation recommendations for non-fishing activities.
3. Revise the timeline associated with the HAPC process to a 5-year timeline.
4. Update EFH research priority objectives.

Amendment 88 implemented on October 24, 2011, replaced Amendment 68:
Implemented the Central Gulf of Alaska Rockfish Program. This program allocates quota share to LLP licenses for rockfish primary and secondary species based on legal landings associated with that LLP during particular qualifying years. Primary rockfish species are northern rockfish, Pacific ocean perch, and pelagic shelf rockfish. Secondary rockfish species are Pacific cod, roughey rockfish, shorttraker rockfish, sablefish, and thornyhead rockfish.

31. In Appendix D, delete existing text and tables, and replace with revised life history text and tables in attached file. Update date in footer.

32. In Appendix E, delete existing text and figures, and replace with revised maps of essential fish habitat text and Figures E-1 to E-43 in attached file. Update date in footer.

33. In Appendix F, Section F.1.5.3, Sablefish, revise the final paragraph as follows :

Summary of Effects—The estimated productivity and sustainable yield of sablefish have declined steadily since the late 1970s. This is demonstrated by a decreasing trend in recruitment and subsequent estimates of biomass reference points and the inability of the stock to rebuild to target biomass levels despite of the decreasing level of the targets and fishing rates below the target fishing rate. While years of strong young-of-the-year survival have occurred in the 1980s and 1990s, the failure of strong recruitment to the mature stage suggests a decreased survival of juveniles during their residence as ~~2- to 4~~ 2- to 4-year-olds on the continental shelf. While climate-related changes are a possible cause for reduced productivity, the observations noted above are consistent with possible effects of fishing on habitat and resulting changes in the juvenile ecology of sablefish, possibly through increased competition for food and space. Given the concern for the decline in the sustainable yield of sablefish, the possibility of the role of fishing effects on juvenile sablefish habitat, and the need for a better understanding of the possible causes, an MT rating is not merited, and sablefish growth to maturity and feeding is rated unknown.

34. In Appendix F, Section F.1.5.4, Atka Mackerel, replace “dependance” with “dependence” in the first full paragraph, and revise the final paragraph as follows :

Stock assessment data do not show a negative trend in spawning biomass and recruitment or evidence of chronic low abundance and recruitment. There is no evidence that the cumulative effects of fishing activities on habitat have impaired the stock’s ability to produce MSY since 1977. Spawning biomass is at a ~~peak~~ relatively high level. The stock has produced several years of above average recruitment since 1977, and recent recruitment has been strong.

35. In Appendix F, Section F.1.5.7, Arrowtooth Flounder, revise the two existing paragraphs as follows :

Summary of Effects—The nearshore areas inhabited by arrowtooth flounder early juveniles are mostly unaffected by current fishery activities. Adult and late juvenile concentrations primarily overlap the EBS sand/mud habitat (34 percent) and the GOA deep shelf habitat (35 percent) (Table B.3-3 of the EFH EIS). Overall, epifaunal prey reduction in those overlaps is predicted to be 3 percent for EBS sand/mud and 1 percent for GOA deep shelf habitats. Given this level of disturbance, and the large percentage of the diet of arrowtooth flounder not including epifauna prey, it is unlikely that the adult feeding would be negatively impacted. The arrowtooth flounder stock is currently at a high level of abundance due to sustained above-average recruitment in the 1980s and 1990s (Turnock ~~et al. 2002~~ and Wilderbuer 2009). No change in weight and length at age has been observed in this stock from bottom trawl surveys conducted from 1984 through 2003.

The BS arrowtooth flounder stock is currently at a high level of abundance due to sustained above-average recruitment in the 1980s (Wilderbuer ~~et al. 2010~~ and Sample 2004). The productivity of the stock is currently believed to correspond to favorable atmospheric forces in which larvae are advected to nearshore nursery areas (Wilderbuer et al. 2002). The GOA stock has increased steadily since the 1970s and is at a very high level. Therefore, the combined evidence from individual fish length-weight analysis, length at age analysis, examination of recruitment, stock biomass, and CPUE trends indicate that the effects of the reductions in habitat features from fishing are minimal or temporary for BSAI and GOA arrowtooth flounder.

36. In Appendix F, Section F.1.5.11, change the title from “Shortraker and Rougheye Rockfish (GOA)” to “Shortraker Rockfish (GOA)”, and revise the existing paragraph as follows :

Summary of Effects—The effects of fishing on the habitat of shortraker ~~and rougheye~~ rockfish in the GOA are either unknown or minimal. There is not enough information available to determine whether

the habitat impacts of fishing affect spawning or growth to maturity of these fish. Virtually nothing is known about the spawning behavior of ~~these shortraker rockfish~~, and information on ~~the juvenile life history of shortraker rockfish~~ is nil. However, adults of ~~both species~~ inhabit areas subject to bottom trawling, ~~as do juveniles of rougheye rockfish~~, so fishing may be affecting the habitat of these fish. Of particular concern is the observed association of adult shortraker ~~and rougheye~~ rockfish with corals such as *Primnoa* spp. on rocky substrate of the slope. This coral is known to be easily damaged by bottom trawls, and it also may take years to recover from such damage. The fragile nature of corals and their long recovery time are reflected in the high values of the long term effect index (LEI) estimated for corals in this document. If corals are important to the long-term survival of adult shortraker ~~and rougheye~~ rockfish, damage to corals by fishing gear may have a negative impact on these fish. ~~The habitat requirements of juvenile rougheye rockfish on the shelf are unknown. However, several studies have observed unidentified small juvenile rockfish on the shelf associated with rocks or sponges. If juvenile rougheye rockfish utilize this habitat, they could be adversely affected by trawling.~~ Effects of fishing on the feeding of adult shortraker ~~and rougheye~~ rockfish appears to be negligible, as their major food items ~~of these fish~~ are relatively small and semi some may be bathypelagic; therefore, these items are generally not retained in large amounts by demersal fishing gear.

37. In Appendix F, Section F.1.5.12, Northern Rockfish, revise the final paragraph as follows:

Summary of Effects—Although northern rockfish may eat a small amount of some epifaunal prey, such as polychaetes ~~crabs and shrimp~~, the largest component of their diet is euphausiids; thus, the percent reductions in epifaunal prey would not be expected to have a significant impact on their feeding. There is no evidence that links habitat features with northern rockfish accomplishing the spawning/breeding process. Consequently, a reduction in living and non-living structure would not be expected to have an effect on spawning/ breeding of GOA northern rockfish. A reduction in living and non-living structure may reasonably jeopardize growth to maturity due to a reduction of refuge habitat for juvenile GOA northern rockfish. However, no scientific studies have been conducted that specifically identify northern rockfish associations with living or non-living structures or the nature of those associations if they exist. Consequently, the effect of a reduction in living or non-living structures on northern rockfish accomplishing the growth to maturity process is unknown. Current stock status trends show no indications of fishing impacting the ability of the stock to maintain MSY, and there is no evidence to suggest that the potential reductions in living and non-living structure on growth and survival to maturity affects the ability of GOA northern rockfish to fulfill its role in a healthy ecosystem.

38. In Appendix F, Section F.1.5.15.5, change the title from “GOA octopi (5 or more species)” to “GOA octopuses (7 or more species)”, and revise the existing paragraph as follows:

Summary of Effects—Essential habitat requirements for species in this category are unknown. No studies have been conducted in the GOA to determine whether fishing activities have an effect on the habitat of octopus~~i~~. Octopus~~es~~i occupy all types of benthic habitats, extending from very shallow subtidal areas to deep slope habitats; thus, any adverse effects to this habitat may influence the health of octopus populations. Knowledge of octopus~~i~~ distributions are insufficient to allow comparison with fishing effects.

39. Insert a new section after Section F.1.5.11 “Shortraker Rockfish”, titled Section F.1.5.12 “Rougheye and Blackspotted Rockfish”, and renumber all subsequent subsections in F.1.5 accordingly. Insert the following text descriptions for the new Section F.1.5.12:

<u>Issue</u>	<u>Evaluation</u>
Spawning/breeding	U (Unknown effect)

Growth to maturity

U (Unknown effect)

Feeding

MT (Minimal, temporary, or no effect)

Summary of Effects—The effects of fishing on the habitat of rougheye and blackspotted rockfish in the GOA are unknown. There is not enough information available to determine whether the habitat impacts of fishing affect spawning or growth to maturity of these fish. Virtually nothing is known about the spawning behavior of these fish, and information on the juvenile life history of rougheye and blackspotted rockfish is very limited. However, adults inhabit areas subject to bottom trawling, as do juveniles of rougheye and blackspotted rockfish, so fishing may be affecting the habitat of these fish. Of particular concern is the observed association of adult rougheye and blackspotted rockfish with corals such as *Primnoa* spp. This coral is known to be easily damaged by bottom trawls, and it also may take years to recover from such damage. The fragile nature of corals and their long recovery time are reflected in the high values of LEI estimated for corals in this document. If corals are important to the long-term survival of adult rougheye and blackspotted rockfish, damage to corals by fishing gear may have a negative impact on these fish. The habitat requirements of juvenile rougheye and blackspotted rockfish on the shelf are unknown. However, several studies have observed unidentified small juvenile rockfish on the shelf associated with rocks or sponges. If juvenile rougheye rockfish utilize this habitat, they could be adversely affected by trawling. Effects of fishing on the feeding of rougheye and blackspotted rockfish appears to be negligible, as their major food items are relatively small and some may be bathypelagic; therefore, these items are generally not retained in large amounts by fishing gear.

40. In Appendix F, Section F.1.6.1, add a new paragraph to the end of the section, as follows:

The evaluation of fishing effects on EFH for GOA groundfish species was reconsidered as part of the Council's EFH 5-year Review for 2010, and is documented in the Final Summary Report for that review (NPFMC and NMFS 2010). The review evaluated new information since the development of the EFH EIS, for individual species and their habitat needs, as well as the distribution of fishing intensity, spatial habitat classifications, classification of habitat features, habitat- and feature-specific recovery rates, and gear- and habitat-specific sensitivity of habitat features. Based on the review, the Council concluded that recent research results are consistent with the habitat sensitivity and recovery parameters and distributions of habitat types used in the analysis of fishing effects documented in the EFH EIS. The review noted that fishing intensity has decreased overall, gear regulations have been designated to reduce habitat damage, and area closures have limited the expansion of effort into areas of concern.

41. In Appendix F, Section F.1.6.2.1, References, add the following references in alphabetical order, and delete references that are marked below in *strikeout*:

NPFMC and NMFS. 2010. Essential Fish Habitat (EFH) 5-year Review for 2010 Summary Report: Final. April 2010. <http://www.alaskafisheries.noaa.gov/habitat/efh/review.htm>.

Turnock, B.J. and T.K. Wilderbuer. 2009. Arrowtooth flounder. In Appendix B Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501. Pp. 627-680.

Wilderbuer, T.K., D. Nichol, and K. Aydin. 2010b. Arrowtooth flounder. In Stock Assessment and Fishery Evaluation Report for Groundfish Resources of the Bering Sea/Aleutian Islands Regions. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, Alaska 99501. Pp. 697-762.

~~Turnock, B.J., T.K. Wilderbuer, and E.S. Brown. 2002. Arrowtooth flounder. In Appendix B Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the GOA Region. P~~

~~199-228. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.~~

~~Wilderbuer, T.K. and T.M. Sample. 2004. Arrowtooth flounder. In Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the BSAI Region as Projected for 2005. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage Alaska 99510.~~

42. In Appendix F, delete existing text in Section F.2 Non-fishing Impacts, and replace with the revised Section F.2 in the attached file.

43. In Appendix H, Section H.4.1, delete existing text under the heading “Objectives” and replace with the following:

Establish a scientific research and monitoring program to understand the degree to which impacts have been reduced within habitat closure areas, and to understand how benthic habitat recovery of key species is occurring.

44. In Appendix H, Section H.4.3, delete existing text under the heading “Research Activities” and replace with the following:

- Fishing effort data from observers and remote sensing would be used to study changes in bottom trawl and other fishing gear activity in the closed (and open) areas. Effects of displaced fishing effort would have to be considered. The basis of comparison would be changes in the structure and function of benthic communities and populations, as well as important physical features of the seabed, after comparable harvests of target species are taken with each gear type.
- Monitor the structure and function of benthic communities and populations in the newly closed areas, as well as important physical features of the seabed, for changes that may indicate recovery of benthic habitat. Whether these changes constitute recovery from fishing or just natural variability/shifts requires comparison with an area that is undisturbed by fishing and otherwise comparable.
- Validate the LEI model and improve estimates of recovery rates, particularly for the more sensitive habitats, including coral and sponge habitats in the Aleutian Islands region, possibly addressed through comparisons of benthic communities in trawled and untrawled areas.
- Obtain high resolution mapping of benthic habitats, particularly in the on-shelf regions of the Aleutian Islands.
- Time series of maturity at age should be collected to facilitate the assessment of whether habitat conditions are suitable for growth to maturity.
- In the case of red king crab spawning habitat in southern Bristol Bay, research the current impacts of trawling on habitat in spawning areas and the relationship of female crab distribution with respect to bottom temperature.

45. Update the Table of Contents for the main document.

46. Update the Table of Contents for the appendices.

47. In alphabetical order, add “LEI” to the list of acronyms used in the FMP (page ix), with the definition “long-term effect index”.

Life History Features and Habitat Requirements of Fishery Management Plan Species

This appendix describes habitat requirements and life histories of the groundfish species managed by this fishery management plan. Each species or species group is described individually, however, summary tables that denote habitat associations (Table D-1), biological associations (Table D-2), and predator-prey associations (Table D-3) are also provided.

In each individual section, a species-specific table summarizes habitat. The following abbreviations are used in these habitat tables to specify location, position in the water column, bottom type, and other oceanographic features.

Location

BAY = nearshore bays, with depth if appropriate (e.g., fjords)
BCH = beach (intertidal)
BSN = basin (>3,000 m)
FW = freshwater
ICS = inner continental shelf (1–50 m)
IP = island passes (areas of high current), with depth if appropriate
LSP = lower slope (1,000–3,000 m)
MCS = middle continental shelf (50–100 m)
OCS = outer continental shelf (100–200 m)
USP = upper slope (200–1,000 m)

Water column

D = demersal (found on bottom)
N = neustonic (found near surface)
P = pelagic (found off bottom, not necessarily associated with a particular bottom type)
SD/SP = semi-demersal or semi-pelagic, if slightly greater or less than 50% on or off bottom

General

NA = not applicable
U = unknown
EBS = eastern Bering Sea
GOA = Gulf of Alaska
EFH = essential fish habitat

Bottom Type

C = coral
CB = cobble
G = gravel
K = kelp
M = mud
MS = muddy sand
R = rock
S = sand
SAV = subaquatic vegetation (e.g., eelgrass, not kelp)
SM = sandy mud

Oceanographic Features

CL = thermocline or pycnocline
E = edges
F = fronts
G = gyres
UP = upwelling

Table 0.1 Summary of habitat associations for groundfish of the GOA.

[illegible]

[illegible]

GOA Groundfish Species	LIFE STAGE	Nearshore		Shelf		Slope		Stratum Reference	Location		Physical Oceano- graphy	Substrate										Structure		Community Associations										Oceano- graphic Properties			LIFE STAGE																																							
		Freshwater	Estuarine	Intertidal	Subtidal	1-50m	51-100m		101-200m	Outer		Upper	301-500m	501-700m	701-1000m	1001-3000m	>3000m	Shallows	Island Pass	Bay/Fjord	Bank	Flat	Edge	Gully	Surface	Near surface	Semi-demersal	Demersal	Pelagic	201-1000m (epi)	>1000m (bathy)	Upwelling areas	Gyres	Thermocline	Pycnocline	Fronts		Edges (ice, bath)	Organic Debris	Mud	Sand	Gravel	Mud & sand	Mud & gravel	Sand & mud	Gravel & mud	Gravel & sand	Gravel & sand & mud	Gravel & mud & sand	Cobble	Rock	Bars	Sinks	Slumps/Rockfalls/Debris	Channels	Ledges	Pinnacles	Seamount	Reefs	Vertical Walls	Man-made	Algal Cover	Anenomes	Echinoderms	Soft Coral	Hard Coral	Mollusca	Drift Algae/Kelp	Kelp	Polychaetes	Sea Grasses	Sea Onions	Tunicates	Temperature (Celsius)	Salinity (ppt)	Oxygen Conc (ppm)

Table 0.2 Summary of biological associations for GOA groundfish.

GOA Groundfish Species	Life Stage	Reproductive Traits																											
		Age at Maturity (unless otherwise noted)				Fertilization/ Egg Development						Spawning Behavior								Spawning Season									
		Female	Male	External	Internal	Oviparous	Ovoviparous	Aplacental viviparous	Viviparous	Batch Spawner	Broadcast Spawner	Egg Case Deposition	Nest Builder	Egg/Young Guarder	Egg/Young Bearer	January	February	March	April	May	June	July	August	September	October	November	December		
50%	100%	50%	100%																										
Walleye Pollock	M	4-5		4-5		x							x																
Pacific Cod	M	5		5		x							x																
Sablefish	M	65cm		67c		x							x																
Yellowfin Sole	M	10.5				x							x																
Northern Rock Sole	M	9				x							x																
Southern Rock Sole	M	9				x							x																
Alaska Plaice	M	6-7				x																				x			
Rex Sole	M	24cm		16cm		x																				x			
Dover Sole	M	6.7	11			x							x																
Flathead Sole	M	8.7				x							x																
Arrowtooth Flounder	M	5		4		x																				x			
Pacific Ocean Perch	M	10.5	20.0				x					x	x													x			
Northern Rockfish	M	13					x					x	x																
Shortraker Rockfish	M	20+					x					x	x																
Rougheye/Blackspotted Rock	M	19+					x					x	x													x			
Dusky Rockfish	M	11					x					x	x																
Yelloweye Rockfish	M	22		18			x		x																				
Thornyhead Rockfish	M	21.5 cm							x				x																
Atka Mackerel	M	3.6		3.6		x							x			x	x												
Skates	M						x	x							x														
Squid	M						x						x																
Sculpins	M					x										x													
Octopus	M						x						x		x														
Sharks	M	35		21			x	x	x	x	x			x			x	x	x						x	x			
Eulachon	M	3	5	3	5	x		x					x							x	x	x							
Capelin	M	2	4	2	4	x		x					x							x	x	x	x						
Sand Lance	M	1	2	1	2	x		x					x							x	x					x			

Table 0.3 **Summary of reproductive traits for GOA groundfish.**

[illegible]

[illegible]

[illegible]

D.1 Walleye pollock (*Theragra calcogramma*)

The Gulf of Alaska (GOA) pollock stocks are managed under the Fishery Management Plan for Groundfish of the Gulf of Alaska (FMP), and the eastern Bering Sea and Aleutian Islands pollock stocks are managed under the Fishery Management Plan for Groundfish of the Bering Sea and Aleutian Islands Management Area. Pollock occur throughout the area covered by the FMP and straddle into the Canadian and Russian Exclusive Economic Zone (EEZ), the U.S. EEZ, international waters of the central Bering Sea, and into the Chukchi Sea.

D.1.1 Life History and General Distribution

Pollock is the most abundant species within the eastern Bering Sea comprising 75 to 80 percent of the catch and 60 percent of the biomass. In the GOA, pollock is the second most abundant groundfish stock comprising 25 to 50 percent of the catch and 20 percent of the biomass.

Four stocks of pollock are recognized for management purposes: GOA, eastern Bering Sea, Aleutian Islands, and Aleutian Basin. For the contiguous sub-regions (i.e., areas adjacent to their management delineation), there appears to be some relationship among the eastern Bering Sea, Aleutian Islands, and Aleutian Basin stocks. Some strong year classes appear in all three places suggesting that pollock may expand from one area into the others or that discrete spawning areas benefit (in terms of recruitment) from similar environmental conditions. There appears to be stock separation between the GOA stocks and stocks to the north.

The most abundant stock of pollock is the eastern Bering Sea stock which is primarily distributed over the eastern Bering Sea outer continental shelf between approximately 70 m and 200 m. Information on pollock distribution in the eastern Bering Sea comes from commercial fishing locations, annual bottom trawl surveys, and regular (every two or three years) echo-integration mid-water trawl surveys.

The Aleutian Islands stock extends through the Aleutian Islands from 170° W. to the end of the Aleutian Islands (Attu Island), with the greatest abundance in the eastern Aleutian Islands (170° W. to Segum Pass). Most of the information on pollock distribution in the Aleutian Islands comes from regular (every two or three years) bottom trawl surveys. These surveys indicate that pollock are primarily located on the Bering Sea side of the Aleutian Islands, and have a spotty distribution throughout the Aleutian Islands chain, particularly during the summer months when the survey is conducted. Thus, the bottom trawl data may be a poor indicator of pollock distribution because a significant portion of the pollock biomass is likely to be unavailable to bottom trawls. Also, many areas of the Aleutian Islands shelf are untrawlable due to the rough bottom.

The Aleutian Basin stock, appears to be distributed throughout the Aleutian Basin, which encompasses the U.S. EEZ, Russian EEZ, and international waters in the central Bering Sea. This stock appears throughout the Aleutian Basin apparently for feeding, but concentrates near the continental shelf for spawning. The principal spawning location is thought to be near Bogoslof Island in the eastern Aleutian Islands, but data from pollock fisheries in the first quarter of the year indicate that there are other concentrations of deepwater spawning concentrations in the central and western Aleutian Islands. The Aleutian Basin spawning stock appears to be derived from migrants from the eastern Bering Sea shelf stock, and possibly some western Bering Sea pollock. Recruitment to the stock occurs generally around age 5 with younger fish being rare in the Aleutian Basin. Most of the pollock in the Aleutian Basin appear to originate from strong year classes also observed in the Aleutian Islands and eastern Bering Sea shelf region.

The GOA stock extends from southeast Alaska to the Aleutian Islands (170° W.), with the greatest abundance in the western and central regulatory areas (147° W. to 170° W.). Most of the information on pollock distribution in the GOA comes from annual winter echo-integration mid-water trawl surveys and

regular (every two or three years) bottom trawl surveys. These surveys indicate that pollock are distributed throughout the shelf regions of the GOA at depths less than 300 m. The bottom trawl data may not provide an accurate view of pollock distribution because a significant portion of the pollock biomass may be pelagic and unavailable to bottom trawls. The principal spawning location is in Shelikof Strait, but other spawning concentrations in the Shumagin Islands, the east side of Kodiak Island, and near Prince William Sound also contribute to the stock.

Peak pollock spawning occurs on the southeastern Bering Sea and eastern Aleutian Islands along the outer continental shelf around mid-March. North of the Pribilof Islands spawning occurs later (April and May) in smaller spawning aggregations. The deep spawning pollock of the Aleutian Basin appear to spawn slightly earlier, late February and early March. In the GOA, peak spawning occurs in late March in Shelikof Strait. Peak spawning in the Shumagin area appears to be 2 to 3 weeks earlier than in Shelikof Strait.

Spawning occurs in the pelagic zone and eggs develop throughout the water column (70 to 80 m in the Bering Sea shelf, 150 to 200 m in Shelikof Strait). Development is dependent on water temperature. In the Bering Sea, eggs take about 17 to 20 days to develop at 4 °C in the Bogoslof area and 25.5 days at 2 °C on the shelf. In the GOA, development takes approximately 2 weeks at ambient temperature (5 °C). Larvae are also distributed in the upper water column. In the Bering Sea the larval period lasts approximately 60 days. The larvae eat progressively larger naupliar stages of copepods as they grow and then small euphausiids as they approach transformation to juveniles (approximately 25 mm standard length). In the GOA, larvae are distributed in the upper 40 m of the water column, and their diet is similar to Bering Sea larvae. Fisheries-Oceanography Coordinated Investigations survey data indicate larval pollock may utilize the stratified warmer upper waters of the mid-shelf to avoid predation by adult pollock, which reside in the colder bottom water.

At age 1 pollock are found throughout the eastern Bering Sea both in the water column and on the bottom depending on temperature. Age 1 pollock from strong year-classes appear to be found in great numbers on the inner shelf, and farther north on the shelf than weak year classes, which appear to be more concentrated on the outer continental shelf. From age 2 to 3 pollock are primarily pelagic and then are most abundant on the outer and mid-shelf northwest of the Pribilof Islands. As pollock reach maturity (age 4) in the Bering Sea, they appear to move from the northwest to the southeast shelf to recruit to the adult spawning population. Strong year-classes of pollock persist in the population in significant numbers until about age 12, and very few pollock survive beyond age 16. The oldest recorded pollock was age 31.

Growth varies by area with the largest pollock occurring on the southeastern shelf. On the northwest shelf the growth rate is slower. A newly maturing pollock is around 40 centimeters (cm).

The upper size limit for juvenile pollock in the eastern Bering Sea and GOA is about 38 to 42 cm. This is the size of 50 percent maturity. There is some evidence that this has changed over time.

D.1.2 Fishery

The eastern Bering Sea pollock fishery has since 1990 been divided into two fishing periods: an “A season” occurring from January through March, and a “B season” occurring from June through October. The A season concentrates fishing effort on prespawning pollock in the southeastern Bering Sea. During the B season fishing is more dispersed with concentrations in the southeastern Bering Sea and extending north generally along the 200 m isobaths. During the B season the offshore fleet (catcher/processors and motherships) are required to fish north of 56° N. latitude while the area to the south is reserved for catcher vessels delivering to shoreside processing plants on Unalaska and Akutan Islands.

Since 1992, the GOA pollock total allowable catch (TAC) has been apportioned spatially and temporally to reduce impacts on Steller sea lions. Although the details of the apportionment scheme have evolved over time, the general objective is to allocate the TAC to management areas based on the distribution of

surveyed biomass, and to establish three or four seasons between mid-January and autumn during which some fraction of the TAC can be taken. The Steller Sea Lion Protection Measures implemented in 2001 establish four seasons in the Central and Western GOA beginning January 20, March 10, August 25, and October 1, with 25 percent of the total TAC allocated to each season. Allocations to management areas 610, 620, and 630 are based on the seasonal biomass distribution as estimated by groundfish surveys. In addition, a new harvest control rule was implemented that requires a cessation of fishing when spawning biomass declines below 20 percent of the unfished stock biomass estimate.

In the GOA approximately 90 percent of the pollock catch is taken using pelagic trawls. During winter, fishing effort usually is targeted primarily on pre-spawning aggregations in Shelikof Strait and near the Shumagin Islands. The pollock fishery has a very low bycatch rate with discards averaging about 2 percent since 1998 (with the 1991 to 1997 average around 9 percent). Most of the discards in the pollock fishery are juvenile pollock, or pollock too large to fit filleting machines. In the pelagic trawl fishery the catch is almost exclusively pollock.

The eastern Bering Sea pollock fishery primarily harvests mature pollock. The age where fish are selected by the fishery roughly corresponds to the age at maturity (management guidelines are oriented towards conserving spawning biomass). Fishery selectivity increases to a maximum around age 6 to 8 and then declines slightly. The reduced selectivity for older ages is due to pollock becoming increasingly demersal with age. Younger pollock form large schools and are semi-demersal, thereby being easier to locate by fishing vessels. Immature fish (ages 2 and 3) are usually caught in low numbers. Generally the catch of immature pollock increases when strong year-classes occur and the abundance of juveniles increase sharply. This occurred with the 1989 year-class, the second largest year-class on record. Juvenile bycatch increased sharply in 1991 and 1992 when this year-class was age 2 and 3. Under the 1999 American Fisheries Act (AFA), the pollock fishery became rationalized and effectively ended the “race for fish.” This generally slowed the pace of the fishery and also reduced the tendency to catch smaller pollock. A secondary problem is that strong to moderate year-classes may reside in the Russian EEZ adjacent to the U.S. EEZ as juveniles. Russian catch-age data and anecdotal information suggest that juveniles may comprise a major portion of the catch. There is a potential for the Russian fishery to reduce subsequent abundance in the U.S. fishery.

The GOA pollock fishery also targets mature pollock. Fishery selectivity increases to a maximum around age 5 to 7 and then declines. In both the eastern Bering Sea and GOA, the selectivity pattern varies between years due to shifts in fishing strategy and changes in the availability of different age groups over time.

In response to continuing concerns over the possible impacts groundfish fisheries may have on rebuilding populations of Steller sea lions, NMFS and the North Pacific Fishery Management Council (Council) have made changes to the Atka mackerel and pollock fisheries in the Bering Sea and Aleutian Islands (BSAI) and GOA. These have been designed to reduce the possibility of competitive interactions with Steller sea lions. For the pollock fisheries, comparisons of seasonal fishery catch and pollock biomass distributions (from surveys) by area in the eastern Bering Sea led to the conclusion that the pollock fishery had disproportionately high seasonal harvest rates within critical habitat which could lead to reduced sea lion prey densities. Consequently, the management measures were designed to redistribute the fishery both temporally and spatially according to pollock biomass distributions. The underlying assumption in this approach was that the independently derived area-wide and annual exploitation rate for pollock would not reduce local prey densities for sea lions. Here NMFS examines the temporal and spatial dispersion of the fishery to evaluate the potential effectiveness of the measures.

Three types of measures were implemented in the pollock fisheries:

- Additional pollock fishery exclusion zones around sea lion rookery or haulout sites;

- Phased-in reductions in the seasonal proportions of TAC that can be taken from critical habitat; and
- Additional seasonal TAC releases to disperse the fishery over the year.

Prior to the management measures, the pollock fishery occurred in each of the three major fishery management regions of the North Pacific ocean managed by the Council: the Aleutian Islands (1,001,780 square kilometer [km²] inside the U.S. EEZ), the eastern Bering Sea (968,600 km²), and the GOA (1,156,100 km²). The marine portion of Steller sea lion critical habitat in Alaska west of 150° W. encompasses 386,770 km² of ocean surface, or 12 percent of the fishery management regions.

Prior to 1999, a total of 84,100 km², or 22 percent of critical habitat, was closed to the pollock fishery. Most of this closure consisted of the 10 and 20 nm radius all-trawl fishery exclusion zones around sea lion rookeries (48,920 km² or 13 percent of critical habitat). The remainder was largely management area 518 (35,180 km², or 9 percent of critical habitat), which was closed pursuant to an international agreement to protect spawning stocks of central Bering Sea pollock.

In 1999, an additional 83,080 km² (21 percent) of critical habitat in the Aleutian Islands was closed to pollock fishing along with 43,170 km² (11 percent) around sea lion haulouts in the GOA and eastern Bering Sea. Consequently, a total of 210,350 km² (54 percent) of critical habitat was closed to the pollock fishery. The portion of critical habitat that remained open to the pollock fishery consisted primarily of the area between 10 and 20 nm from rookeries and haulouts in the GOA and parts of the eastern Bering Sea foraging area.

The BSAI pollock fishery was also subject to changes in total catch and catch distribution. Disentangling the specific changes in the temporal and spatial dispersion of the eastern Bering Sea pollock fishery resulting from the Steller sea lion management measures from those resulting from implementation of the 1999 AFA is difficult. The AFA reduced the capacity of the catcher/processor fleet and permitted the formation of cooperatives in each industry sector by 2000. Both of these changes were expected to reduce the rate at which the catcher/processor sector (allocated 36 percent of the eastern Bering Sea pollock TAC) caught pollock beginning in 1999, and the fleet as a whole in 2000. Because of some of its provisions, the AFA gave the industry the ability to respond efficiently to changes mandated for sea lion conservation that otherwise could have been more disruptive to the industry.

In 2000, further reductions in seasonal pollock catches from BSAI Steller sea lion critical habitat were realized by closing the entire Aleutian Islands region to pollock fishing and by phased-in reductions in the proportions of seasonal TAC that could be caught from the Sea Lion Conservation Area, an area which overlaps considerably with Steller sea lion critical habitat. In 1998, over 22,000 mt of pollock were caught in the Aleutian Island regions, with over 17,000 mt caught in Aleutian Islands critical habitat. Since 1998 directed fishery removals of pollock have been prohibited.

D.1.3 Relevant Trophic Information

Juvenile pollock through newly maturing pollock primarily utilize copepods and euphausiids for food. At maturation and older ages pollock become increasingly piscivorous, with pollock (cannibalism) a major food item in the Bering Sea. Most of the pollock consumed by pollock are age 0 and 1 pollock, and recent research suggests that cannibalism can regulate year-class size. Weak year-classes appear to be those located within the range of adults, while strong year-classes are those that are transported to areas outside the range of adult abundance.

Being the dominant species in the eastern Bering Sea, pollock is an important food source for other fish, marine mammals, and birds. On the Pribilof Islands hatching success and fledgling survival of marine birds has been tied to the availability of age 0 pollock to nesting birds.

D.1.4 Habitat and Biological Associations

Egg-Spawning: Pelagic on outer continental shelf generally over 100 to 200 m depth in Bering Sea. Pelagic on continental shelf over 100 to 200 m depth in GOA.

Larvae: Pelagic outer to mid-shelf region in the Bering Sea. Pelagic throughout the continental shelf within the top 40 m in the GOA.

Juveniles: Age 0 appears to be pelagic, as is age 2 and 3. Age 1 pelagic and demersal with a widespread distribution and no known benthic habitat preference.

Adults: Adults occur both pelagically and demersally on the outer and mid-continental shelf of the GOA, eastern Bering Sea, and Aleutian Islands. In the eastern Bering Sea few adult pollock occur in waters shallower than 70 m. Adult pollock also occur pelagically in the Aleutian Basin. Adult pollock range throughout the Bering Sea in both the U.S. and Russian waters, however, the maps provided for this document detail distributions for pollock in the U.S. EEZ and the Aleutian Basin.

Habitat and Biological Associations: Walleye Pollock

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	14 d. at 5 °C	None	Feb–Apr	OCS, UCS	P	NA	G?	
Larvae	60 days	copepod nauplii and small euphausiids	Mar–Jul	MCS, OCS	P	NA	G?, F	pollock larvae with jellyfish
Juveniles	0.4 to 4.5 years	pelagic crustaceans, copepods, and euphausiids	Aug +	OCS, MCS, ICS	P, SD	NA	CL, F	
Adults	4.5 to 16 years	pelagic crustaceans and fish	spawning Feb–Apr	OCS, BSN	P, SD	U	F, UP	increasingly demersal with age

D.1.5 Literature

- A'mar, Z. T., Punt, A. E., and Dorn, M. W. 2009. The evaluation of two management strategies for the Gulf of Alaska walleye pollock fishery under climate change. – ICES Journal of Marine Science, 66.
- Bailey, K.M. 2000. Shifting control of recruitment of walleye pollock *Theragra chalcogramma* after a major climatic and ecosystem change. Mar. Ecol. Prog. Ser 198:215-224.
- Bailey, K.M., P.J. Stabeno, and D.A. Powers. 1997. The role of larval retention and transport features in mortality and potential gene flow of walleye pollock. J. Fish. Biol. 51(Suppl. A):135-154.
- Bailey, K.M., S.J. Picquelle, and S.M. Spring. 1996. Mortality of larval walleye pollock (*Theragra chalcogramma*) in the western Gulf of Alaska, 1988-91. Fish. Oceanogr. 5 (Suppl. 1):124-136.
- Bailey, K.M., T.J. Quinn II, P. Bentzen, and W.S. Grant. 1999. Population structure and dynamics of walleye pollock, *Theragra chalcogramma*. Advances in Mar. Biol. 37: 179-255.
- Bakkala, R.G., V.G. Wespestad and L.L. Low. 1987. Historical trends in abundance and current condition of walleye pollock in the eastern Bering Sea. Fish. Res., 5:199-215.
- Barbeaux, S. J., and M. W. Dorn. 2003. Spatial and temporal analysis of eastern Bering Sea echo integration-trawl survey and catch data of walleye pollock, *Theragra chalcogramma*. NOAA Technical Memorandum NMFS-AFSC-136.
- Barbeaux, S. J., and D. Fraser (In Press). Aleutian Islands cooperative acoustic survey study 2006. NMFS AFSC NOAA Technical Memorandum. 90 p. NTIS. NTIS number pending

- Bates, R.D. 1987. Ichthyoplankton of the Gulf of Alaska near Kodiak Island, April-May 1984. NWAFC Proc. Rep. 87-11, 53 pp.
- Bond, N.A., and J.E. Overland 2005. The importance of episodic weather events to the ecosystem of the Bering Sea shelf. *Fisheries Oceanography*, Vol. 14, Issue 2, pp. 97-111.
- Brodeur, R.D. and M.T. Wilson. 1996. A review of the distribution, ecology and population dynamics of age-0 walleye pollock in the Gulf of Alaska. *Fish. Oceanogr.* 5 (Suppl. 1):148-166.
- Brown, A.L. and K.M. Bailey. 1992. Otolith analysis of juvenile walleye pollock *Theragra chalcogramma* from the western Gulf of Alaska. *Mar. Bio.* 112:23-30.
- Dorn, M., S. Barbeaux, M. Guttormsen, B. Megrey, A. Hollowed, E. Brown, and K. Spalinger. 2002. Assessment of Walleye Pollock in the Gulf of Alaska. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, 2002. North Pacific Fishery Management Council, Box 103136, Anchorage, AK 99510. 88p.
- Grant, W.S. and F.M. Utter. 1980. Biochemical variation in walleye pollock *Theragra chalcogramma*: population structure in the southeastern Bering Sea and Gulf of Alaska. *Can. J. Fish. Aquat. Sci.* 37:1093-1100.
- Guttormsen, M. A., C. D. Wilson, and S. Stienessen. 2001. Echo integration-trawl survey results for walleye pollock in the Gulf of Alaska during 2001. In Stock Assessment and Fishery Evaluation Report for Gulf of Alaska. Prepared by the Gulf of Alaska Groundfish Plan Team, North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510. North Pacific Fisheries Management Council, Anchorage, AK.
- Hinckley, S. 1987. The reproductive biology of walleye pollock, *Theragra chalcogramma*, in the Bering Sea, with reference to spawning stock structure. *Fish. Bull.* 85:481-498.
- Hollowed, A.B., J.N. Ianelli, P. Livingston. 2000. Including predation mortality in stock assessments: a case study for Gulf of Alaska pollock. *ICES J. Mar. Sci.* 57:279-293.
- Hughes, S. E. and G. Hirschhorn. 1979. Biology of walleye pollock, *Theragra chalcogramma*, in Western Gulf of Alaska. *Fish. Bull.*, U.S. 77:263-274.
- Ianelli, J.N. 2002. Bering Sea walleye pollock stock structure using morphometric methods. Tech. Report Hokkaido National Fisheries Research Inst. No. 5, 53-58.
- Ianelli, J.N., S. Barbeaux, T. Honkalehto, G. Walters, and N. Williamson. 2002. Bering Sea-Aleutian Islands Walleye Pollock Assessment for 2003. In Stock assessment and fishery evaluation report for the groundfish resources of the Eastern Bering Sea and Aleutian Island Region, 2002. North Pacific Fishery Management Council, Box 103136, Anchorage, AK 99510. 88p.
- Kendall, A.W., Jr. and S.J. Picquelle. 1990. Egg and larval distributions of walleye pollock *Theragra chalcogramma* in Shelikof Strait, Gulf of Alaska. *U.S. Fish. Bull.* 88(1):133-154.
- Kim, S. and A.W. Kendall, Jr. 1989. Distribution and transport of larval walleye pollock (*Theragra chalcogramma*) in Shelikof Strait, Gulf of Alaska, in relation to water movement. *Rapp. P.-v. Reun. Cons. int. Explor. Mer* 191:127-136.
- Kotwicki, S., T.W. Buckley, T. Honkalehto, and G. Walters. 2005. Variation in the distribution of walleye pollock (*Theragra chalcogramma*) with temperature and implications for seasonal migration. *U.S. Fish. Bull.* 103:574-587.
- Kotwicki, S., A. DeRobertis, P von Szalay, and R. Towler. 2009. The effect of light intensity on the availability of walleye pollock (*Theragra chalcogramma*) to bottom trawl and acoustic surveys. *Can. J. Fish. Aquat. Sci.* 66(6): 983-994
- Livingston, P.A. 1991. Groundfish food habits and predation on commercially important prey species in the eastern Bering Sea from 1884-1986. U.S. Dept. Commerce, NOAA Tech Memo. NMFS F/NWC-207.
- Meuter, F.J. and B.L. Norcross. 2002. Spatial and temporal patterns in the demersal fish community on the shelf and upper slope regions of the Gulf of Alaska. *Fish. Bull.* 100:559-581.

- Mueter, F.J., C. Ladd, M.C. Palmer, and B.L. Norcross. 2006. Bottom-up and top-down controls of walleye pollock (*Theragra chalcogramma*) on the Eastern Bering Sea shelf. *Progress in Oceanography*, Volume 68, 2:152-183.
- Moss, J.H., E.V. Farley, Jr., and A.M. Feldmann, J.N. Ianelli. 2009. Spatial Distribution, Energetic Status, and Food Habits of Eastern Bering Sea Age-0 Walleye Pollock. *Transactions of the American Fisheries Society* 138:497–505.
- Mulligan, T.J., Chapman, R.W. and B.L. Brown. 1992. Mitochondrial DNA analysis of walleye pollock, *Theragra chalcogramma*, from the eastern Bering Sea and Shelikof Strait, Gulf of Alaska. *Can. J. Fish. Aquat. Sci.* 49:319-326.
- Olsen, J.B., S.E. Merkouris, and J.E. Seeb. 2002. An examination of spatial and temporal genetic variation in walleye pollock (*Theragra chalcogramma*) using allozyme, mitochondrial DNA, and microsatellite data. *Fish. Bull.* 100:752-764.
- Rugen, W.C. 1990. Spatial and temporal distribution of larval fish in the western Gulf of Alaska, with emphasis on the period of peak abundance of walleye pollock (*Theragra chalcogramma*) larvae. *NWAFRC Proc. Rep.* 90-01, 162 pp.
- Stram, D. L., and J. N. Ianelli. 2009. Eastern Bering Sea pollock trawl fisheries: variation in salmon bycatch over time and space. In C. C. Krueger and C. E. Zimmerman, editors. *Pacific salmon: ecology and management of western Alaska's populations*. American Fisheries Society, Symposium 70, Bethesda, Maryland.
- Shima, M. 1996. A study of the interaction between walleye pollock and Steller sea lions in the Gulf of Alaska. Ph.D. dissertation, University of Washington, Seattle, WA 98195.
- Stabeno, P.J., J.D. Schumacher, K.M. Bailey, R.D. Brodeur, and E.D. Cokelet. 1996. Observed patches of walleye pollock eggs and larvae in Shelikof Strait, Alaska: their characteristics, formation and persistence. *Fish. Oceanogr.* 5 (Suppl. 1): 81-91.
- Wespestad V.G., and T.J. Quinn, II. 1997. Importance of cannibalism in the population dynamics of walleye pollock. In: *Ecology of Juvenile Walleye Pollock, Theragra chalcogramma*. NOAA Technical Report, NMFS 126.
- Wespestad, V.G. 1993. The status of BS pollock and the effect of the “Donut Hole” fishery. *Fisheries* 18(3):18-25.
- Wolotira, R.J., Jr., T.M. Sample, S.F. Noel, and C.R. Iten. 1993. Geographic and bathymetric distributions for many commercially important fishes and shellfishes off the west coast of North America, based on research survey and commercial catch data, 1912-84. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-AFSC-6, 184 pp.

D.2 Pacific cod (*Gadus macrocephalus*)

D.2.1 Life History and General Distribution

Pacific cod is a transoceanic species, occurring at depths from shoreline to 500 m. The southern limit of the species' distribution is about latitude 34° N. with a northern limit of about latitude 63° N. Adults are largely demersal and form aggregations during the peak spawning season, which extends approximately from January through May. Pacific cod eggs are demersal and adhesive. Eggs hatch in about 15 to 20 days. Little is known about the distribution of Pacific cod larvae, which undergo metamorphosis at about 25 to 35 mm. Juvenile Pacific cod start appearing in trawl surveys at a fairly small size, as small as 10 cm in the eastern Bering Sea. Pacific cod can grow to be more than 1 m in length, with weights in excess of 10 kilogram (kg). Natural mortality is currently estimated to be 0.34 in the BSAI and 0.38 in the GOA. Approximately 50 percent of Pacific cod are mature by age 5 in the BSAI and age 4 in the GOA. The maximum recorded age of a Pacific cod is 17 years in the BSAI and 14 years in the GOA.

The estimated size at 50 percent maturity is 58 cm in the BSAI and 50 cm in the GOA.

D.2.2 Fishery

The fishery is conducted with bottom trawl, longline, pot, and jig gear. More than 100 vessels participate in each of the three largest fisheries (trawl, longline, pot). The trawl fishery is typically concentrated during the first few months of the year, whereas fixed-gear fisheries may sometimes run, intermittently, at least, throughout the year. Historically, bycatch of crab and halibut has sometimes caused the Pacific cod fisheries to close prior to reaching the TAC. In the BSAI, trawl fishing is concentrated immediately north of Unimak Island, whereas the longline fishery is distributed along the shelf edge to the north and west of the Pribilof Islands. In the GOA, the trawl fishery has centers of activity around the Shumagin Islands and south of Kodiak Island, while the longline fishery is located primarily in the vicinity of the Shumagin Islands.

D.2.3 Relevant Trophic Information

Pacific cod are omnivorous. In terms of percent occurrence, the most important items in the diet of Pacific cod in the BSAI and GOA are polychaetes, amphipods, and crangonid shrimp. In terms of numbers of individual organisms consumed, the most important dietary items are euphausiids, miscellaneous fishes, and amphipods. In terms of weight of organisms consumed, the most important dietary items are walleye pollock, fishery discards, and yellowfin sole. Small Pacific cod feed mostly on invertebrates, while large Pacific cod are mainly piscivorous. Predators of Pacific cod include halibut, salmon shark, northern fur seals, sea lions, harbor porpoises, various whale species, and tufted puffin.

D.2.4 Habitat and Biological Associations

Egg/Spawning: Spawning takes place in the sublittoral-bathyal zone (40 to 290 m) near the bottom. Eggs sink to the bottom after fertilization and are somewhat adhesive. Optimal temperature for incubation is 3 to 6 °C, optimal salinity is 13 to 23 parts per thousand (ppt), and optimal oxygen concentration is from 2 to 3 ppm to saturation. Little is known about the optimal substrate type for egg incubation.

Larvae: Larvae are epipelagic, occurring primarily in the upper 45 m of the water column shortly after hatching, moving downward in the water column as they grow.

Juveniles: Juveniles occur mostly over the inner continental shelf at depths of 60 to 150 m.

Adults: Adults occur in depths from the shoreline to 500 m. Average depth of occurrence tends to vary directly with age for at least the first few years of life, with mature fish concentrated on the outer continental shelf. Preferred substrate is soft sediment, from mud and clay to sand.

Habitat and Biological Associations: Pacific cod

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	15 to 20 days	NA	winter–spring	ICS, MCS, OCS	D	M, SM, MS, S	U	optimum 3–6 °C optimum salinity 13–23 ppt
Larvae	U	copepods?	winter–spring	U	P?, N?	U	U	
Early Juveniles	to 2 years	small invertebrates (euphausiids, mysids, shrimp)	all year	ICS, MCS	D	M, SM, MS, S	U	
Late Juveniles	to 5 years	pollock, flatfish, fishery discards, crab	all year	ICS, MCS, OCS	D	M, SM, MS, S	U	
Adults	5+ yr	pollock, flatfish, fishery discards, crab	spawning (Jan–May) non-spawning (Jun–Dec)	ICS, MCS, OCS ICS, MCS, OCS	D	M, SM, MS, S, G	U	

D.2.5 Literature

- Abookire, A.A., J.T. Duffy-Anderson, and C.M. Jump. 2007. Habitat associations and diet of young-of-the-year Pacific cod (*Gadus macrocephalus*) near Kodiak, Alaska. *Marine Biology* 150:713-726.
- Albers, W.D., and P.J. Anderson. 1985. Diet of Pacific cod, *Gadus macrocephalus*, and predation on the northern pink shrimp, *Pandalus borealis*, in Pavlof Bay, Alaska. *Fish. Bull.*, U.S. 83:601-610.
- Alderdice, D.F., and C.R. Forrester. 1971. Effects of salinity, temperature, and dissolved oxygen on early development of the Pacific cod (*Gadus macrocephalus*). *J. Fish. Res. Board Can.* 28:883-902.
- Bakkala, R.G. 1984. Pacific cod of the EBS. *Int. N. Pac. Fish. Comm. Bull.* 42:157-179.
- Brodeur, R.D., and W. C. Rugen. 1994. Diel vertical distribution of ichthyoplankton in the northern Gulf of Alaska. *Fish. Bull.*, U.S. 92:223-235.
- Dunn, J.R., and A.C. Matarese. 1987. A review of the early life history of northeast Pacific gadoid fishes. *Fish. Res.* 5:163-184.
- Forrester, C.R., and D.F. Alderdice. 1966. Effects of salinity and temperature on embryonic development of Pacific cod (*Gadus macrocephalus*). *J. Fish. Res. Board Can.* 23:319-340.
- Hirschberger, W.A., and G.B. Smith. 1983. Spawning of twelve groundfish species in Alaska and Pacific Coast regions, 1975-81. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS F/NWC-44. 50 p.
- Hurst, T.P., D.W. Cooper, J.S. Scheingross, E.M. Seale, B.J. Laurel, and M.L. Spencer. 2009. Effects of ontogeny, temperature, and light on vertical movements of larval Pacific cod (*Gadus macrocephalus*). *Fisheries Oceanography* 18:301-311.
- Ketchen, K.S. 1961. Observations on the ecology of the Pacific cod (*Gadus macrocephalus*) in Canadian waters. *J. Fish. Res. Board Can.* 18:513-558.
- Laurel, B.J., T.P. Hurst, L.A. Copeman, and M. W. Davis. 2008. The role of temperature on the growth and survival of early and late hatching Pacific cod larvae (*Gadus macrocephalus*). *Journal of Plankton Research* 30:1051-1060.
- Laurel, B.J., C.H. Ryer, B. Knoth, and A.W. Stoner. 2009. Temporal and ontogenetic shifts in habitat use of juvenile Pacific cod (*Gadus macrocephalus*). *Journal of Experimental Marine Biology and Ecology* 377:28-35.

- Laurel, B.J., A.W. Stoner, C.H. Ryer, T.P. Hurst, and A.A. Abookire. 2007. Comparative habitat associations in juvenile Pacific cod and other gadids using seines, baited cameras and laboratory techniques. 2007. *Journal of Experimental Marine Biology and Ecology* 351:42-55.
- Livingston, P.A. 1989. Interannual trends in Pacific cod, *Gadus macrocephalus*, predation on three commercially important crab species in the EBS. *Fish. Bull.*, U.S. 87:807-827.
- Livingston, P.A. 1991. Pacific cod. In P.A. Livingston (editor), *Groundfish food habits and predation on commercially important prey species in the EBS from 1984 to 1986*, p. 31-88. U.S. Dept. Commer., NOAA Tech. Memo. NMFS F/NWC-207.
- Matarese, A.C., A.W. Kendall Jr., D.M. Blood, and B.M. Vinter. 1989. Laboratory guide to early life history stages of northeast Pacific fishes. U.S. Dept. Commerce, NOAA Tech. Rep. NMFS 80. 652 p.
- Moiseev, P.A. 1953. Cod and flounders of far eastern waters. *Izv. Tikhookean. Nauchno-issled. Inst. Rybn. Khoz. Okeanogr.* 40. 287 p. (Transl. from Russian: Fish. Res. Board Can. Transl. Ser. 119.)
- NOAA. 1987. Bering, Chukchi, and Beaufort Seas--Coastal and ocean zones strategic assessment: Data Atlas. U.S. Dept. Commerce, NOAA, National Ocean Service.
- NOAA. 1990. West coast of North America--Coastal and ocean zones strategic assessment: Data Atlas. U.S. Dept. Commerce, NOAA, National Ocean Service and NMFS.
- Phillips, A.C., and J.C. Mason. 1986. A towed, self-adjusting sld sampler for demersal fish eggs and larvae. *Fish. Res.* 4:235-242.
- Poltev, Yu.N. 2007. Specific features of spatial distribution of Pacific cod *Gadus macrocephalus* in waters off the eastern coast of the northern Kuril Islands and the southern extremity of Kamchatka. *Journal of Ichthyology* 47:726-738.
- Rugen, W.C., and A.C. Matarese. 1988. Spatial and temporal distribution and relative abundance of Pacific cod (*Gadus macrocephalus*) larvae in the western GOA. NWAFC Proc. Rep. 88-18. Available from Alaska Fish. Sci. Center, 7600 Sand Point Way NE., Seattle, WA 98115-0070.
- Savin, A.B. 2008. Seasonal distribution and migrations of Pacific cod *Gadus macrocephalus* (Gadidae) in Anadyr Bay and adjacent waters. *Journal of Ichthyology* 48:610-621.
- Shi, Y., D. R. Gunderson, P. Munro, and J. D. Urban. 2007. Estimating movement rates of Pacific cod (*Gadus macrocephalus*) in the Bering Sea and the Gulf of Alaska using mark-recapture methods. NPRB Project 620 Final Report. North Pacific Research Board, 1007 West 3rd Avenue, Suite 100, Anchorage, AK 99501.
- Stone, R.P. 2006. Coral habitat in the Aleutian Islands of Alaska: depth distribution, fine-scale species associations, and fisheries interactions. *Coral Reefs* 25:229-238.
- Thompson, G., J. Ianelli, R. Lauth, S. Gaichas, and K. Aydin. 2008. Assessment of the Pacific cod stock in the Eastern Bering Sea and Aleutian Islands Area. In Plan Team for the Groundfish Fisheries of the Bering Sea and Aleutian Islands (compiler), *Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions*, p. 221-401. North Pacific Fishery Management Council, 605 West 4th Avenue, Suite 306, Anchorage, AK 99501.
- Thompson, G., J. Ianelli, and M. Wilkins. 2008. Assessment of the Pacific cod stock in the Gulf of Alaska. In Plan Team for the Groundfish Fisheries of the Gulf of Alaska (compiler), *Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska*, p. 169-301. North Pacific Fishery Management Council, 605 West 4th Avenue, Suite 306, Anchorage, AK 99501.
- Westrheim, S.J. 1996. On the Pacific cod (*Gadus macrocephalus*) in British Columbia waters, and a comparison with Pacific cod elsewhere, and Atlantic cod (*G. morhua*). *Can. Tech. Rep. Fish. Aquat. Sci.* 2092. 390 p.
- Yeung, C., and R.A. McConnaughey. 2008. Using acoustic backscatter from a sidescan sonar to explain fish and invertebrate distributions: a case study in Bristol Bay, Alaska. *ICES Journal of Marine Science* 65:242-254.

D.3 Sablefish (*Anoplopoma fimbria*)

D.3.1 Life History and General Distribution

Sablefish are distributed from Mexico through the GOA to the Aleutian Chain, Bering Sea, along the Asian coast from Sagami Bay, and along the Pacific sides of Honshu and Hokkaido Islands and the Kamchatka Peninsula. Adult sablefish occur along the continental slope, shelf gullies, and in deep fjords such as Prince William Sound and southeast Alaska, at depths generally greater than 200 m. Adults are assumed to be demersal. Spawning or very ripe sablefish are observed in late winter or early spring along the continental slope. Eggs are apparently released near the bottom where they incubate. After hatching and yolk adsorption, the larvae rise to the surface, where they have been collected with neuston nets. Larvae are oceanic through the spring and by late summer, small pelagic juveniles (10 to 15 cm) have been observed along the outer coasts of Southeast Alaska, where they apparently move into shallow waters to spend their first winter. During most years, there are only a few places where juveniles have been found during their first winter and second summer. It is not clear if the juvenile distribution is highly specific or appears so because sampling is highly inefficient and sparse. During the occasional times of large year-classes, the juveniles are easily found in many inshore areas during their second summer. They are typically 30 to 40 cm long during their second summer, after which they apparently leave the nearshore bays. One or two years later, they begin appearing on the continental shelf and move to their adult distribution as they mature.

Pelagic ocean conditions appear to determine when strong young-of-the-year survival occurs. Water mass movements and temperature appear to be related to recruitment success (Sigler et al. 2001). Above-average young of the year survival was somewhat more likely with northerly winter currents and much less likely for years when the drift was southerly. Recruitment success also appeared related to water temperature. Recruitment was above average in 61 percent of the years when temperature was above average, but was above average in only 25 percent of the years when temperature was below average. Recruitment success did not appear to be directly related to the presence of El Niño or eddies, but these phenomena could potentially influence recruitment indirectly in years following their occurrence (Sigler et al. 2001).

While pelagic oceanic conditions determine the egg, larval, and juvenile survival through their first summer, juvenile sablefish spend 3 to 4 years in demersal habitat along the shorelines and continental shelf before they recruit to their adult habitat, primarily along the upper continental slope, outer continental shelf, and deep gullies. As juveniles in the inshore waters and on the continental shelf, they are subject to a myriad of factors that determine their ability to grow, compete for food, avoid predation, and otherwise survive to adults. Perhaps demersal conditions that may have been brought about by bottom trawling (habitat, bycatch, and increased competitors) have limited the ability of the large year classes that, though abundant at the young-of-the-year stage, survive to adults.

Size at 50 percent maturity is as follows:

Bering males 65 cm, females 67 cm
Sea:

Aleutian males 61 cm, females 65 cm
Islands:

GOA: males 57 cm, females 65 cm

At the end of the second summer (approximately 1.5 years old), they are 35 to 40 cm long.

D.3.2 Fishery

The major fishery for sablefish in Alaska uses longlines; however sablefish are valuable in the trawl fishery as well. Sablefish enter the longline fishery at 4 to 5 years of age, perhaps slightly younger in the trawl fishery. The longline fishery takes place between March 1 and November 15. The take of the trawl share of sablefish occurs primarily in association with fisheries for other species, such as rockfish, where they are taken as allowed bycatch. Grenadier (*Albatrossia pectoralis* and *Coryphaenoides acrolepis*), and deeper dwelling rockfish, such as shortraker, rougheye, and thornyhead rockfish, are the primary bycatch in the longline sablefish fishery. Halibut also are taken. By regulation, there is no directed trawl fishery for sablefish; however, directed fishing standards have allowed some trawl hauls to target sablefish, where the bycatch is similar to the longline fishery, in addition perhaps to some deep dwelling flatfish. Pot fishing for sablefish has increased in the BSAI in recent years as a response to depredation of longline catches by killer whales.

In addition to the fishery for sablefish, there are significant fisheries for other species that may have an effect on the habitat of sablefish, primarily juveniles. As indicated above, before moving to adult habitat on the continental slope and deep gullies, sablefish 2 to 4 years of age reside on the continental shelf, where significant trawl fisheries have taken place. It is difficult to evaluate the potential effect such fisheries could have had on sablefish survival, as a clear picture of the distribution and intensity of the groundfish fishery prior to 1997 has not been available. It is worth noting however, that the most intensely trawled area from 1998 to 2002, which is just north of the Alaska Peninsula, was closed to trawling by Japan in 1959 and apparently was untrawled until it was opened to U.S. trawling in 1983 (Witherell 1997, Fredin 1987). Juvenile sablefish of the 1977 year class were observed in the western portion of this area by the Alaska Fisheries Science Center trawl survey in 1978 to 1980 at levels of abundance that far exceed levels that have been seen since (Umeda et al. 1983). Observations of 1-year-old and young-of-the-year sablefish in inshore waters from 1980 to 1990 indicate that above-average egg to larval survival has occurred for a number of year classes since.

D.3.3 Relevant Trophic Information

Larval sablefish feed on a variety of small zooplankton ranging from copepod nauplii to small amphipods. The epipelagic juveniles feed primarily on macrozooplankton and micronekton (i.e., euphausiids).

In their demersal stage, juvenile sablefish less than 60 cm feed primarily on euphausiids, shrimp, and cephalopods (Yang and Nelson 2000, Yang et al. 2006) while sablefish greater than 60 cm feed more on fish. Both juvenile and adult sablefish are considered opportunistic feeders. Fish most important to the sablefish diet include pollock, eulachon, capelin, Pacific herring, Pacific cod, Pacific sand lance, and some flatfish, with pollock being the most predominant (10 to 26 percent of prey weight, depending on year). Squid, euphausiids, pandalid shrimp, Tanner crabs, and jellyfish were also found, squid being the most important of the invertebrates (Yang and Nelson 2000, Yang et al. 2006). Feeding studies conducted in Oregon and California found that fish made up 76 percent of the diet (Laidig et al. 1997). Off the southwest coast of Vancouver Island, euphausiids dominated sablefish diet (Tanasichuk 1997). Among other groundfish in the GOA, the diet of sablefish overlaps mostly with that of large flatfish, arrowtooth flounder and Pacific halibut (Yang and Nelson 2000).

Nearshore residence during their second year provides sablefish with the opportunity to feed on salmon fry and smolts during the summer months, while young-of-the-year sablefish are commonly found in the stomachs of salmon taken in the Southeast Alaska troll fishery during the late summer.

D.3.4 Habitat and Biological Associations

The estimated productivity and sustainable yield of the combined GOA, Bering Sea, and Aleutian Islands sablefish stock have declined steadily since the late 1970s. This is demonstrated by a decreasing trend in recruitment and subsequent estimates of biomass reference points and the inability of the stock to rebuild

to the target biomass levels despite the decreasing level of the targets and fishing rates below the target fishing rate. While years of strong young-of-the-year survival has occurred in the 1980s and the 1990s, the failure of strong recruitment to the mature stage suggests a decreased survival of juveniles during their residence as 2 to 4 year olds on the continental shelf.

Habitat and Biological Associations: Sablefish

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	14 to 20 days	NA	late winter–early spring: Dec–Apr	USP, LSP, BSN	P, 200–3,000 m	NA	U	
Larvae	up to 3 months	copepod nauplii, small copepodites	spring–summer: Apr–July	MCS, OCS, USP, LSP, BSN	N, neustonic near surface	NA	U	
Early Juveniles	up to 3 years	small prey fish, sandlance, salmon, herring		OCS, MCS, ICS, during first summer, then observed in BAY and IP, until end of 2nd summer; not observed until found on shelf	P when offshore during first summer, then D, SD/SP when inshore	NA when pelagic. The bays where observed were soft bottomed, but not enough observed to assume typical.	U	
Late Juveniles	3 to 5 years	opportunistic: other fish, shellfish, worms, jellyfish, fishery discards	all year	continental slope, and deep shelf gullies and fjords.	Presumably D	varies	U	
Adults	5 to 35+ years	opportunistic: other fish, shellfish, worms, jellyfish, fishery discards	apparently year around, spawning movements (if any) are undescribed	continental slope, and deep shelf gullies and fjords.	Presumably D	varies	U	

D.3.5 Literature

- Allen, M.J., and G.B. Smith. 1988. Atlas and Zoogeography of common fishes in the BS and northeastern Pacific. U.S. Dep. Commer., NOAA Tech. Rept. NMFS 66, 151 p.
- Boehlert, G.W., and M.M. Yoklavich. 1985. Larval and juvenile growth of sablefish, *Anoplopoma fimbria*, as determined from otolith increments. Fish. Bull. 83:475-481.
- Fredin, R. A. 1987. History of regulation of Alaska groundfish fisheries. NWAFC Processed Report 87_07.
- Grover, J.J., and B.L. Olla. 1986. Morphological evidence for starvation and prey size selection of sea-caught larval sablefish, *Anoplopoma fimbria*. Fish. Bull. 84:484-489.
- Grover, J.J., and B.L. Olla. 1987. Effects of and El Niño event on the food habits of larval sablefish, *Anoplopoma fimbria*, off Oregon and Washington. Fish. Bull. 85: 71-79.
- Grover, J.J., and B.L. Olla. 1990. Food habits of larval sablefish, *Anoplopoma fimbria* from the BS. Fish Bull. 88:811-814.
- Hunter, J.R., B.J. Macewicz, and C.A. Kimbrell. 1989. Fecundity and other aspects of the reproduction of Sablefish, *Anoplopoma fimbria*, in Central California Waters. Calif. Coop. Fish. Invest. Rep. 30: 61-72.
- Kendall, A.W., Jr., and A.C. Matarese. 1984. Biology of eggs, larvae, and epipelagic juveniles of sablefish, *Anoplopoma fimbria*, in relation to their potential use in management. Mar. Fish. Rev. 49(1):1-13.

- Laidig, T. E., P. B. Adams, and W. M. Samiere. 1997. Feeding habits of sablefish, *Anoplopoma fimbria*, off the coast of Oregon and California. In M. Saunders and M. Wilkins (eds.). Proceedings of the International Symposium on the Biology and Management of Sablefish. pp 65-80. NOAA Tech. Rep. 130.
- Mason, J.C., R.J. Beamish, and G.A. McFralen. 1983. Sexual maturity, fecundity, spawning, and early life history of sablefish (*Anoplopoma fimbria*) off the Pacific coast of Canada. Can. J. Fish. Aquat. Sci. 40:2121-2134.
- McFarlane, G.A., and R.J. Beamish. 1992. Climatic influence linking copepod production with strong year-classes in sablefish, *Anoplopoma fimbria*. Can J. Fish. Aquat. Sci. 49:743-753.
- Moser, H.G., R.L. Charter, P.E. Smith, N.C.H. Lo., D.A. Ambrose, C.A. Meyer, E.M. Sanknop, and W. Watson. 1994. Early life history of sablefish, *Anoplopoma fimbria*, off Washington, Oregon, and California with application to biomass estimation. Calif. Coop. Oceanic Fish. Invest. Rep. 35:144-159.
- NOAA. 1990. Sablefish, *Anoplopoma fimbria*. Pl 3.2.22. IN: West Coast of North America Coastal and Ocean Zones Strategic Assessment Data Atlas. Invertebrate and Fish Volume. U.S. Dep. Commer. NOAA. OMA/NOS, Ocean Assessment Division, Strategic Assessment Branch.
- Rutecki, T.L., and E.R. Varosi. 1993. Distribution, age, and growth of juvenile sablefish in Southeast Alaska. Paper presented at International Symposium on the Biology and Management of Sablefish. Seattle, Wash. April 1993.
- Rutecki, T.L., and E.R. Varosi. 1993. Migrations of Juvenile Sablefish in Southeast Alaska. Paper presented at International Symposium on the Biology and Management of Sablefish. Seattle, Wash. April 1993.
- Sasaki, T. 1985. Studies on the sablefish resources in the North Pacific Ocean. Bulletin 22, (1-108), Far Seas Fishery Laboratory. Shimizu, 424, Japan.
- Sigler, M.F., E.R. Varosi, and T.R. Rutecki. 1993. Recruitment curve for sablefish in Alaska based on recoveries of fish tagged as juveniles. Paper presented at International Symposium on the Biology and Management of Sablefish. Seattle, Wash. April 1993.
- Sigler, M. F., T. L. Rutecki, D. L. Courtney, J. F. Karinen, and M.-S. Yang. 2001. Young-of-the-year sablefish abundance, growth, and diet. Alaska Fisheries Research Bulletin 8(1): 57-70.
- Smith, G.B., G.E. Walters, P.A. Raymore, Jr., and W.A. Hirschberger. 1984. Studies of the distribution and abundance of juvenile groundfish in the northwestern GOA, 1980-82: Part I, Three-year comparisons. NOAA Tech. Memo. NMFS F/NWC-59. 100p.
- Tanasichuk, R. W. 1997. Diet of sablefish, *Anoplopoma fimbria*, from the southwest coast of Vancouver Island. In M. Saunders and M. Wilkins (eds.). Proceedings of the International Symposium on the Biology and Management of Sablefish. pp 93-98. NOAA Tech. Rep. 130.
- Umeda, Y., T. Sample, and R. G. Bakkala. 1983. Recruitment processes of sablefish in the EBS. In Proceedings of the International Sablefish Symposium March 1983, Anchorage, Alaska. Alaska Sea Grant Report 83-8. Walters, G.E., G.B. Smith, P.A. Raymore, and W.A. Hirschberger. 1985. Studies of the distribution and abundance of juvenile groundfish in the northwestern GOA, 1980-82: Part II, Biological characteristics in the extended region. NOAA Tech. Memo. NMFS F/NWC-77. 95 p.
- Wing, B.L. 1985. Salmon Stomach contents from the Alaska Troll Logbook Program, 1977-84. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-91, 41 p.
- Wing, B.L. 1997. Distribution of sablefish, *Anoplopoma fimbria*, larvae in the eastern GOA: Neuston-net tows versus oblique tows. In: M. Wilkins and M. Saunders (editors), Proc. Int. Sablefish Symp., April 3-4, 1993, p. 13-25. U.S. Dep. Commer., NOAA Tech. Rep. 130.
- Wing, B.L., and D.J. Kamikawa. 1995. Distribution of neustonic sablefish larvae and associated ichthyoplankton in the eastern GOA, May 1990. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-53, 48 p.
- Wing, B.L., C. Derrah, and V. O'Connell. 1997. Ichthyoplankton in the eastern GOA, May 1990. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-376, 42 p.
- Wing, B.L. and D.J. Kamikawa. 1995. Distribution of neustonic sablefish larvae and associated ichthyoplankton in the eastern GOA, May 1990. NOAA Tech. Memo. NMFS-AFSC-53.

- Witherell, D 1997. A brief history of bycatch management measures for EBS groundfish fisheries. Marine Fisheries Review. Wolotera, R.J., Jr., T.M. Sample, S.F. Noel, and C.R. Iten. 1993. Geographic and bathymetric distributions for many commercially important fishes and shellfishes off the west coast of North America, based on research survey and commercial catch data, 1912-1984. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-6, 184 p.
- Yang, M-S. 1993. Food habits of the commercially important groundfishes in the GOA in 1990. NOAA Tech. Memo. NMFS-AFSC-22. 150 p.
- Yang, M-S. and M.W. Nelson. 2000. Food habits of the commercially important groundfishes in the GOA in 1990, 1993, and 1996. NOAA Technical Memorandum NMFS-AFSC-112.
- Yang, M-S., K. Dodd, R. Hibshman, and A. Whitehouse. 2006. Food habits of groundfishes in the Gulf of Alaska in 1999 and 2001. NOAA Technical Memorandum NMFS-AFSC-164.

D.4 Yellowfin sole (*Limanda aspera*)

Yellowfin sole is part of the shallow water flatfish management complex in the GOA.

D.4.1 Life History and General Distribution

Yellowfin sole are distributed in North American waters from off British Columbia, Canada (approximately latitude 49° N.) to the Chukchi Sea (about latitude 70° N.) and south along the Asian coast to about latitude 35° N. off the South Korean coast in the Sea of Japan. Adults exhibit a benthic lifestyle and are consistently caught in shallow areas along the Alaska Peninsula and around Kodiak Island during resource assessment surveys in the GOA. From over-winter grounds near the shelf margins, adults begin a migration onto the inner shelf in April or early May each year for spawning and feeding. A protracted and variable spawning period may range from as early as late May through August occurring primarily in shallow water. Fecundity varies with size and was reported to range from 1.3 to 3.3 million eggs for fish 25 to 45 cm long. Larvae have primarily been captured in shallow shelf areas in the Kodiak Island area and have been measured at 2.2 to 5.5 mm in July and 2.5 to 12.3 mm in late August and early September in the Bering Sea. The age or size at metamorphosis is unknown. Juveniles are separate from the adult population, remaining in shallow areas until they reach approximately 15 cm. The estimated age of 50 percent maturity is 10.5 years (approximately 29 cm) for females based on samples collected in 1992 and 1993. Natural mortality rate is believed to range from 0.12 to 0.16.

The approximate upper size limit of juvenile fish is 27 cm.

D.4.2 Fishery

Yellowfin sole are classified as part of the shallow water flatfish management complex and are caught in bottom trawls directed at northern and southern rock sole and in pursuit of other bottom-dwelling species. Recruitment begins at about age 6 and they are fully selected at age 13.

D.4.3 Relevant Trophic Information

Groundfish predators include Pacific cod, skates, and Pacific halibut, mostly on fish ranging from 7 to 25 cm standard length.

D.4.4 Habitat and Biological Associations

Larvae/Juveniles: Planktonic larvae for at least 2 to 3 months until metamorphosis occurs, usually inhabiting shallow areas.

Adults: Summertime spawning and feeding on sandy substrates typically nearshore in shallow shelf areas feeding mainly on bivalves, polychaetes, amphipods and echiurids. Wintertime migration to deeper waters of the shelf margin to avoid extreme cold water temperatures, feeding diminishes.

Habitat and Biological Associations: Yellowfin sole

Stage - EFH Level	Duration or Age	Diet/Prey	Season/Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs		NA	summer	BAY, BCH	P			
Larvae	2 to 3 months?	U phyto/zooplankton?	summer, autumn?	BAY, BCH, ICS	P			
Early Juveniles	to 5.5 years	polychaetes, bivalves, amphipods, echiurids	all year	BAY, ICS, OCS, MCS	D	S		
Late Juveniles	5.5 to 10 years	polychaetes, bivalves, amphipods, echiurids	all year	BAY, ICS, OCS, MCS, IP	D	S		
Adults	10+ years	polychaetes, bivalves, amphipods, echiurids	spawning/ feeding May–August non-spawning Nov–April	BAY, BCH, ICS, MCS, OCS, IP	D	S	ice edge	

D.4.5 Literature

- Auster, P.J., Malatesta, R.J., Langton, R.W., L. Watling, P.C. Valentine, C.S. Donaldson, E.W. Langton, A.N. Shepard, and I.G. Babb. 1996. The impacts of mobile fishing gear on seafloor habitats in the Gulf of Maine (Northwest Atlantic): Implications for conservation of fish populations. Rev. in Fish. Sci. 4(2): 185-202.
- Bakkala, R.G., V.G. Wespestad, and L.L. Low. 1982. The yellowfin sole (*Limanda aspera*) resource of the EBS--Its current and future potential for commercial fisheries. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-33, 43 p.
- Fadeev, N.W. 1965. Comparative outline of the biology of fishes in the southeastern part of the BS and condition of their resources. [In Russ.] Tr. Vses. Nauchno-issled. Inst.Morsk. Rybn. Khoz. Okeanogr. 58 (Izv. Tikhookean. Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 53):121-138. (Trans. By Isr. Prog. Sci. Transl., 1968), p 112-129. In P.A. Moiseev (Editor), Soviet Fisheries Investigations in the northeastern Pacific, Pt. IV. Avail. Natl. Tech. Inf. Serv., Springfield, VA as TT 67-51206.
- Kashkina, A.A. 1965. Reproduction of yellowfin sole (*Limanda aspera*) and changes in its spawning stocks in the EBS. Tr. Vses. Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 58 (Izv. Tikhookean. Nauchno-issled. Inst. Rbn. Khoz. Okeanogr. 53):191-199. [In Russ.] Transl. By Isr. Prog. Sci. Transl., 1968, p. 182-190. In P.A. Moiseev (Editor), Soviet fisheries investigations in the northeastern Pacific, Part IV. Avail. Natl. Tech. Inf. Serv., Springfield, VA., as TT67-51206.
- Livingston, P.A. and Y. DeReynier. 1996. Groundfish food habits and predation on commercially important prey species in the EBS from 1990 to 1992. AFSC processed Rep. 96-04, 51 p. Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Seattle, WA 98115.
- Musienko, L.N. 1963. Ichthyoplankton of the BS (data of the BS expedition of 1958-59). Tr. Vses Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 48 (Izv. Tikhookean. Nauchno-issled. Inst. Rybn. Khoz. Okeanogr. 50)239-269. [In Russ.] Transl. By Isr. Prog. Sci. Transl., 1968, p. 251-286. In P.A. Moiseev (Editor), Soviet fisheries investigations in the northeastern Pacific, Part I. Avail. Natl. Tech. Inf. Serv., Springfield, VA, as TT67-51203.
- Musienko, L.N. 1970. Reproduction and Development of BS. Tr. Vses Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 70 (Izv. Tikhookean. Nauchno-issled. Inst. Rybn. Khoz. Okeanogr. 72)161-224. [In Russ.] Transl. By Isr. Prog. Sci. Transl., 1972, p. 161-224. In P.A. Moiseev (Editor), Soviet fisheries

- investigations in the northeastern Pacific, Part V. Avail. Natl. Tech. Inf. Serv., Springfield, VA., as TT71-50127.
- Nichol, D.G. 1994. Maturation and Spawning of female yellowfin sole in the EBS. Preceding of the International North Pacific Flatfish Symposium, Oct. 26-28, 1994, Anchorage, AK. Alaska Sea Grant Program.
- Wakabayashi, K. 1986. Interspecific feeding relationships on the continental shelf of the EBS, with special reference to yellowfin sole. Int. N. Pac. Fish. Comm. Bull. 47:3-30.
- Waldron, K.D. 1981. Ichthyoplankton. In D.W. Hood and J.A. Calder (Editors), The EBS shelf: Oceanography and resources, Vol. 1, p. 471-493. U.S. Dep. Commer., NOAA, Off. Mar. Poll. Assess., U.S. Gov. Print. Off., Wash., D.C.
- Wilderbuer, T.K., G.E. Walters, and R.G. Bakkala. 1992. Yellowfin sole, *Pleuronectes asper*, of the EBS: Biological Characteristics, History of Exploitation, and Management. Mar. Fish. Rev. 54(4) p 1-18.

D.5 Northern rock sole (*Lepidopsetta polyxystra*)

The shallow water flatfish management complex in the GOA consists of eight species: northern rock sole (*Lepidopsetta polyxystra*), southern rock sole (*Lepidopsetta bilineata*), yellowfin sole (*Limanda aspera*), starry flounder (*Platichthys stellatus*), butter sole (*Isopsetta isolepis*), English sole (*Parophrys vetulus*), Alaska plaice (*Pleuronectes quadrituberculatus*), and sand sole (*Psettichthys melanostictus*). The two rock sole species in the GOA have distinct characteristics and overlapping distributions. These two species of rock sole and yellowfin sole are the most abundant and commercially important species of this management complex in the GOA, and the description of their habitat and life history best represents the shallow water complex species.

D.5.1 Life History and General Distribution

Northern rock sole are distributed from Puget Sound through the BSAI to the Kuril Islands, overlapping with southern rock sole in the GOA (Orr and Matarese 2000). Centers of abundance occur off the Kamchatka Peninsula (Shubnikov and Lisovenko 1964), British Columbia (Forrester and Thompson 1969), the central GOA, and in the southeastern Bering Sea (Alton and Sample 1976). Adults exhibit a benthic lifestyle and, in the eastern Bering Sea, occupy separate winter (spawning) and summertime feeding distributions on the continental shelf. Northern rock sole spawn during the winter through early spring period of December through March. Soviet investigations in the early 1960s established two spawning concentrations: an eastern concentration north of Unimak Island at the mouth of Bristol Bay and a western concentration eastward of the Pribilof Islands between 55°30' and 55°0' N. and approximately 165°2' W. (Shubnikov and Lisovenko 1964). Northern rock sole spawning in the GOA has been found to occur at depths of 43 to 61 m (Stark and Somerton 2002). Spawning females deposit a mass of eggs that are demersal and adhesive (Alton and Sample 1976). Fertilization is believed to be external. Incubation time is temperature dependent and may range from 6.4 days at 11 °C to about 25 days at 2.9 °C (Forrester 1964). Newly hatched larvae are pelagic and have occurred sporadically in eastern Bering Sea plankton surveys (Waldron and Vinter 1978). Kamchatka larvae are reportedly 20 mm in length when they assume their side-swimming, bottom-dwelling form (Alton and Sample 1976, Orr and Matarese 2000). Forrester and Thompson (1969) report that by age 1, they are found with adults on the continental shelf during summer.

In the springtime, after spawning, northern rock sole begin actively feeding and exhibit a widespread distribution throughout the shallow waters of the continental shelf. This migration has been observed on both the eastern (Alton and Sample 1976) and western (Shvetsov 1978) areas of the Bering Sea and in the GOA. Summertime trawl surveys indicate most of the population can be found at depths from 50 to 100 m (Armistead and Nichol 1993). The movement from winter/spring to summer grounds is in response to

warmer temperatures in the shallow waters and the distribution of prey on the shelf seafloor (Shvetsov 1978). In September, with the onset of cooling in the northern latitudes, northern rock sole begin the return migration to the deeper wintering grounds. Fecundity varies with size and was reported to be 450,000 eggs for fish 42 cm long. Larvae are pelagic, but their occurrence in plankton surveys in the eastern Bering Sea is rare (Musienko 1963). Juveniles are separate from the adult population, remaining in shallow areas until they reach age 1 (Forrester 1964). The estimated age of 50 percent maturity is 7 years for northern rock sole females (approximately 33 cm). The natural mortality rate is believed to range from 0.18 to 0.20 (Turnock et al. 2002).

D.5.2 Fishery

Northern rock sole are caught in bottom trawls both as a directed fishery and in the pursuit of other bottom-dwelling species. Recruitment begins at about age 4 and they are fully selected at age 11. Historically, the fishery has nearshore to the Kodiak Island area and along the Alaska peninsula. They are caught as bycatch in Pacific cod, bottom pollock, and other flatfish fisheries and are caught with these species and Pacific halibut in rock sole directed fisheries.

D.5.3 Relevant Trophic Information

Groundfish predators to rock sole include Pacific cod, walleye pollock, skates, Pacific halibut, and yellowfin sole, mostly on fish ranging from 5 to 15 cm standard length.

D.5.4 Habitat and Biological Associations

Larvae/Juveniles: Planktonic larvae for at least 2 to 3 months until metamorphosis occurs, juveniles inhabit shallow areas at least until age 1.

Adults: Summertime feeding on primarily sandy substrates of the eastern Bering Sea shelf. Widespread distribution mainly on the middle and inner portion of the shelf, feeding on bivalves, polychaetes, amphipods, and miscellaneous crustaceans. Wintertime migration to deeper waters of the shelf margin for spawning and to avoid extreme cold water temperatures, feeding diminishes.

Habitat and Biological Associations: Northern rock sole

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs		NA	winter	OCS	D			
Larvae	2 to 3 months?	U phyto/zooplankton?	winter/spring	OCS, MCS, ICS	P			
Early Juveniles	to 3.5 years	polychaetes, bivalves, amphipods, misc. crustaceans	all year	BAY, ICS, OCS, MCS	D	S, G		
Late Juveniles	up to 9 years	polychaetes, bivalves, amphipods, misc. crustaceans	all year	BAY, ICS, OCS, MCS	D	S, G		
Adults	9+ years	polychaetes, bivalves, amphipods, misc. crustacean	feeding May–September spawning Dec–April	MCS, ICS MCS, OCS	D	S, G	ice edge	

D.5.5 Literature

Alton, M.S., and T.M. Sample. 1976. Rock sole (Family Pleuronectidae) p. 461-474. *In*: Demersal fish and shellfish resources in the BS in the baseline year 1975. Principal investigators Walter T. Pereyra, Jerry E. Reeves,

- and Richard Bakkala. U.S. Dep. Comm., Natl. Oceanic Atmos. Admin., Natl. Mar. Serv., Northwest and Alaska Fish Center, Seattle, WA. Processed Rep., 619 p.
- Armistead, C.E., and D.G. Nichol. 1993. 1990 Bottom Trawl Survey of the EBS Continental Shelf. U.S. Dep. Commer., NOAA Tech. Mem. NMFS-AFSC-7, 190 p.
- Auster, P.J., R.J. Malatesta., R.W. Langton., L. Watling, P.C. Valentine, C.S. Donaldson, E.W. Langton, A.N. Shepard, and I.G. Babb. 1996. The impacts of mobile fishing gear on seafloor habitats in the Gulf of Maine (Northwest Atlantic): Implications for conservation of fish populations. Rev. in Fish. Sci. 4(2): 185-202.
- Forrester, C.R. 1964. Demersal Quality of fertilized eggs of rock sole. J. Fish. Res. Bd. Canada, 21(6), 1964. P. 1531.
- Forrester, C.R., and J.A. Thompson. 1969. Population studies on the rock sole, *Lepidopsetta bilineata*, of northern Hecate Strait British Columbia. Fish. Res. Bd. Canada, Tech. Rep. No. 108, 1969. 104 p.
- Livingston, P.A., and Y. DeReynier. 1996. Groundfish food habits and predation on commercially important prey species in the EBS from 1990 to 1992. AFSC processed Rep. 96-04, 51 p. Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Seattle, WA 98115.
- Musienko, L.N. 1963. Ichthyoplankton of the BS (data of the BS expedition of 1958-59). Tr. Vses Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 48 (Izv. Tikhookean. Nauchno-issled. Inst. Rybn. Khoz. Okeanogr. 50)239-269. [In Russ.] Transl. By Isr. Prog. Sci. Transl., 1968, p. 251-286. In P. A. Moiseev (Editor), Soviet fisheries investigations in the northeastern Pacific, Part I. Avail. Natl. Tech. Inf. Serv., Springfield, VA., as TT67-51203.
- Orr, J. W. and A. C. Matarese. 2000. Revision of the genus *Lepidopsetta* Gill, 1862 (Teleostei: Pleuronectidae) based on larval and adult morphology, with a description of a new species from the North Pacific Ocean and Bering Sea. Fish. Bull. 98:539-582 (2000).
- Shubnikov, D.A., and L.A. Lisovenko. 1964. Data on the biology of rock sole in the southeastern BS. Tr. Vses. Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 49 (Izv. Tikhookean. Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 51) : 209-214. (Transl. In Soviet Fisheries Investigations in the Northeast Pacific, Part II, p. 220-226, by Israel Program Sci. Transl., 1968, available Natl. Tech. Inf. Serv., Springfield, VA, as TT 67-51204).
- Shvetsov, F.G. 1978. Distribution and migrations of the rock sole, *Lepidopsetta bilineata*, in the regions of the Okhotsk Sea coast of Paramushir and Shumshu Islands. J. Ichthol., 18 (1), 56-62, 1978.
- Stark, J.W., and D. A. Somerton. 2002. Maturation, spawning and growth of rock soles off Kodiak Island in the GOA. J. Fish. Biology (2002) 61, 417-431.
- Turnock, B.J., T.K. Wilderbuer, and E.S. Brown. 2002. Flatfish. In Appendix B Stock Assessment and Fishery Evaluation for Groundfish Resources of the GOA Region. Pages 169-197. Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.
- Waldron, K.D., and B.M. Vinter. 1978. Ichthyoplankton of the EBS. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv. Seattle, WA, Processed rep., 88 p.

D.6 Southern rock sole (*Lepidopsetta bilineata*)

The shallow water flatfish management complex in the GOA consists of eight species: southern rock sole (*Lepidopsetta bilineata*), northern rock sole (*Lepidopsetta polyxystra*), yellowfin sole (*Limanda aspera*), starry flounder (*Platichthys stellatus*), butter sole (*Isopsetta isolepis*), English sole (*Parophrys vetulus*), Alaska plaice (*Pleuronectes quadrituberculatus*), and sand sole (*Psettichthys melanostictus*). The rock sole resource in the GOA consists of two separate species: a northern and a southern form that have distinct characteristics and overlapping distributions. The two species of rock sole and yellowfin sole are the most abundant and commercially important species of this management complex in the GOA, and the description of their habitat and life history best represents the shallow water complex species.

D.6.1 Life History and General Distribution

Southern rock sole are distributed from Baja California waters north into the GOA and the eastern Aleutian Islands. Centers of abundance occur off the Kamchatka Peninsula (Shubnikov and Lisovenko 1964), British Columbia (Forrester and Thompson 1969), the central GOA, and to a lesser extent in the extreme southeastern Bering Sea (Alton and Sample 1976, Orr and Matarese 2000). Adults exhibit a benthic lifestyle and occupy separate winter (spawning) and summertime feeding distributions on the continental shelf. Southern rock sole spawn during the summer in the GOA (Stark and Somerton 2002). Before they were identified as two separate species, Russian investigations in the early 1960s established two spawning concentrations: an eastern concentration north of Unimak Island at the mouth of Bristol Bay and a western concentration eastward of the Pribilof Islands between 55°30' and 55°0' N. and approximately 165°2' W. (Shubnikov and Lisovenko 1964). Southern rock sole spawning in the GOA was found to occur at depths of 35 and 120 m. Spawning females deposit a mass of eggs that are demersal and adhesive (Alton and Sample 1976). Fertilization is believed to be external. Incubation time is temperature dependent and may range from 6.4 days at 11 °C to about 25 days at 2.9 °C (Forrester 1964). Newly hatched larvae are pelagic (Waldron and Vinter 1978) and have been captured on all sides of Kodiak Island and along the Alaska Peninsula (Orr and Matarese 2000). Kamchatka larvae are reportedly 20 mm in length when they assume their side-swimming, bottom-dwelling form (Alton and Sample 1976) and have been present in nearshore juvenile sampling catches around Kodiak Island in September and October (Abookire et al. 2007). Forrester and Thompson (1969) report that age 1 fish are found with adults on the continental shelf during summer.

In the springtime southern rock sole begin actively feeding and commence a migration to the shallow waters of the continental shelf to spawn in summer. Summertime trawl surveys indicate most of the population can be found at depths from 50 to 100 m (Armistead and Nichol 1993). The movement from winter/spring to summer grounds may be a response to warmer temperatures in the shallow waters and the distribution of prey on the shelf seafloor (Shvetsov 1978). In September, with the onset of cooling in the northern latitudes, southern rock sole begin the return migration to the deeper wintering grounds. Fecundity varies with size and was reported to be 450,000 eggs for fish 42 cm long. Larvae are pelagic and settlement occurs in September and October. The age or size at metamorphosis is unknown. Juveniles are separate from the adult population, remaining in shallow areas until they reach age 1 (Forrester 1964). The estimated age of 50 percent maturity is 9 years for southern rock sole females at approximately 35 cm length (Stark and Somerton 2002). The natural mortality rate is believed to range from 0.18 to 0.20 (Turnock et al. 2002).

D.6.2 Fishery

Southern rock sole are caught in bottom trawls both as a directed fishery and in the pursuit of other bottom-dwelling species. Recruitment begins at about age 4 and they are fully selected at age 11. Historically, the fishery has occurred on continental shelf areas proximate to Kodiak Island. They are caught as bycatch in Pacific cod, bottom pollock, and other shallow water flatfish species and are caught with these species and Pacific halibut in rock sole directed fisheries.

D.6.3 Relevant Trophic Information

Groundfish predators to southern rock sole include Pacific cod, walleye pollock, skates, Pacific halibut, and yellowfin sole, mostly on fish ranging from 5 to 15 cm standard length.

D.6.4 Habitat and Biological Associations

Larvae/Juveniles: Planktonic larvae for at least 2 to 3 months until metamorphosis occurs, juveniles inhabit shallow areas at least until age 1.

Adults: Summertime feeding and spawning on primarily sandy substrates of the eastern Bering Sea shelf. Widespread distribution mainly on the middle and inner portion of the shelf, feeding on bivalves, polychaetes, amphipods and miscellaneous crustaceans. Wintertime migration to deeper waters of the shelf margin to avoid extreme cold water temperatures, feeding diminishes.

Habitat and Biological Associations: Southern rock sole

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs		NA	summer	OCS	D			
Larvae	2 to 3 months?	U phyto/zooplankton?	summer	OCS, MCS, ICS	P			
Early Juveniles	to 3.5 years	polychaetes, bivalves, amphipods, misc. crustaceans	all year	BAY, ICS, OCS, MCS	D	S, G		
Late Juveniles	up to 9 years	polychaetes, bivalves, amphipods, misc. crustaceans	all year	BAY, ICS, OCS, MCS	D	S, G		
Adults	9+ years	polychaetes, bivalves, amphipods, misc. crustaceans	feeding May–September spawning June–August	MCS, ICS MCS, OCS	D	S, G	ice edge	

D.6.5 Literature

- Abookire, A., C. H. Ryer, T.P. Hurst and A. W. Stoner. 2007. A multi-species view of nursery areas: flatfish assemblages in coastal Alaska. *Estuarine, Coastal and Shelf Science*.
- Alton, M.S., and T.M. Sample. 1976. Rock sole (Family Pleuronectidae) p. 461-474. *In: Demersal fish and shellfish resources in the BS in the baseline year 1975*. Principal investigators Walter T. Pereyra, Jerry E. Reeves, and Richard Bakkala. U.S. Dep. Comm., Natl. Oceanic Atmos. Admin., Natl. Mar. Serv., Northwest and Alaska Fish Center, Seattle, WA. Processed Rep., 619 p.
- Armistead, C.E., and D.G. Nichol. 1993. 1990 Bottom Trawl Survey of the EBS Continental Shelf. U.S. Dep. Commer., NOAA Tech. Mem. NMFS-AFSC-7, 190 p.
- Auster, P.J., R.J. Malatesta., R.W. Langton., L. Watling, P.C. Valentine, C.S. Donaldson, E.W. Langton, A.N. Shepard, and I.G. Babb. 1996. The impacts of mobile fishing gear on seafloor habitats in the Gulf of Maine (Northwest Atlantic): Implications for conservation of fish populations. *Rev. in Fish. Sci.* 4(2): 185-202.
- Forrester, C.R. 1964. Demersal Quality of fertilized eggs of rock sole. *J. Fish. Res. Bd. Canada*, 21(6), 1964. P. 1531.
- Forrester, C.R., and J.A. Thompson. 1969. Population studies on the rock sole, *Lepidopsetta bilineata*, of northern Hecate Strait British Columbia. *Fish. Res. Bd. Canada, Tech. Rep. No. 108*, 1969. 104 p.
- Livingston, P.A., and Y. DeReynier. 1996. Groundfish food habits and predation on commercially important prey species in the EBS from 1990 to 1992. AFSC processed Rep. 96-04, 51 p. Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Seattle, WA 98115.
- Musienko, L.N. 1963. Ichthyoplankton of the BS (data of the BS expedition of 1958-59). Tr. Vses Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 48 (Izv. Tikhookean. Nauchno-issled. Inst. Rybn. Khoz. Okeanogr. 50)239-269. [In Russ.] Transl. By Isr. Prog. Sci. Transl., 1968, p. 251-286. In P. A. Moiseev (Editor), Soviet fisheries investigations in the northeastern Pacific, Part I. Avail. Natl. Tech. Inf. Serv., Springfield, VA., as TT67-51203.
- Orr, J. W. and A. C. Matarese. 2000. Revision of the genus *Lepidopsetta* Gill, 1862 (Teleostei: Pleuronectidae) based on larval and adult morphology, with a description of a new species from the North Pacific Ocean and Bering Sea. *Fish. Bull.* 98:539-582 (2000).

- Shubnikov, D.A., and L.A. Lisovenko. 1964. Data on the biology of rock sole in the southeastern BS. Tr. Vses. Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 49 (Izv. Tikookean. Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 51) : 209-214. (Transl. In Soviet Fisheries Investigations in the Northeast Pacific, Part II, p. 220-226, by Israel Program Sci. Transl., 1968, available Natl. Tech. Inf. Serv., Springfield, VA, as TT 67-51204).
- Shvetsov, F.G. 1978. Distribution and migrations of the rock sole, *Lepidopsetta bilineata*, in the regions of the Okhotsk Sea coast of Paramushir and Shumshu Islands. J. Ichthol., 18 (1), 56-62, 1978.
- Stark, J.W., and D. A. Somerton. 2002. Maturation, spawning and growth of rock soles off Kodiak Island in the GOA. J. Fish. Biology (2002) 61, 417-431.
- Turnock, B.J., T.K. Wilderbuer, and E.S. Brown. 2002. Flatfish. In Appendix B Stock Assessment and Fishery Evaluation for Groundfish Resources of the GOA Region. Pages 169-197. Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.
- Waldron, K.D., and B.M. Vinter. 1978. Ichthyoplankton of the EBS. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv. Seattle, WA, Processed rep., 88 p.

D.7 Alaska plaice (*Pleuronectes quadrituberculatus*)

Alaska plaice are managed as part of the shallow water flatfish assemblage in the GOA.

D.7.1 Life History and General Distribution

Alaska plaice inhabit continental shelf waters of the North Pacific ranging from the GOA to the Bering and Chukchi Seas and in Asian waters as far south as Peter the Great Bay (Pertseva-Ostroumova 1961; Quast and Hall 1972). Adults exhibit a benthic lifestyle and live year round on the shelf and move seasonally within its limits (Fadeev 1965). Alaska plaice are caught in near shore areas along the Alaska Peninsula and Kodiak Island in summer resource assessment surveys. From over-winter grounds near the shelf margins, adults begin a migration onto the central and northern shelf of the eastern Bering Sea, primarily at depths of less than 100 m, although it is unknown if this behavior is also consistent with the GOA. Spawning usually occurs in March and April on hard sandy ground (Zhang 1987). The eggs and larvae are pelagic and transparent and have been found in ichthyoplankton sampling in late spring and early summer over a widespread area of the continental shelf, particularly in the Shelikof Strait area (Waldron and Favorite 1977).

Fecundity estimates (Fadeev 1965) indicate female fish produce an average of 56,000 eggs at lengths of 28 to 30 cm and 313,000 eggs at lengths of 48 to 50 cm. The age or size at metamorphosis is unknown. The estimated length of 50 percent maturity is 32 cm from collections made in March and 28 cm from April, which corresponds to an age of 6 to 7 years. Natural mortality rate estimates range from 0.19 to 0.22 (Wilderbuer and Zhang 1999).

The approximate upper size limit of juvenile fish is 27cm.

D.7.2 Fishery

Alaska plaice are caught in bottom trawls, primarily in pursuit of other bottom-dwelling species such as flatfish of the shallow water group. Recruitment begins at about age 6, and they are fully selected at age 12.

D.7.3 Relevant Trophic Information

Groundfish predators include Pacific halibut (Novikov 1964) yellowfin sole, beluga whales, and fur seals (Salveson 1976).

D.7.4 Habitat and Biological Associations

Larvae/Juveniles: Planktonic larvae for at least 2 to 3 months until metamorphosis occurs, usually inhabiting shallow areas.

Adults: Summertime feeding on sandy substrates of the eastern Bering Sea shelf. Wide-spread distribution mainly on the middle, northern portion of the shelf, feeding on polychaete, amphipods and echinurids (Livingston and DeReynier 1996). Wintertime migration to deeper waters of the shelf margin to avoid extreme cold water temperatures. Feeding diminishes until spring after spawning.

Habitat and Biological Associations: Alaska plaice

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs		NA	spring and summer	ICS, MCS OCS	P			
Larvae	2–4 months?	U phyto/zooplankton?	spring and summer	ICS, MCS	P			
Juveniles	up to 7 years	polychaete, amphipods, echinurids	all year	ICS, MCS	D	S, M		
Adults	7+ years	polychaete, amphipods, echinurids	spawning March–May non-spawning and feeding June–February	ICS, MCS ICS, MCS	D	S, M	ice edge	

D.7.5 Literature

- Auster, P.J., Malatesta, R.J., Langton, R.W., L. Watling, P.C. Valentine, C.S. Donaldson, E.W. Langton, A.N. Shepard, and I.G. Babb. 1996. The impacts of mobile fishing gear on seafloor habitats in the Gulf of Maine (Northwest Atlantic): Implications for conservation of fish populations. *Rev. in Fish. Sci.* 4(2): 185-202.
- Fadeev, N.W. 1965. Comparative outline of the biology of fishes in the southeastern part of the Bering Sea and condition of their resources. [In Russ.] *Tr. Vses. Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* 58 (Izv. Tikhookean. Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 53):121-138. (Trans. By Isr. Prog. Sci. Transl., 1968), p 112-129. In P.A. Moiseev (Editor), *Soviet Fisheries Investigations in the northeastern Pacific*, Pt. IV. Avail. Natl. Tech. Inf. Serv., Springfield, Va. As TT 67-51206.
- Livingston, P.A. and Y. DeReynier. 1996. Groundfish food habits and predation on commercially important prey species in the eastern Bering Sea from 1990 to 1992. AFSC processed Rep. 96-04, 51 p. Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Seattle, WA 98115.
- Novikov, N.P. 1964. Basic elements of the biology of the Pacific Halibut (*Hippoglossus stenolepis* Schmidt) in the Bering Sea. *Tr. Vses. Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* 49 (Izv. Tikhookean. Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 51):167-204. (Transl. In *Soviet Fisheries Investigations in the Northeast Pacific*, Part II, p.175-219, by Israel Program Sci. Transl., 1968, avail. Natl. Tech. Inf. Serv. Springfield, VA, as TT67-51204.)
- Pertseva-Ostroumova, T.A. 1961. The reproduction and development of far eastern flounders. (Transl. By Fish. Res. Bd. Can. 1967. Transl. Ser. 856, 1003 p.).
- Quast, J.C. and E.L. Hall. 1972. List of fishes of Alaska and adjacent waters with a guide to some of their literature. U.S. Dep. Commer. NOAA, Tech. Rep. NMFS SSRF-658, 48p.
- Salveson, S.J. 1976. Alaska plaice. In *Demersal fish and shellfish resources of the eastern Bering Sea in the baseline year 1975* (eds. W.T. Pereyra, J.E. Reeves, and R.G. Bakkala). Processed Rep., 619 p. NWAFC, NMFS, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

- Waldron, K.D. and F. Favorite. 1977. Ichthyoplankton of the eastern Bering Sea. In Environmental assessment of the Alaskan continental shelf, Annual reports of principal investigators for the year ending March 1977, Vol. IX. Receptors-Fish, littoral, benthos, p. 628-682. U.S. Dep. Comm., NOAA, and U.S. Dep. Int., Bur. Land. Manage.
- Wilderbuer, T.K. and C.I. Zhang. 1999. Evaluation of the population dynamics and yield characteristics of Alaska plaice (*Pleuronectes quadrituberculatus*) in the eastern Bering Sea Fisheries Research 41 (1999) 183-200.
- Wilderbuer, T.K., D.G. Nichol, and P.D. Spencer. 2010. Alaska Plaice. In Stock Assessment and Fishery Evaluation Report for Groundfish Resources of the Bering Sea/Aleutian Islands Regions. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, Alaska 99501. Pp. 969-1020.
- Zhang, C.I. 1987. Biology and Population Dynamics of Alaska plaice, *Pleuronectes quadrituberculatus*, in the Eastern Bering Sea. PhD. dissertation, University of Washington: p.1-225.

D.8 Rex sole (*Glyptocephalus zachirus*)

D.8.1 Life History and General Distribution

Rex sole are distributed from Baja California to the Bering Sea and western Aleutian Islands (Hart 1973, Miller and Lea 1972). They are most abundant at depths between 100 and 200 m and are found fairly uniformly throughout the GOA outside the spawning season. The spawning period off Oregon is reported to range from January through June with a peak in March and April (Hosie and Horton 1977). Using data from research surveys, Hirschberger and Smith (1983) found that spawning in the GOA occurred from February through July, with a peak period in April and May, although they had few, if any, observations from October to February. More recently, Abookire (2006) found evidence for spawning starting in October and ending in June, based on one year's worth of monthly histological sampling (October through July) that included both research survey and fishery samples. It seems reasonable, then, that the actual spawning season extends from October to July. Fecundity estimates from samples collected off the Oregon coast ranged from 3,900 to 238,100 ova for fish 24 to 59 cm (Hosie and Horton 1977). During the spawning season, adult rex sole concentrate along the continental slope, but also appear on the outer shelf (Abookire and Bailey 2007). Eggs are fertilized near the sea bed, become pelagic, and probably require a few weeks to hatch (Hosie and Horton 1977). Abookire and Bailey (2007) concluded that larval duration is about 9 months in the GOA (rather than 12 months off the coast of Oregon) and that size-at-transformation for rex sole is 49 to 72 mm. Although maturity studies from Oregon indicate that females are 50 percent mature at 24 cm, females in the GOA achieve 50 percent maturity at larger size (35.2 cm) and grow faster such that they achieve 50 percent maturity at about the same age (5.1 years) as off Oregon (Abookire 2006). Juveniles less than 15 cm are rarely found with the adult population. The natural mortality rate used in recent stock assessments is 0.17 (Stockhausen et al. 2007).

D.8.2 Fishery

Rex sole are caught in bottom trawls both as a directed fishery and in the pursuit of other bottom-dwelling species. Recruitment begins at about age 3 or 4. They are caught as bycatch in the Pacific ocean perch, Pacific cod, bottom pollock, and other flatfish fisheries and are caught with these species and Pacific halibut in rex sole directed fisheries.

D.8.3 Relevant Trophic Information

Based on results from an ecosystem model for the GOA (Aydin et al. 2007), rex sole in the GOA occupy an intermediate trophic level. Polychaetes, euphausiids, and miscellaneous worms were the most important prey for rex sole. Other major prey items included benthic amphipods, polychaetes, and shrimp

(Livingston and Goiney, 1983; Yang, 1993; Yang and Nelson, 2000). Important predators on rex sole include longnose skate and arrowtooth flounder.

D.8.4 Habitat and Biological Associations

Larvae/Juveniles: Planktonic larvae for an unknown time period until metamorphosis occurs, juvenile distribution is unknown.

Adults: Spring spawning and summer feeding on a combination of sand, mud, and gravel substrates of the continental shelf. Widespread distribution mainly on the middle and outer portion of the shelf, feeding mainly on polychaetes, euphausiids, and miscellaneous worms.

Habitat and Biological Associations: Rex sole

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	several weeks	NA	Oct –July	ICS?, MCS, OCS	P			
Larvae	9 months	U phyto/zooplankton?	spring summer	ICS?, MCS, OCS	P			
Juveniles	ages 1–5 years	polychaetes, euphausiids, misc. worms	all year	MCS, ICS, OCS	D	G, S, M		
Adults	ages 5–33 years	polychaetes, amphipods, euphausiids, misc. worms	spawning Oct–July non-spawning July–Sep	MCS, OCS, USP	D	G, S, M		

D.8.5 Literature

- Abookire, A.A. 2006. Reproductive biology, spawning season, and growth of female rex sole (*Glyptocephalus zachirus*) in the Gulf of Alaska. Fish. Bull. 104: 350-359.
- Abookire, A.A. and K.M. Bailey. 2007. The distribution of life cycle stages of two deep-water pleuronectids, Dover sole (*Microstomus pacificus*) and rex sole (*Glyptocephalus zachirus*), at the northern extent of their range in the Gulf of Alaska. J. Sea Res. 57:198-208.
- Auster, P.J., Malatesta, R.J., Langton, R.W., L. Watling, P.C. Valentine, C.S. Donaldson, E.W. Langton, A.N. Shepard, and I.G. Babb. 1996. The impacts of mobile fishing gear on seafloor habitats in the Gulf of Maine (Northwest Atlantic): Implications for conservation of fish populations. Rev. in Fish. Sci. 4(2): 185-202.
- Aydin, K., S. Gaichas, I. Ortiz, D. Kinzey, and N. Friday. 2007. A comparison of the Bering Sea, Gulf of Alaska, and Aleutian Islands large marine ecosystems through food web modeling. U.S. Dep. Commer., NOAA NMFS Tech Memo. NMFS-AFSC-178. 298 p.
- Hart, J.L. 1973. Pacific fishes of Canada. Fish. Res. Board Canada, Bull. No. 180. 740 p.
- Hosie, M.J., and H.F. Horton. 1977. Biology of the rex sole, *Glyptocephalus zachirus*, in waters off Oregon. Fish. Bull. Vol. 75, No. 1, 1977, p. 51-60.
- Hirschberger, W.A., and G.B. Smith. 1983. Spawning of twelve groundfish species in the Alaska and Pacific coast regions. 50 p. NOAA Tech. Mem. NMFS F/NWC-44. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv.
- Kendall, A.W., Jr., and J.R. Dunn. 1985. Ichthyoplankton of the continental shelf near Kodiak Island, Alaska. NOAA Tech. Rep. NMFS 20, U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv.

- Livingston, P.A., and B.J. Goiney, Jr. 1983. Food habits literature of North Pacific marine fishes: a review and selected bibliography. NOAA Tech. Mem. NMFS F/NWC-54, U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv.
- Matarese, A.C., D.M. Blood, S.J. Piquelle and J. Benson. 2003. Atlas of abundance and distribution patterns of ichthyoplankton from the northeast Pacific Ocean and Bering Sea ecosystems based on research conducted by the Alaska Fisheries Science Center (1972-1996). NOAA Prof. Paper NMFS 1. 281 p.
- Miller, D.J., and R.N. Lea. 1972. Guide to the coastal marine fishes of California. Calif. Dep. Fish. Game, Fish. Bull. 157, 235 p.
- Stockhausen, W.T., B. Matta, B.J. Turnock, M.E. Wilkins and M.H. Martin. 2007. 6. Gulf of Alaska Rex Sole Stock Assessment. In Appendix B: Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska. p 399-450. North Pac. Fish. Mgmt. Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.
- Yang, M. S. 1993. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-22, 150 p.
- Yang, M.-S. and M.W. Nelson. 2000. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990, 1993, and 1996. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-112, 174 p.

D.9 Dover sole (*Microstomus pacificus*)

D.9.1 Life History and General Distribution

Dover sole are distributed in deep waters of the continental shelf and upper slope from northern Baja California to the Bering Sea and the western Aleutian Islands (Hart 1973, Miller and Lea 1972). They exhibit a widespread distribution throughout the GOA. Adults are demersal and are mostly found in water deeper than 300 m in the winter but occur in highest biomass in the 100- to 200-m depth range during summer in the GOA (Turnock et al. 2002). The spawning period off Oregon is reported to range from January through May (Hunter et al. 1992). Off California, Dover sole spawn in deep water, and the larvae eventually settle in the shallower water of the continental shelf. They gradually move down the slope into deeper water as they grow and reach sexual maturity (Jacobson and Hunter 1993, Vetter et al. 1994, Hunter et al. 1990). For mature adults, most of the biomass may inhabit the oxygen minimum zone in deep waters. Spawning in the GOA has been observed from January through August, with a peak period in May (Hirschberger and Smith 1983), although a more recent study found spawning limited to February through May (Abookire and Macewicz 2003). Eggs have been collected in neuston and bongo nets in the summer, east of Kodiak Island (Kendall and Dunn 1985), but the duration of the incubation period is unknown. Larvae were captured in bongo nets only in summer over mid-shelf and slope areas (Kendall and Dunn 1985). The age or size at metamorphosis is unknown, but the pelagic larval period is known to be protracted and may last as long as 2 years (Markle et al. 1992). Pelagic postlarvae as large as 48 mm have been reported, and the young may still be pelagic at 10 cm (Hart 1973). Dover sole are batch spawners, and Hunter et al. (1992) concluded that the average 1 kg female spawns its 83,000 advanced yolked oocytes in about nine batches. A comparison of maturity studies from Oregon and the GOA indicates that females mature at similar age in both areas (6 to 7 years), but GOA females are much larger (44 cm) than their southern counterparts (33 cm) at 50 percent maturity (Abookire and Macewicz 2003). Juveniles less than 25 cm are rarely found with the adult population from bottom trawl surveys (Martin and Clausen 1995). The natural mortality rate used in recent stock assessments is 0.085 yr^{-1} based on a maximum observed age in the GOA of 54 years (Stockhausen et al. 2007).

D.9.2 Fishery

Dover sole are caught in bottom trawls, both as a directed fishery and in the pursuit of other bottom-dwelling species. Recruitment begins at about age 5. They are caught as bycatch in the rex sole, thornyhead rockfish, and sablefish fisheries, and they are caught with these species and Pacific halibut in Dover sole directed fisheries.

D.9.3 Relevant Trophic Information

Dover sole commonly feed on brittle stars, polychaetes, and other miscellaneous worms (Aydin et al. 2007; Buckley et al. 1999). Important predators include walleye pollock and Pacific halibut (Aydin et al. 2007).

D.9.4 Habitat and Biological Associations

Larvae/Juveniles: Dover sole are planktonic larvae for up to 2 years until metamorphosis occurs; juvenile distribution is unknown.

Adults: Dover sole are winter and spring spawners, and summer feeding occurs on soft substrates (combination of sand and mud) of the continental shelf and upper slope. Shallower summer distribution occurs mainly on the middle to outer portion of the shelf and upper slope. Dover sole commonly feed on brittle stars, polychaetes, and other miscellaneous worms (Aydin et al. 2007; Buckley et al. 1999).

Habitat and Biological Associations: Dover sole

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs		NA	spring, summer	ICS?, MCS, OCS, USP	P			
Larvae	up to 2 years	U phyto/zooplankton?	all year	ICS?, MCS, OCS, USP	P			
Early Juveniles	to 3 years	polychaetes, amphipods, annelids	all year	MCS?, ICS?	D	S, M		
Late Juveniles	3 to 5 years	polychaetes, amphipods, annelids	all year	MCS?, ICS?	D	S, M		
Adults	5+ years	polychaetes, amphipods, annelids	spawning Jan–August non–spawning July–January	MCS, OCS, USP	D	S, M		

D.9.5 Literature

- Abookire, A. A. and B. J. Macewicz. 2003. Latitudinal variation in reproductive biology and growth of female Dover sole (*Microstomus pacificus*) in the North Pacific, with emphasis on the Gulf of Alaska stock. *J. Sea Res.* 50: 187-197.
- Auster, P.J., Malatesta, R.J., Langton, R.W., L. Watling, P.C. Valentine, C.S. Donaldson, E.W. Langton, A.N. Shepard, and I.G. Babb. 1996. The impacts of mobile fishing gear on seafloor habitats in the Gulf of Maine (Northwest Atlantic): Implications for conservation of fish populations. *Rev. in Fish. Sci.* 4(2): 185-202.
- Aydin, K., S. Gaichas, I. Ortiz, D. Kinzey, and N. Friday. 2007. A comparison of the Bering Sea, Gulf of Alaska, and Aleutian Islands large marine ecosystems through food web modeling. NOAA NMFS Tech Memo, NMFS-AFSC-178. 298 p.

- Buckley, T.W., G.E. Tyler, D.M. Smith and P.A. Livingston. 1999. Food habits of some commercially important groundfish off the coasts of California, Oregon, Washington, and British Columbia. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-102, 173 p.
- Hart, J.L. 1973. Pacific fishes of Canada. Fish. Res. Board Canada, Bull. No. 180. 740 p.
- Hunter, J.R., J.L. Butler, C.A. Kimbrell, and E.A. Lynn. 1990. Bathymetric patterns in size, age, sexual maturity, water content, caloric density of Dover sole, *Microstomus pacificus*. CALCOFI Rep., Vol. 31, 1990.
- Hunter, J.R., B.J. Macewicz, N.C. Lo, and C.A. Kimbrell. 1992. Fecundity, spawning, and maturity of female Dove sole *Microstomus pacificus*, with an evaluation of assumptions and precision. Fish. Bull. 90:101-128(1992).
- Hirschberger, W.A., and G.B. Smith. 1983. Spawning of twelve groundfish species in the Alaska and Pacific coast regions. 50 p. NOAA Tech. Mem. NMFS F/NWC-44. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv.
- Jacobson, L.D., and J.R. Hunter. 1993. Bathymetric Demography and Management of Dover Sole. NAJFM 13:405-420. 1993.
- Kendall, A.W. Jr., and J.R. Dunn. 1985. Ichthyoplankton of the continental shelf near Kodiak Island, Alaska. NOAA Tech. Rep. NMFS 20, U.S. Dep. Commer, NOAA, Natl. Mar. Fish. Serv.
- Livingston, P.A., and B.J. Goiney, Jr. 1983. Food habits literature of North Pacific marine fishes: a review and selected bibliography. NOAA Tech. Mem. NMFS F/NWC-54, U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv.
- Markle, D.F., Harris, P, and C. Toole. 1992. Metamorphosis and an overview of early-life-history stages in Dover sole *Microstomus pacificus*. Fish. Bull. 90:285-301.
- Martin, M.H., and D.M. Clausen. 1995. Data report: 1993 GOA Bottom Trawl Survey. U.S. Dept. Commer., NOAA, Natl. Mar. Fish. Serv., NOAA Tech. Mem. NMFS-AFSC-59, 217 p.
- Miller, D.J., and R.N. Lea. 1972. Guide to the coastal marine fishes of California. Calif. Dept. Fish. Game, Fish. Bull. 157, 235 p.
- Stockhauen, W.T., B.J. Turnock, M.E. Wilkins and M.H. Martin. 2007. 5. Gulf of Alaska Deepwater Flatfish. In: Appendix B Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska. p 339-398. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.
- Turnock, B.J., T.K. Wilderbuer, and E.S. Brown. 2002. Flatfish. In Appendix B Stock assessment and fishery evaluation Report for the groundfish resources of the GOA. p 169-197. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.
- Vetter, R.D., E.A. Lynn, M. Garza, and A.S. Costa. 1994. Depth zonation and metabolic adaptation in Dover sole, *Microstomus pacificus*, and other deep-living flatfishes: factors that affect the sole. Mar. Biol. (1994) 120:145-159.

D.10 Flathead sole (*Hippoglossoides elassodon*)

D.10.1 Life History and General Distribution

Flathead sole are distributed from northern California, off Point Reyes, northward along the west coast of North America and throughout the GOA and the Bering Sea, the Kuril Islands, and possibly the Okhotsk Sea (Hart 1973).

Adults exhibit a benthic lifestyle and occupy separate winter spawning and summertime feeding distributions in the GOA. From over-winter grounds near the shelf margins, adults begin a migration onto the mid- and outer continental shelf in April or May each year for feeding. In the GOA, the spawning period may start as early as March but is known to occur in April through June, primarily in deeper waters near the margins of the continental shelf. Eggs are large (2.75 to 3.75 mm), and females have egg counts

ranging from about 72,000 (20 cm fish) to almost 600,000 (38 cm fish). Eggs hatch in 9 to 20 days depending on incubation temperatures within the range of 2.4 to 9.8 °C and have been found in ichthyoplankton sampling on the western portion of the GOA shelf in April through June (Porter 2004). Porter (2004) found that egg density increased late in development such that mid-stage eggs were found near the surface but eggs about to hatch were found at depth (125 to 200 m). Larvae absorb the yolk sac in 6 to 17 days, but the extent of their distribution is unknown. Nearshore sampling indicates that newly settled larvae are in the 30 to 50 mm size range (Norcross et al. 1996, Abookire et al. 2001). Flathead sole females in the GOA become 50 percent mature at 8.7 years or about 33 cm (Stark 2004). Juveniles less than age 2 have not been found with the adult population and remain in shallow areas. The natural mortality rate used in recent stock assessments is 0.2 (Stockhausen et al. 2007).

D.10.2 Fishery

Flathead sole are caught in bottom trawls both as a directed fishery and in the pursuit of other bottom-dwelling species. Recruitment begins at about age 3. They are caught as bycatch in Pacific cod, bottom pollock, and other flatfish fisheries and are caught with these species and Pacific halibut in flathead sole directed fisheries.

D.10.3 Relevant Trophic Information

Based on results from an ecosystem model for the GOA (Aydin et al. 2007), flathead sole in the GOA occupy an intermediate trophic level as both juvenile and adults. Pandalid shrimp and brittle stars were the most important prey for adult flathead sole in the GOA (64 percent by weight in sampled stomachs; Yang and Nelson 2000), while euphausiids and mysids constituted the most important prey items for juvenile flathead sole. Other major prey items included polychaetes, mollusks, bivalves, and hermit crabs for both juveniles and adults. Commercially important species that were consumed included age-0 Tanner crab (3 percent) and age-0 walleye pollock (less than 0.5 percent by weight).

Important predators on flathead sole include arrowtooth flounder, walleye pollock, Pacific cod, and other groundfish (Aydin et al. 2007). Pacific cod and Pacific halibut are the major predators on adults, while arrowtooth flounder, sculpins, walleye pollock, and Pacific cod are the major predators on juveniles.

D.10.4 Habitat and Biological Associations

Larvae: Planktonic larvae for 3 to 5 months until metamorphosis occurs.

Juveniles: Usually inhabit shallow areas (less than 100 m), preferring muddy habitats.

Adults: Spring spawning and summer feeding on sand and mud substrates of the continental shelf. Widespread distribution mainly on the middle and outer portion of the shelf, feeding mainly on pandalid shrimp and brittle stars.

Habitat and Biological Associations: Flathead sole

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs		NA	winter	ICS, MCS, OCS	P			
Larvae	U	U phyto/zooplankton?	spring, summer	ICS, MCS, OCS	P			
Juveniles	U	polychaetes, bivalves, ophiuroids	all year	MCS, ICS, OCS	D	S, M		
Adults	U	polychaetes, bivalves, ophiuroids, pollock, Tanner crab	spawning Jan–April non-spawning May–December	MCS, OCS, ICS	D	S, M	ice edge	

D.10.5 Literature

- Abookire, A.A., J.F. Piatt and B.L. Norcross. 2001. Juvenile groundfish habitat in Kachemak Bay, Alaska, during late summer. Alaska Research Fishery Bulletin 8: 45-56.
- Auster, P.J., Malatesta, R.J., Langton, R.W., L. Watling, P.C. Valentine, C.S. Donaldson, E.W. Langton, A.N. Shepard, and I.G. Babb. 1996. The impacts of mobile fishing gear on sea floor habitats in the Gulf of Maine (Northwest Atlantic): Implications for conservation of fish populations. Rev. in Fish. Sci. 4(2): 185-202.
- Aydin, K., S. Gaichas, I. Ortiz, D. Kinzey, and N. Friday. 2007. A comparison of the Bering Sea, Gulf of Alaska, and Aleutian Islands large marine ecosystems through food web modeling. U.S. Dep. Commer., NOAA NMFS Tech Memo. NMFS-AFSC-178. 298 p.
- Forrester, C.R., and D.F. Alderdice. 1967. Preliminary observations on embryonic development of the flathead sole (*Hippoglossoides elassodon*). Fish. Res. Board Can. Tech. Rep. 100: 20 p
- Hart, J.L. 1973. Pacific fishes of Canada. Fish. Res. Board Canada, Bull. No. 180. 740 p.
- Livingston, P.A., and Y. DeReynier. 1996. Groundfish food habits and predation on commercially important prey species in the EBS from 1990 to 1992. AFSC processed Rep. 96-04, 51 p. Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Seattle, WA 98115.
- Matarese, A.C., D.M. Blood, S.J. Piquelle and J. Benson. 2003. Atlas of abundance and distribution patterns of ichthyoplankton from the northeast Pacific Ocean and Bering Sea ecosystems based on research conducted by the Alaska Fisheries Science Center (1972-1996). NOAA Prof. Paper NMFS 1. 281 p.
- Miller, B.S. 1969. Life history observations on normal and tumor bearing flathead sole in East Sound, Orcas Island (Washington). Ph.D. Thesis. Univ. Wash. 131 p.
- Norcross, B.L., A. Blanchard and B.A. Holladay. 1999. Comparison of models for defining nearshore flatfish nursery areas in Alaskan waters. Fish. Oc. 8: 50-67.
- Norcross, B.L., B.A. Holladay, S.C. Dressel, and M. Frandsen. 1996. Recruitment of juvenile flatfishes in Alaska: habitat preference near Kodiak Island. U. Alaska Coastal Marine Institute, OCS Study MMS 96-0003, Vol. 1.
- Norcross, B.L., F.J. Muter, B.A. Holladay. 1997. Habitat models for juvenile pleuronectids around Kodiak Island, Alaska. Fish. Bull. 95: 504-520.
- Pacunski, R.E. 1990. Food habits of flathead sole (*Hippoglossoides elassodon*) in the EBS. M.S. Thesis. Univ. Wash. 106 p.
- Porter, S.M. 2004. Temporal and spatial distribution and abundance of flathead sole (*Hippoglossoides elassodon*) eggs and larvae in the western Gulf of Alaska. Fish. Bull. 103:648-658.
- Stark, J.W. 2004. A comparison of the maturation and growth of female flathead sole in the central Gulf of Alaska and south-eastern Bering Sea. J. Fish. Biol. 64: 876-889.

- Stockhausen, W.T., M.E. Wilkins and M.H. Martin. 2007. 8. Gulf of Alaska Flathead Sole Stock Assessment. . In Appendix B: Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska. p 505-562. North Pac. Fish. Mgmt. Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.
- Waldron, K.D. 1981. Ichthyoplankton. In D.W. Hood and J.A. Calder (Editors), The EBS shelf: Oceanography and resources, Vol. 1, p. 471-493. U.S. Dep. Commer., NOAA, Off. Mar. Poll. Assess., U.S. Gov. Print. Off., Wash., D.C.
- Yang, M-S. and M.W. Nelson. 2000. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990, 1993, and 1996. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-112, 174 p.

D.11 Arrowtooth flounder (*Atheresthes stomias*)

D.11.1 Life History and General Distribution

Arrowtooth flounder are distributed in North American waters from central California to the eastern Bering Sea on the continental shelf and upper slope.

Adults exhibit a benthic lifestyle and occupy separate winter and summer distributions on the eastern Bering Sea shelf. From over-winter grounds near the shelf margins and upper slope areas, adults begin a migration onto the middle and inner shelf in April or early May each year with the onset of warmer water temperatures. A protracted and variable spawning period may range from as early as September through March (Rickey 1994, Hosie 1976). Little is known of the fecundity of arrowtooth flounder. Larvae have been found from ichthyoplankton sampling over a widespread area of the eastern Bering Sea shelf in April and May and also on the continental shelf east of Kodiak Island during winter and spring (Waldron and Vinter 1978, Kendall and Dunn 1985). Nearshore sampling in the Kodiak Island area indicates that newly settled larvae are in the 40 to 60 mm size range (Norcross et al. 1996). Juveniles are separate from the adult population, remaining in shallow areas until they reach the 10 to 15 cm range (Martin and Clausen 1995). The estimated length at 50 percent maturity is 28 cm for males (4 years) and 37 cm for females (5 years) from samples collected off the Washington coast (Rickey 1994) and 47 cm for GOA females (Zimmerman 1997). The natural mortality rate used in stock assessments differs by sex with females estimated at 0.2 and male natural mortality estimated at 0.35 (Turnock et al. 2009, Wilderbuer et al. 2009).

The approximate upper size limit of juvenile fish is 27 cm in males and 46 cm in females.

D.11.2 Fishery

Arrowtooth flounder are caught in bottom trawls usually in pursuit of other higher value bottom-dwelling species. Historically, they have been undesirable to harvest due to a flesh softening condition caused by protease enzyme activity. Recruitment begins at about age 3 and females are fully selected at age 10. They are caught as bycatch in Pacific cod, bottom pollock, sablefish, and other flatfish fisheries.

D.11.3 Relevant Trophic Information

Arrowtooth flounder are very important as a large, aggressive and abundant predator of other groundfish species. Groundfish predators include Pacific cod and pollock, mostly on small fish.

D.11.4 Habitat and Biological Associations

Larvae/Juveniles: Planktonic larvae for at least 2 to 3 months until metamorphosis occurs; juveniles usually inhabit shallow areas until about 10 cm in length.

Adults: Widespread distribution mainly on the middle and outer portions of the continental shelf, feeding mainly on walleye pollock and other miscellaneous fish species when arrowtooth flounder attain lengths

greater than 30 cm. Wintertime migration to deeper waters of the shelf margin and upper continental slope to avoid extreme cold water temperatures and for spawning.

Habitat and Biological Associations: Arrowtooth flounder

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs		NA	winter, spring?	ICS, OCS	P			
Larvae	2 to 3 months?	U phyto/ zooplankton?	spring, summer?	BAY, ICS, OCS	P			
Juveniles	males - up to 4 years females - up to 5 years	euphausiids, crustaceans, amphipods, pollock	all year	ICS, OCS, USP	D	G,M,S		
Adults	males 4+ years females 5+ years	pollock, Gadidae sp., misc. fish, euphausiids	spawning Nov–March non-spawning April–Oct	ICS, OCS, USP, BAY	D	G,M,S	ice edge (EBS)	

D.11.5 Literature

- Auster, P.J., Malatesta, R.J., Langton, R.W., L. Watling, P.C. Valentine, C.S. Donaldson, E.W. Langton, A.N. Shepard, and I G. Babb. 1996. The impacts of mobile fishing gear on seafloor habitats in the Gulf of Maine (Northwest Atlantic): Implications for conservation of fish populations. *Rev. in Fish. Sci.* 4(2): 185-202.
- Hart, J.L. 1973. Pacific fishes of Canada. *Fish. Res. Board Can. Bull.* 180, 740 p.
- Hosie, M.J. 1976. The arrowtooth flounder. *Oregon Dep. Fish. Wildl. Info. Rep.* 76-3, 4 p.
- Kendall, A.W., Jr., and J.R. Dunn. 1985. Ichthyoplankton of the continental shelf near Kodiak Island, Alaska. NOAA Tech. Rep. NMFS 20, U.S. Dep. Commer, NOAA, Natl. Mar. Fish. Serv.
- Livingston, P.A., and Y. DeReynier. 1996. Groundfish food habits and predation on commercially important prey species in the EBS from 1990 to 1992. AFSC processed Rep. 96-04, 51 p. Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Seattle, WA 98115.
- Martin, M.H., and D.M. Clausen. 1995. Data report: 1993 GOA Bottom Trawl Survey. U.S. Dept. Commer., NOAA, Natl. Mar. Fish. Serv., NOAA Tech. Mem. NMFS-AFSC-59, 217 p.
- Norcross, B.L., B.A. Holladay, S.C. Dressel, and M. Frandsen. 1996. Recruitment of juvenile flatfishes in Alaska: habitat preference near Kodiak Island. U. Alaska Coastal Marine Institute, OCS Study MMS 96-0003, Vol. 1.
- Rickey, M.H. 1994. Maturity, spawning, and seasonal movement of arrowtooth flounder, *Atheresthes stomias*, off Washington. *Fish. Bull.* 93:127-138 (1995).
- Turnock, B.J., T.K. Wilderbuer, and E.S. Brown. 2009. Arrowtooth flounder. In Appendix B Stock Assessment and Fishery Evaluation Report for the groundfish resources of the GOA. Council, 605 W. 4th Ave., Suite 306, Anchorage, AK 99501.
- Waldron, K.D., and B.M. Vinter. 1978. Ichthyoplankton of the EBS. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv. Seattle, WA, Processed rep., 88 p.
- Wilderbuer, T.K., D.G. Nichol, and K. Aydin. 2009. Arrowtooth flounder. In Stock Assessment and Fishery Evaluation Report for the groundfish resources of the BSAI. Council, 605 W. 4th Ave., Suite 306, Anchorage, AK 99501.
- Zimmerman, M. 1997. Maturity and fecundity of arrowtooth flounder, *Atheresthes stomias*, from the GOA. *Fish. Bull.* 95:598-611 (1997).

D.12 Pacific ocean perch (*Sebastes alutus*)

D.12.1 Life History and General Distribution

Pacific ocean perch (*Sebastes alutus*) have a wide distribution in the North Pacific from southern California around the Pacific rim to northern Honshu Island, Japan, including the Bering Sea. The species appears to be most abundant in northern British Columbia, the GOA, and the Aleutian Islands (Allen and Smith 1988). Adults are found primarily offshore on the outer continental shelf and the upper continental slope in depths from 150 to 420 m. Seasonal differences in depth distribution have been noted by many investigators. In the summer, adults inhabit shallower depths, especially those between 150 and 300 m. In the fall, the fish apparently migrate farther offshore to depths from approximately 300 to 420 m. They reside in these deeper depths until about May, when they return to their shallower summer distribution (Love et al. 2002). This seasonal pattern is probably related to summer feeding and winter spawning. Although small numbers of Pacific ocean perch are dispersed throughout their preferred depth range on the continental shelf and slope, most of the population occurs in patchy, localized aggregations (Hanselman et al. 2001). Pacific ocean perch are generally considered to be semi-demersal, but there can be a significant pelagic component to their distribution. Pacific ocean perch often move off-bottom at night to feed, apparently following diel euphausiid migrations. Commercial fishing data in the GOA since 1995 show that pelagic trawls fished off-bottom have accounted for as much as 20 percent of the annual harvest of this species.

There is much uncertainty about the life history of Pacific ocean perch, although generally more is known than for other rockfish species (Kendall and Lenarz 1986). The species appears to be viviparous (the eggs develop internally and receive at least some nourishment from the mother), with internal fertilization and the release of live young. Insemination occurs in the fall, and sperm are retained within the female until fertilization takes place approximately 2 months later. The eggs hatch internally, and parturition (release of larvae) occurs in April and May. Information on early life history is very sparse, especially for the first year of life. Pacific ocean perch larvae are thought to be pelagic and drift with the current. Oceanic conditions may sometimes cause advection to suboptimal areas (Ainley et al. 1993), resulting in high recruitment variability. However, larval studies of rockfish have been hindered by difficulties in species identification since many larval rockfish species share the same morphological characteristics (Kendall 2000). Genetic techniques using allozymes (Seeb and Kendall 1991) and mitochondrial DNA (Li 2004) are capable of identifying larvae and juveniles to species, but are expensive and time-consuming. Post-larval and early young-of-the-year Pacific ocean perch have been positively identified in offshore, surface waters of the GOA (Gharrett et al. 2002), which suggests this may be the preferred habitat of this life stage. Transformation to a demersal existence may take place within the first year (Carlson and Haight 1976). Small juveniles probably reside inshore in very rocky, high relief areas and begin to migrate to deeper offshore waters of the continental shelf by age 3 (Carlson and Straty 1981). As they grow, they continue to migrate deeper, eventually reaching the continental slope, where they attain adulthood.

Pacific ocean perch is a slow growing species, with a low rate of natural mortality (estimated at 0.06), a relatively old age at 50 percent maturity (10.5 years for females in the GOA), and a very old maximum age of 98 years in Alaska (84 years maximum age in the GOA) (Hanselman et al. 2007a). Age at 50 percent recruitment to the commercial fishery has been estimated to be between 7 and 8 years in the GOA. Despite their viviparous nature, the fish is relatively fecund with number of eggs per female in Alaska ranging from 10,000 to 300,000, depending upon size of the fish (Leaman 1991).

For GOA, the upper size limit of juvenile fish is 38 cm for females; it is unknown for males, but is presumed to be slightly smaller than for females based on what is commonly the case in other species of *Sebastes*.

D.12.2 Fishery

The Pacific ocean perch is the most abundant GOA rockfish and the most important commercially. The species was fished intensely in the 1960s by foreign factory trawlers (350,000 mt at its peak in 1965), and the population declined drastically due to this pressure. The domestic fishery began developing in 1985. Quotas climbed rapidly, and the species was declared overfished in 1989. A rebuilding plan was put into place, and quotas were small in the early 1990s. After some good recruitments and high survey biomass estimates, the stock was declared to be recovered in 1995. Pacific ocean perch are caught almost exclusively with trawls. Before 1996, nearly all the catch was taken by factory trawlers using bottom trawls, but a sizeable portion (up to 20 percent some years) has also been taken by pelagic trawls since then. Also in 1996, a shore-based fishery developed that consisted of smaller vessels operating out of the port of Kodiak. These shore-based trawlers now account for more than 50 percent of the catch in the central GOA. The fishery in the Gulf in recent years has occurred in the summer months, especially July, due to management regulations. Reflecting the summer distribution of this species, the fishery is concentrated in a relatively narrow depth band at approximately 180 to 250 m along the outer continental shelf and shelf break, inside major gullies and trenches running perpendicular to the shelf break, and along the upper continental slope. Major fishing grounds include Ommaney Trough (which is no longer fished because of a North Pacific Fishery Management Council amendment that prohibits trawling in the eastern GOA), Yakutat Canyon, Amatuli Trough, off Portlock and Albatross Banks, Shelikof Trough, off Shumagin Bank, and south of Unimak and Unalaska Islands. A localized depletion analysis has shown that after fairly intense fishing, localized areas recovered to their former levels in the following year (Hanselman et al. 2007b).

In 2007, the Central Gulf of Alaska Rockfish Pilot Program was implemented to enhance resource conservation and improve economic efficiency for harvesters and processors who participate in the Central Gulf of Alaska rockfish fishery. This 5-year rationalization program established cooperatives among trawl vessels and processors, which receive exclusive harvest privileges for rockfish management groups. The program was revised and reimplemented in 2012. The primary rockfish management groups are northern rockfish, Pacific ocean perch, and pelagic shelf rockfish. Effects of this program on Pacific ocean perch include (1) extended fishing season lasting from May 1 through November 15, (2) changes in spatial distribution of fishing effort within the Central GOA, (3) improved at-sea and plant observer coverage for vessels participating in the rockfish fishery, and (4) a higher potential to harvest 100 percent of the TAC in the Central GOA region.

Major bycatch species in the GOA Pacific ocean perch trawl fishery from 1994 to 1996 (the most recent years for which an analysis was done) included (in descending order by percent bycatch rate) other species of rockfish, arrowtooth flounder, and sablefish. Among the other species of rockfish, northern rockfish and shortraker/rougheye were most common, followed by pelagic shelf rockfish (Ackley and Heifetz 2001).

Because collection of small juvenile Pacific ocean perch is virtually unknown in any existing type of commercial fishing gear, it is assumed that fishing does not occur in their habitat. Trawling on the offshore fishing grounds of adults may affect the composition of benthic organisms, but the impact of this on Pacific ocean perch or other fish is unknown.

D.12.3 Relevant Trophic Information

Pacific ocean perch are mostly planktivorous (Carlson and Haight 1976, Yang 1993, 1996, Yang and Nelson 2000, Yang 2003). In a sample of 600 juvenile perch stomachs, Carlson and Haight (1976) found that juveniles fed on an equal mix of calanoid copepods and euphausiids. Larger juveniles and adults fed primarily on euphausiids and, to a lesser degree, on copepods, amphipods, and mysids (Yang and Nelson 2000). In the Aleutian Islands, myctophids have increasingly comprised a substantial portion of the

Pacific ocean perch diet, which also compete for euphausiid prey (Yang 2003). It has been suggested that Pacific ocean perch and walleye pollock compete for the same euphausiid prey. Consequently, the large removals of Pacific ocean perch by foreign fishermen in the GOA in the 1960s may have allowed walleye pollock stocks to greatly expand in abundance.

Pacific ocean perch predators are likely sablefish, Pacific halibut, and sperm whales (Major and Shippen 1970). Juveniles are consumed by seabirds (Ainley et al. 1993), other rockfish (Hobson et al. 2001), salmon, lingcod, and other large demersal fish.

D.12.4 Habitat and Biological Associations

Egg/Spawning: Little information is known. Insemination is thought to occur after adults move to deeper offshore waters in the fall. Parturition is reported to occur from 20 to 30 m off the bottom at depths from 360 to 400 m.

Larvae: Little information is known. Earlier information suggested that after parturition, larvae rise quickly to near surface, where they become part of the plankton. More recent data from British Columbia indicates that larvae may remain at depths of 175 m for some period of time (perhaps 2 months), after which they slowly migrate upward in the water column.

Post-larvae and early young-of-the year: A recent, preliminary study has identified Pacific ocean perch in these life stages from samples collected in epipelagic waters far offshore in the GOA (Gharrett et al. 2002). Some of the samples were as much as 180 km from land, beyond the continental slope and over very deep water.

Juveniles: Again, information is very sparse, especially for younger juveniles. It is unknown how long young-of-the-year remain in a pelagic stage before eventually becoming demersal. At ages 1 to 3, the fish probably live in very rocky inshore areas. Afterward, they move to progressively deeper waters of the continental shelf. Older juveniles are often found together with adults at shallower locations of the continental slope in the summer months.

Adults: Commercial fishery and research data have consistently indicated that adult Pacific ocean perch are found in aggregations over reasonably smooth, trawlable bottom of the outer continental shelf and upper continental slope (Westrheim 1970; Matthews et al. 1989; Krieger 1993). Generally, they are found in shallower depths (150 to 300 m) in the summer, and deeper (300 to 420 m) in the fall, winter, and early spring. Observations from a manned submersible in Southeast Alaska found adult Pacific ocean perch associated with pebble substrate on flat or low-relief bottom (Krieger 1993). Pacific ocean perch have been observed in association with sea whips in both the GOA (Krieger 1993) and the Bering Sea (Brodeur 2001). The fish can at times also be found off-bottom in the pelagic environment, especially at night when they may move up in the water column to feed. There presently is little evidence to support previous conjectures that adult Pacific ocean perch populations might be denser in rough, untrawlable bottom.

Habitat and Biological Associations: Pacific ocean perch

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	Internal incubation; ~90 d	NA	winter–spring	NA	NA	NA	NA	NA
Larvae	U; 2 months?	U; assumed to be micro-zooplankton	spring–summer	ICS, MCS, OCS, USP, LSP, BSN	P	NA	U	U
Post-larvae/ early juvenile	U; 2 months to ?	U	summer to ?	LSP, BSN	Epipelagic	NA	U	U
Juveniles	<1 year (?) to 10 years	calanoid copepods (young juv.) euphausiids (older juv.)	all year	ICS, MCS, OCS, USP	D	R (<age 3); CB,G, M?, SM?, MS? (>age 3)	U	U
Adults	10 to 84 years of age (98 years in Aleutian Islands)	euphausiids	insemination (fall); fertilization, incubation (winter); larval release (spring); feeding in shallower depths (summer)	OCS, USP	D, SD, P	CB, G, M?, SM?, MS?	U	U

D.12.5 Literature

- Ackley, D. R., and J. Heifetz. 2001. Fishing practices under maximum retainable bycatch rates in Alaska's groundfish fisheries. *Alaska Fish. Res. Bull.* 8(1): 22-44.
- Ainley, D.G., W.J. Sydeman., R.H. Parrish., and W.H. Lenarz. 1993. Oceanic factors influencing distribution of young rockfish (*Sebastes*) in central California: A predator's perspective. *CalCOFI Report* 34: 133-139.
- Allen, M.J., and G. B. Smith. 1988. Atlas and zoogeography of common fishes in the BS and northeastern Pacific. U.S. Dep. Commer., NOAA Tech. Rept. NMFS 66, 151 p.
- Brodeur, R.D. 2001. Habitat-specific distribution of Pacific ocean perch (*Sebastes alutus*) in Pribilof Canyon, BS. *Cont. Shelf Res.* 21: 207-224.
- Carlson, H.R., and R.E. Haight. 1976. Juvenile life of Pacific ocean perch, *Sebastes alutus*, in coastal fiords of southeast Alaska: their environment, growth, food habits, and schooling behavior. *Trans. Am. Fish. Soc.* 105:191-201.
- Carlson, H.R., and R.R. Straty. 1981. Habitat and nursery grounds of Pacific rockfish, *Sebastes* spp., in rocky coastal areas of Southeast Alaska. *Mar. Fish. Rev.* 43: 13-19.
- Chikuni, S. 1975. Biological study on the population of the Pacific ocean perch in the North Pacific. *Bull. Far Seas Fish. Res. Lab* 12: 1-119.
- de Bruin, J., R. Gosden, C. Finch, and B. Leaman. 2004. Ovarian aging in two species of long-lived rockfish, *Sebastes aleutianus* and *S. alutus*. *Biol. Reprod.* 71: 1036-1042.
- Doyle, M.J. 1992. Patterns in distribution and abundance of ichthyoplankton off Washington, Oregon, and Northern California (1980-1987). U.S. Dep. Commer. NOAA NMFS AFSC Processed Rept. 92-14, 344 p.
- Freese, J.L., and B.L. Wing. 2003. Juvenile red rockfish, *Sebastes* sp., associations with sponges in the GOA. *Mar. Fish. Rev.* 65:38-42 (in press).

- Gillespie, G.E., R.D. Stanley, and B.M. Leaman. 1992. Early life history of rockfishes in British Columbia; preliminary results of the first year of investigation. Proc. 1992 W. Groundfish Conf. Alderbrook Inn Resort, Union, WA, Jan 27-30, 1992.
- Gharrett, A.J., Z. Li, C.M. Kondzela, and A.W. Kendall. 2002. Final report: species of rockfish (*Sebastes* spp.) collected during ABL-OCC cruises in the GOA in 1998-2002. (Unpubl. manuscript. available from the NMFS Auke Bay Laboratory, 11305 Glacier Hwy., Juneau AK 99801.)
- Gunderson, D.R. 1971. Reproductive patterns of Pacific ocean perch (*Sebastes alutus*) off Washington and British Columbia and their relation to bathymetric distribution and seasonal abundance. J. Fish. Res. Bd. Can. 28: 417-425.
- Gunderson, D.R., and M.O. Nelson. 1977. Preliminary report on an experimental rockfish survey conducted off Monterey, California and in Queen Charlotte Sound, British Columbia during August-September, 1976. Prepared for Feb. 15-16, 1977, Interagency Rockfish Survey Coordinating Committee Meeting, NWAFC, Seattle, WA. Unpubl. manuscript. 82 p.
- Hanselman, D.H. 2004. Gulf of Alaska Pacific ocean perch: stock assessment, survey design and sampling. Ph.D. Thesis. University of Alaska Fairbanks, School of Fisheries and Ocean Sciences. 172 pp.
- Hanselman, D. H., J. Heifetz, J. Fujioka, Shotwell, S.K., and J. N. Ianelli. 2007a. Gulf of Alaska Pacific ocean perch. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 2008. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.
- Hanselman, D.H., and Quinn II, T.J. 2004: Sampling rockfish populations: adaptive sampling and hydroacoustics. In Sampling rare or elusive species. Edited by W. Thompson, Island Press, Washington. pp. 271-296.
- Hanselman, D.H., T.J. Quinn II, C. Lunsford, J. Heifetz and D.M. Clausen. 2003. Applications in adaptive cluster sampling of Gulf of Alaska rockfish. Fish. Bull. 101(3): 501-512.
- Hanselman, D., P.D. Spencer, S.K. Shotwell, and R.R. Reuter. 2007b. Localized depletion of three Alaskan rockfish species. Proceedings of the 23rd Lowell Wakefield Fisheries Symposium: Biology, Assessment, and Management of North Pacific Rockfishes.
- Hanselman, D.H., T.J. Quinn, II, J. Heifetz., D. Clausen., and C. Lunsford. 2001. Spatial inferences from adaptive cluster sampling of GOA rockfish. In Spatial Processes and Management of Marine Populations. University of Alaska Sea Grant, PO Box 755040 203 O'Neill Bldg. Fairbanks AK 99775-5040, <http://www.uafr.alaska.edu/seagrant/>.
- Hobson, E.S., J.R. Chess., and D.F. Howard. 2001. Interannual variation in predation on first-year *Sebastes* spp. by three northern California predators. Fish. Bull. 99: 292-302.
- Ito, D.H. 1982. A cohort analysis of Pacific ocean perch stocks from the GOA and BS regions. U.S. Dep. Commer., NWAFC Processed Rept. 82-15, 157 p.
- Ito, D.H., and J.N. Ianelli. 1996. Pacific ocean perch. In Stock assessment and fishery evaluation report for the groundfish resources of the BSAI regions, p.331-359. North Pacific Fishery Management Council, 605 W. 4th. Ave., Suite 306, Anchorage, AK 99501-2252.
- Kendall, A.W., and W.H. Lenarz. 1986. Status of early life history studies of northeast Pacific rockfishes. Proc. Int. Rockfish Symp. Oct. 1986, Anchorage Alaska; p. 99-117.
- Kendall, A.W., Jr. 2000. An historical review of *Sebastes* taxonomy and systematics. Mar. Fish. Rev. 62: 1-16.
- Krieger, K.J. 1993. Distribution and abundance of rockfish determined from a submersible and by bottom trawling. Fish. Bull., U.S. 91:87-96.
- Krieger, K.J., and B.L. Wing. 2002. Megafauna associations with deepwater corals (*Primnoa* spp) in the GOA. Hydrobiologia 471: 8.
- Leaman, B.M. 1991. Reproductive styles and life history variables relative to exploitation and management of *Sebastes* stocks. Environmental Biology of Fishes 30: 253-271.

- Li, Z. 2004. Phylogenetic relationships and identification of juveniles of the genus *Sebastes*. University of Alaska-Fairbanks, School of Fisheries and Ocean Sciences. M.S. thesis.
- Love, M.S., M. Yoklavich, and L. Thorsteinson. 2002. The rockfishes of the northeast Pacific. U. of Calif. Press, Berkeley. 405 p.
- Lunsford, C.R. 1999. Distribution patterns and reproductive aspects of Pacific ocean perch (*Sebastes alutus*) in the GOA. M.S. Thesis. Univ. of Alaska Fairbanks, Juneau AK. 154 p.
- Lunsford, C.R., L. Haldorson, J.T. Fujioka, and T.J. Quinn II. 2001. Distribution patterns and survey design considerations of Pacific ocean perch (*Sebastes alutus*) in the GOA. Spatial Processes and Management of Marine Populations, Alaska Sea Grant College Program. Lowell Wakefield Fisheries Symposium. Anchorage, AK., AK_SG_01_02.
- Major, R.L., and H.H. Shippen. 1970. Synopsis of biological data on Pacific ocean perch, *Sebastes alutus*. FAO Fisheries Synopsis No. 79, NOAA Circular 347, 38 p.
- Malecha, P. W., D. H. Hanselman, and J. Heifetz. 2007. Growth and mortality of rockfish (Scorpaenidae) from Alaskan waters. NOAA Tech. Memo. NMFS-AFSC-172. 61 p.
- Martin, M.H., and D.M. Clausen. 1995. Data report: 1993 GOA bottom trawl survey. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-59. 217 p.
- Matarese, A.C., A.W. Kendall, Jr., D.M. Blood, and B.M. Vinter. 1989. Laboratory guide to early life history stages of northeast Pacific fishes. U.S. Dep. Commer. NOAA Tech. Rept. NMFS 80, 652 p.
- Matthews, K.R., J.R. Candy, L.J. Richards, and C.M. Hand. 1989. Experimental gill net fishing on trawlable and untrawlable areas off northwestern Vancouver Island, from the MV Caledonian, August 15-28, 1989. Can. Manuscr. Rep. Fish. Aquat. Sci. 2046, 78 p.
- Mattson, C.R., and B.L. Wing. 1978. Ichthyoplankton composition and plankton volumes from inland coastal waters of southeast Alaska, April-November 1972. U.S. Dep. Commer., NOAA Tech. Rept. NMFS SSRF-723, 11 p.
- Moser, H.G. 1996. SCORPAENIDAE: scorpionfishes and rockfishes. In: Moser, H.G., editor. The early stages of fishes in the California Current region, p. 733-795. CalCOFI Atlas No.33. 1505 p.
- NOAA (National Oceanic and Atmospheric Administration). 1990. Pacific ocean perch, *Sebastes alutus*. In: West coast of North America coastal and ocean zones strategic assessment: data atlas. Invertebrate and fish volume, Plate 3.2.20. U.S. Dep. Commer. NOAA. OMA/NOS, Ocean Assessments Division, Strategic Assessment Branch.
- Seeb, L.W. 1993. Biochemical identification of larval rockfishes of the genus *Sebastes*. Final Report Contract #43ABNF001082. U.S. Dept. Commer. NOAA/NMFS NWAFC/RACE Division, Seattle, WA. 28 p.
- Seeb, L.W., and A.W. Kendall, Jr. 1991. Allozyme polymorphisms permit the identification of larval and juvenile rockfishes of the genus *Sebastes*. Environmental Biology of Fishes 30:191-201.
- Spencer, P., D. Hanselman, and M. Dorn. 2007. The effect of maternal age of spawning on estimation of Fmsy for Alaska Pacific ocean perch. In: Heifetz, J., DiCosimo J., Gharrett, A.J., Love, M.S, O'Connell, V.M, and Stanley, R.D. (eds.). Biology, Assessment, and Management of North Pacific Rockfishes. Alaska Sea Grant, University of Alaska Fairbanks. pp 513 – 533.
- Stark, J.W., and D.M. Clausen. 1995. Data report: 1990 GOA bottom trawl survey. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-49. 221 p.
- Westrheim, S.J. 1970. Survey of rockfishes, especially Pacific ocean perch, in the northeast Pacific Ocean, 1963-66. J. Fish. Res. Bd. Canada 27: 1781-1809.
- Westrheim, S.J. 1975. Reproduction, maturation, and identification of larvae of some *Sebastes* (Scorpaenidae) species in the northeast Pacific Ocean. J. Fish. Res. Board Can. 32: 2399-2411.
- Wing, B.L. 1985. Salmon stomach contents from the Alaska troll logbook program, 1977-84. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-91. 41 p.

- Wing, B.L., C. Derrah, and V. O'Connell. 1997. Ichthyoplankton in the eastern GOA, May 1990. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-376, 42 p.
- Wolotira, R.J., Jr., T.M. Sample, S.F. Noel, and C.R. Iten. 1993. Geographic and bathymetric distributions for many commercially important fishes and shellfishes off the west coast of North America, based on research survey and commercial catch data, 1912-1984. U.S. Dep. Commer., NOAA Tech. Memo. NMFS - AFSC-6, 184 p.
- Yang, M-S. 1993. Food habits of the commercially important groundfishes in the GOA in 1990. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-22, 150 p.
- Yang, M-S. 1996. Diets of the important groundfishes in the AI in summer 1991. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-60, 105 p.
- Yang, M-S. 2003. Food habits of the important groundfishes of the AI in 1994 and 1997. National Marine Fisheries Service. AFSC Processed report 2003-07: 233 pp.
- Yang, M-S., and M.W. Nelson. 2000. Food habits of the commercially important groundfishes in the GOA in 1990, 1993, and 1996. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-112, 174 p.

D.13 Northern rockfish (*Sebastes polyspinis*)

D.13.1 Life History and General Distribution

Northern rockfish range from northern British Columbia through the GOA and Aleutian Islands to eastern Kamchatka and the Kuril Islands, including the Bering Sea (Mecklenburg et al. 2002). The species is most abundant from about Portlock Bank in the central GOA to the western end of the Aleutian Islands; it is rarely found in the eastern GOA. In the GOA, adult fish appear to be concentrated at discrete, relatively shallow offshore banks of the outer continental shelf (Clausen and Heifetz 2002). Typically, these banks are separated from land by an intervening stretch of deeper water. The preferred depth range is approximately 75 to 150 m in the GOA. Information available at present suggests the fish are mostly demersal, as very few have been caught off-bottom or in pelagic trawls (Clausen and Heifetz 2002). In common with many other rockfish species, northern rockfish tend to have a localized, patchy distribution, even within their preferred habitat, and most of the population occurs in aggregations. Most of what is known about northern rockfish is based on data collected during the summer months from the commercial fishery or in research surveys. Consequently, there is little information on seasonal movements or changes in distribution for this species.

Life history information on northern rockfish is extremely sparse. The fish are assumed to be viviparous, as other *Sebastes* appear to be, with internal fertilization and incubation of eggs. Observations during research surveys in the GOA suggest that parturition (larval release) occurs in the spring, and is mostly completed by summer. Pre-extrusion larvae have been described (Kendall 1989), but field-collected larvae cannot be unequivocally identified to species at present, even using genetic techniques (Li et al. 2006). Length of the larval stage is unknown, but the fish apparently metamorphose to a pelagic juvenile stage, which also has been described (Matarese et al. 1989). However, similar to the larvae, smaller-sized post-larval northern rockfish cannot be positively identified at present, even with genetic methods (Kondzela et al. 2007). There is no information on when the juveniles become benthic or what habitat they occupy. Older juveniles are found on the continental shelf, generally at locations inshore of the adult habitat (Clausen and Heifetz 2002).

Northern rockfish is a slow growing species, with a low rate of natural mortality (estimated at 0.06), a relatively old age at 50 percent maturity (12.8 years for females in the GOA), and an old maximum age of 67 years in the GOA (Heifetz et al. 2007). Size at 50 percent maturity for females has been estimated to be 36 cm; it is unknown for males, but presumed to be slightly smaller than for females based on what is commonly the case in other species of *Sebastes*. No information on fecundity is available.

D.13.2 Fishery

Northern rockfish are caught almost exclusively with bottom trawls. The majority of the catch in the GOA comes from depths of 75 to 125 m (Clausen and Heifetz 2002). Age at 50 percent recruitment is unknown. Before 2007, the fishery in the GOA occurred in the summer months, especially July, due to management regulations. With the implementation of the Central Gulf Rockfish Pilot Program in 2007, catches have been spread out more throughout the year (Heifetz et al. 2007). From 1990 to 1998, catches were concentrated at five relatively shallow, offshore banks of the outer continental shelf, which include Portlock Bank, Albatross Bank, the “Snakehead” south of Kodiak Island, Shumagin Bank, and Davidson Bank (Clausen and Heifetz 2002). Of these, the Snakehead was especially productive. Outside of these banks, catches were generally sparse. Since 1998, Portlock, Albatross, and Shumagin Banks have generally continued to be important, but the amount taken from the Snakehead has diminished greatly (Heifetz et al. 2008). An analysis of catch data indicated that significant depletion of northern rockfish likely occurred in the Snakehead in the 1990s (Hanselman et al. 2007); subsequently, it appears that catch rates in this area have not recovered.

The major bycatch species in the GOA northern rockfish trawl fishery in 1994–96 included (in descending order by percent bycatch rate): dusky rockfish, “other slope rockfish,” and Pacific ocean perch (Ackley and Heifetz 2001). Of these, dusky rockfish was by far the most common bycatch, having a bycatch rate as high as 34 percent, depending on the year.

D.13.3 Relevant Trophic Information

Although no comprehensive food study of northern rockfish in the GOA has been done, one small study indicated euphausiids were by far the predominant food item of adults (Yang 1993). Food studies in the Aleutian Islands have also shown northern rockfish to be planktivorous, with euphausiids and copepods being the main prey items (Yang 1996, 2003). Other foods consumed in the Aleutian Islands included Chaetognaths (arrow worms), amphipods, squid, and polychaetes.

Predators of northern rockfish have not been documented, but likely include species that are known to consume rockfish in Alaska, such as Pacific halibut, sablefish, Pacific cod, and arrowtooth founder.

D.13.4 Habitat and Biological Associations

Egg/Spawning: No information known, except that parturition probably occurs in the spring.

Larvae: No information known. Larval studies are not possible at present because larvae have not been positively identified to species, even when genetic techniques have been used.

Juveniles: No information known for small juveniles (less than 20 cm), except that post-larval fish apparently undergo a pelagic phase immediately after metamorphosis from the larval stage. How long the pelagic stage lasts, and when juveniles assume a demersal existence, is unknown. Observations from manned submersibles in offshore waters of the GOA (e.g., Krieger 1993; Freese and Wing 2003) have consistently indicated that small juvenile rockfish are associated with benthic living and non-living structure and appear to use this structure as refuge. The living structure includes corals and sponges. Although the juvenile rockfish could not be identified to species in the submersible studies, the studies suggest that small juvenile northern rockfish possibly utilize these habitats. Large juvenile northern rockfish have been taken in bottom trawls at various localities of the continental shelf, usually inshore of the adult fishing grounds (Clausen and Heifetz 2002). Substrate preference of these larger juveniles is unknown.

Adults: Commercial fishery and research survey data have consistently indicated that adult northern rockfish in the GOA are primarily found on offshore banks of the outer continental shelf at depths of 75 to 150 m. Preferred substrate in this habitat has not been documented, but observations from trawl surveys suggest that large catches of northern rockfish are often associated with hard or rough bottoms.

For example, some of the largest catches in the trawl surveys have occurred in hauls in which the net hung-up on the bottom or was torn by a rough substrate (Clausen and Heifetz 2002). Generally, the fish appear to be demersal, and most of the population occurs in large aggregations. There is no information on seasonal migrations. Northern rockfish often co-occur with dusky rockfish.

Habitat and Biological Associations: Northern Rockfish

Stage - EFH Level	Duration or Age	Diet/ Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	U	NA	NA	NA	NA	NA	NA	NA
Larvae	U	U	spring–summer	U	P (assumed)	NA	U	U
Early Juveniles	From end of larval stage to ?	U	summer to ?	U	P?	U	U	U
Late Juveniles	to 13 years	U	all year	MCS, OCS	D	U	U	U
Adults	13 to 67 years of age	Euphausiids	U, except that larval release is probably in the spring in the GOA	OCS	D	CB, R	U	often co-occur with dusky rockfish

D.13.5 Literature

- Ackley, D.R., and J. Heifetz. 2001. Fishing practices under maximum retainable bycatch rates in Alaska's groundfish fisheries. *Alaska Fish. Res. Bull.* 8(1): 22-44.
- Clausen, D.M., and J. Heifetz. 2002. The northern rockfish, *Sebastes polycarpus*, in Alaska: commercial fishery, distribution, and biology. *Mar. Fish. Rev.* 64(4): 1-28.
- Freese, J.L., and B.L. Wing. 2003. Juvenile red rockfish, *Sebastes* sp., associations with sponges in the Gulf of Alaska. *Mar. Fish. Rev.* 65(3): 38-42.
- Hanselman, D., P.D. Spencer, S.K. Shotwell, and R.R. Reuter. 2007. Localized depletion of three Alaskan rockfish species. In J. Heifetz, J. DiCosimo, A.J. Gharrett, M.S. Love, V.M. O'Connell, and R.D. Stanley (editors), *Biology, assessment, and management of North Pacific rockfishes*, p. 493-511. Alaska Sea Grant, Univ. of Alaska Fairbanks.
- Heifetz, J., D. Hanselman, D. Courtney, and J. Ianelli. 2007. Gulf of Alaska northern rockfish. In *Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska*, p. 623-674. Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.
- Heifetz, J., D. Hanselman, D. Courtney, S.K. Shotwell, and J.N. Ianelli. 2008. Assessment of northern rockfish in the Gulf of Alaska (executive summary). In *Stock assessment and fishery evaluation report for the groundfish resources of the GOA*, p. 445-452. Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.
- Kendall, A.W. 1989. Additions to knowledge of *Sebastes* larvae through recent rearing. *NWAFRC Proc. Rept.* 89-21. 46 p.
- Krieger, K.J. 1993. Distribution and abundance of rockfish determined from a submersible and by bottom trawling. *Fish. Bull.* 91: 87-96.
- Kondzela, C.M., A.W. Kendall, Z. Li, D.M. Clausen, and A.J. Gharrett. 2007. Preliminary identification of pelagic juvenile rockfishes collected in the Gulf of Alaska. In J. Heifetz, J. DiCosimo, A.J. Gharrett, M.S. Love, V.M. O'Connell, and R.D. Stanley (editors), *Biology, assessment, and management of North Pacific rockfishes*, p. 153-166. Alaska Sea Grant, Univ. of Alaska Fairbanks.
- Li, Z., A.K. Gray, M.S. Love, A. Goto, T. Asahida, and A.J. Gharrett. 2006. A key to selected rockfishes (*Sebastes* spp.) based on mitochondrial DNA restriction fragment analysis. *Fish. Bull.* 104: 182-196.
- Matarese, A.C., A.W. Kendall, Jr., D.M. Blood, and B.M. Vinter. 1989. Laboratory guide to early life history stages of Northeast Pacific fishes. U.S. Dep. Commer. NOAA Tech. Rept. NMFS 80, 652 p.

- Mecklenburg, C.W., T.A. Mecklenburg, and L.K. Thorsteinson. 2002. Fishes of Alaska. Am. Fish. Soc., Bethesda, Maryland. 1,037 p.
- Yang, M-S. 1993. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-22, 150 p.
- Yang, M-S. 1996. Diets of the important groundfishes in the Aleutian Islands in summer 1991. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-60, 105 p.
- Yang, M-S. 2003. Food habits of important groundfishes in the Aleutian Islands in 1994 and 1997. U.S. Dep. Commer., AFSC Proc. Rep. 2003-07, 233 p.

D.14 Shortraker Rockfish (*Sebastes borealis*)

D.14.1 Life History and General Distribution

Shortraker rockfish are found around the arc of the north Pacific from southern California to northern Japan, including the Bering Sea and the Sea of Okhotsk (Mecklenburg et al. 2002). They also occur on seamounts in the GOA (Maloney 2004). Except for the adult stage, information on the life history of shortraker rockfish is extremely limited. Similar to other *Sebastes*, the fish appear to be viviparous; fertilization is internal and the developing eggs receive at least some nourishment from the mother. Parturition (release of larvae) may occur from February through August (McDermott 1994). Larvae can be positively identified only by using genetic techniques (Gray et al. 2006), which greatly hinders study of this life stage. Based on genetic identification, a few larval shortraker rockfish have been found in coastal waters of Southeast Alaska (Gray et al. 2006). Post-larvae are also difficult to identify, but genetic identification confirmed the presence of two specimens in epipelagic offshore waters of the GOA over depths greater than 1,000 m (Kondzela et al. 2007). It is unknown whether this very limited sampling of larval and post-larval fish is a good indication of the habitat preference of these life stages; clearly, additional sampling is needed. Similarly, almost nothing is known about juvenile shortraker rockfish in the GOA; only a few specimens less than 35-cm fork length have ever been caught by fishing gear in this region. Juveniles have been caught in somewhat larger numbers in bottom trawl surveys of the Aleutian Islands (e.g., Harrison 1993), but these data have not been analyzed to determine patterns of distribution or habitat preference. As adults, shortraker rockfish are demersal and inhabit depths from 328 to 3,937 feet (100 to 1,200 m) (Mecklenburg et al. 2002). However, survey and commercial fishery data indicate that the fish are most abundant along a narrow band of the continental slope at depths of 984 to 1,640 feet (300 to 500 m) (Ito 1999), where they often co-occur with rougheye and blackspotted rockfish. Within this habitat, shortraker rockfish tend to have a relatively even distribution when compared with the highly aggregated and patchy distribution of many other rockfish such as Pacific ocean perch (Clausen and Fujioka 2007).

Though relatively little is known about its biology and life history, shortraker rockfish appears to be a K-selected species with late maturation, slow growth, extreme longevity, and low natural mortality. Age of 50 percent maturity for female shortraker rockfish has been estimated to be 21.4 years for the GOA, with a maximum age of 116 years (Hutchinson 2004). Both these values are very old relative to other fish species. Another study reported an even older maximum age of 157 years (Munk 2001). Female length of 50 percent maturity has been estimated to be 44.9 cm (McDermott 1994). There is no information on age or length of maturity for males. Shortraker rockfish attains the largest size of any species in the genus *Sebastes*, with a maximum length of up to 47 inches (120 cm; Mecklenburg et al. 2002). Estimates of natural mortality for shortraker rockfish range between 0.027 and 0.042 (McDermott 1994), and a mortality of 0.03 has been used in recent stock assessments to determine values of acceptable biological catch and overfishing for the GOA (Clausen 2007).

D.14.2 Fishery

Shortraker rockfish since 2005 have been assigned their own values of acceptable biological catch and TAC in the GOA, although technically there is no directed fishery. Instead, all the catch is taken as bycatch in other fisheries. Before 2005, shortraker rockfish were combined with rougheye rockfish for management purposes in the GOA. Shortraker rockfish can be caught with either bottom trawls or longlines. In recent years, each gear type has taken about one half the total catch (Clausen 2007). Most of the trawl catch comes as bycatch in the Pacific ocean perch fishery, whereas the longline catch is taken in the sablefish or Pacific halibut fishery. Although shortraker rockfish are supposedly a “bycatch only” species, present management regulations indirectly allow a limited amount of *de facto* targeted fishing on these fish by rockfish trawlers in some situations (Clausen 2007). In contrast, virtually all the longline catch of shortraker rockfish appears to come as “true” incidental catch. Shortraker rockfish is one of the most valuable rockfish species in Alaska in terms of landed price; consequently, the discard rate for this species is generally quite low.

D.14.3 Relevant Trophic Information

The diet of adult shortraker rockfish in the GOA is not well known, but shrimp, deepwater fish such as myctophids, and squid appear to be the major prey items (Yang and Nelson 2000; Yang et al. 2006). A food study in the Aleutian Islands with a larger sample size of shortraker rockfish also found the diet to be mostly myctophids, squid, and shrimp (Yang 2003). In addition, gammarid amphipods, mysids, and miscellaneous fish were important food items in some years. There is no information on predators of shortraker rockfish. Due to their large size, older shortraker rockfish likely have few potential predators other than very large animals such as sleeper sharks or sperm whales.

D.14.4 Habitat and Biological Associations

Egg/Spawning: The timing of reproductive events is apparently protracted. Similar to all *Sebastes*, egg development for shortraker rockfish is completely internal. One study suggested parturition (i.e., larval release) may occur from February to August (McDermott 1994). Another study indicated the peak month of parturition in Southeast Alaska was April (Westheim 1975). There is no information as to when males inseminate females or if migrations occur for spawning/breeding.

Larvae: Information on larval shortraker rockfish is very limited. Larval shortraker rockfish have been identified in pelagic plankton tows in coastal Southeast Alaska (Gray et al. 2006). Larval studies are hindered because the larvae at present can be positively identified only by genetic analysis, which is both expensive and labor-intensive.

Post-larvae and early young-of-the year: One study used genetics to identify two specimens of post-larval shortraker rockfish from samples collected in epipelagic waters far offshore in the GOA beyond the continental slope (Kondzela et al. 2007). This limited information is the only documentation of habitat preference for this life stage.

Juveniles: Information is negligible regarding the habitat and biological associations of juvenile shortraker rockfish. Only a few specimens less than 14 inches (35 cm) fork length have ever been caught in the GOA. The habitat is presumably demersal, as all specimens caught in the GOA as well others caught in the Aleutian Islands (Harrison 1993) and off Russia (Orlov 2001) have been taken by bottom trawls.

Adults: Adult shortraker rockfish are demersal and in the GOA are concentrated at depths of 984 to 1,640 feet (300 to 500 m) along the continental slope. Much of this area is generally considered by fishermen to be steep and difficult to trawl. Observations from a manned submersible indicated that shortraker rockfish occurred over a wide range of habitats, but soft substrates of sand or mud usually had the highest densities of fish (Krieger 1992). However, this study also showed that habitats with steep slopes and frequent

boulders were used at a higher rate than habitats with gradual slopes and few boulders. Another submersible study also found that shortraker and rougheye rockfish occur more frequently on steep slopes with numerous boulders (Krieger and Ito 1999). Although the study could not distinguish between the two species, it is highly probable that many of the fish were shortraker rockfish. Finally, a third submersible study found that “large” rockfish had a strong association with *Primnoa* spp. coral growing on boulders: less than 1 percent of the observed boulders had coral, but 85 percent of the “large” rockfish, which included redbanded rockfish along with shortraker and rougheye, were next to boulders with coral (Krieger and Wing 2002). Again, in this latter study, “large” rockfish were not positively identified, but it is likely based on location and depth that many were shortraker rockfish.

Habitat and Biological Associations: Shortraker Rockfish

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	U	NA	NA	NA	NA	NA	NA	
Larvae	U	U	parturition: Feb–Aug	U; BAY	probably P	NA	U	
Post-larvae/ early juvenile	U	U	summer to ?	LSP, BSN	probably D	NA	U	
Juveniles	Up to 21 years of age	U	U	OCS?, USP?	probably D	U	U	
Adults	21 to >100 years of age	shrimp, squid, myctophids	year-round?	USP	D	M, S, R, SM, CB, MS, G, C; steep slopes and boulders	U	observed associated with <i>Primnoa</i> coral

D.14.5 Literature

- Clausen, D.M. 2007. Shortraker rockfish and other slope rockfish. In Stock assessment and fishery evaluation report for the groundfish resources of the GOA, p. 735-780. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.
- Clausen, D.M., and J.T. Fujioka. 2007. Variability in trawl survey catches of Pacific ocean perch, shortraker rockfish, and rougheye rockfish in the Gulf of Alaska. In J. Heifetz, J. DiCosimo, A.J. Gharrett, M.S. Love, V.M. O’Connell, and R.D. Stanley (editors), Biology, assessment, and management of North Pacific rockfishes, p. 411-428. Alaska Sea Grant, Univ. of Alaska Fairbanks.
- Gray, A.K., A.W. Kendall, B.L. Wing, M.G. Carls, J. Heifetz, Z. Li, and A.J. Gharrett. 2006. Identification and first documentation of larval rockfishes in Southeast Alaskan waters was possible using mitochondrial markers but not pigmentation patterns. Trans. Am. Fish. Soc. 135: 1-11.
- Harrison, R.C. 1993. Data report: 1991 bottom trawl survey of the Aleutian Islands area. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-12, 144 p.
- Hutchinson, C.E. 2004. Using radioisotopes in the age determination of shortraker (*Sebastes borealis*) and canary (*Sebastes pinniger*) rockfish. Master’s Thesis. Univ. Washington, Seattle. 84 p.
- Kondzela, C.M., A.W. Kendall, Z. Li, D.M. Clausen, and A.J. Gharrett. 2007. Preliminary identification of pelagic juvenile rockfishes collected in the Gulf of Alaska. In J. Heifetz, J. DiCosimo, A.J. Gharrett, M.S. Love, V.M. O’Connell, and R.D. Stanley (editors), Biology, assessment, and management of North Pacific rockfishes, p. 153-166. Alaska Sea Grant, Univ. of Alaska Fairbanks.
- Krieger, K. 1992. Shortraker rockfish, *Sebastes borealis*, observed from a manned submersible. Mar. Fish. Rev., 54(4): 34-37.

- Krieger, K.J., and D.H. Ito. 1999. Distribution and abundance of shortraker rockfish, *Sebastes borealis*, and rougheye rockfish, *Sebastes aleutianus*, determined from a manned submersible. Fish. Bull. 97: 264-272.
- Krieger, K.J., and B.L. Wing. 2002. Megafauna associations with deepwater corals (*Primnoa* spp.) in the GOA. Hydrobiologia 471: 83-90.
- Ito, D.H. 1999. Assessing shortraker and rougheye rockfishes in the GOA: addressing a problem of habitat specificity and sampling capability. PhD. Dissertation. Univ. Washington, Seattle. 205 p.
- Maloney, N. E. 2004. Sablefish, *Anoplopoma fimbria*, populations on Gulf of Alaska seamounts. Mar. Fish. Rev. 66(3): 1-12.
- McDermott, S.F. 1994. Reproductive biology of rougheye and shortraker rockfish, *Sebastes aleutianus* and *Sebastes borealis*. Masters Thesis. Univ. Washington, Seattle. 76 p.
- Mecklenburg, C.W., T.A. Mecklenburg, and L.K. Thorsteinson. 2002. Fishes of Alaska. Am. Fish. Soc., Bethesda, Maryland. 1,037 p.
- Munk, K.M. 2001. Maximum ages of groundfishes off Alaska and British Columbia and considerations of age determination. Alaska Fish. Res. Bull. 8(1): 12-21.
- Orlov, A. M. 2001. Ocean current patterns and aspects of life history of some northwestern Pacific scorpaenids. In: G. H. Kruse, N. Bez, A. Booth, M. W. Dorn, A. Hills, R. N. Lipcius, D. Pelletier, C. Roy, S. J. Smith, and D. Witherell (editors), Spatial processes and management of marine populations. Pub. No. AK-SG-01-02. Univ. Alaska Sea Grant College Program, Fairbanks AK.
- Westrheim, S.J. 1975. Reproduction, maturation, and identification of larvae of some *Sebastes* (Scorpaenidae) species in the northeast Pacific Ocean. J. Fish. Res. Board Can. 32:2399-2411.
- Yang, M-S., and M.W. Nelson. 2000. Food habits of the commercially important groundfishes in the GOA in 1990, 1993, and 1996. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-112, 174 p.
- Yang, M-S. 2003. Food habits of the important groundfishes in the AI in 1994 and 1999. AFSC Proc. Rep 2003-07. 233 p. (Available from NMFS, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115).
- Yang, M-S., K. Dodd, R. Hibshman, and A. Whitehouse. 2006. Food habits of groundfishes in the Gulf of Alaska in 1999 and 2001. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-164, 199 p.

D.15 Rougheye rockfish (*Sebastes aleutianus*) and blackspotted rockfish (*Sebastes melanostictus*)

D.15.1 Life History and General Distribution

Orr and Hawkins (2008) formally verified the presence of two species, rougheye rockfish (*Sebastes aleutianus*) and blackspotted rockfish (*S. melanostictus*), in what was once considered a single variable species with light and dark color morphs. They used combined genetic analyses of 339 specimens from Oregon to Alaska to identify the two species and formulated general distribution and morphological characteristics for each. Rougheye rockfish is typically pale with spots absent from the dorsal fin and possible mottling on the body. Blackspotted rockfish is darker with spotting almost always present on the dorsal fin and body. The two species occur in sympatric distribution with rougheye extending farther south along the Pacific Rim and blackspotted extending into the western Aleutian Islands. The overlap is quite extensive (Gharrett et al. 2005, 2006). At present there is difficulty in field identification between the two species. Scientists and observers are currently evaluating new techniques to determine whether rapid and accurate field identification can occur. Ongoing research in this area may distinguish particular habitat preference that might be useful for separating the species and determine whether the two species have significantly different life history traits (i.e., age of maturity and growth). Until such information is

available, it will be difficult to undertake distinct population assessments. In the stock assessment, rougheye and blackspotted rockfish are referred together as the rougheye rockfish complex.

Rougheye and blackspotted rockfish inhabit the outer continental shelf and upper continental slope of the northeastern Pacific. Their distribution extends around the arc of the North Pacific from Japan to Point Conception, California, and includes the Bering Sea (Kramer and O'Connell 1988). The center of abundance appears to be Alaskan waters, particularly the eastern GOA. Adults in the GOA inhabit a narrow band along the upper continental slope at depths of 984 to 1,640 feet (300 to 500 m); outside of this depth interval, abundance decreases considerably (Ito 1999). This species often co-occurs with shortraker rockfish (*Sebastes borealis*) in trawl or longline hauls.

Though relatively little is known about their biology and life history, rougheye and blackspotted rockfish appear to be K-selected with late maturation, slow growth, extreme longevity, and low natural mortality. Age and size at 50 percent maturity for female rougheye rockfish is estimated at 19 years and 44 cm, respectively (McDermott 1994). There is no information on male size at maturity or on maximum size of juvenile males. Rougheye is considered the oldest of the *Sebastes* spp. with a maximum age of 205 years (Chilton and Beamish 1982, Munk 2001). It is also considered one of the larger rockfish attaining sizes of up to 38 inches (98 cm) (Mecklenburg et al. 2002). Natural mortality is low, estimated to be on the order of 0.004 to 0.07 (Archibald et al. 1981, McDermott 1994, Nelson and Quinn 1987, Clausen et al. 2003, Shotwell et al. 2007).

D.15.2 Fishery

Although rougheye and blackspotted rockfish are found as far south as southern California, commercial quantities are primarily harvested from Washington north to Alaska waters. Commercial harvests usually occur on the continental slope from 984 to 1,640 feet (300 to 500 m) deep. Rougheye and blackspotted rockfish have been managed as “bycatch” only species since the creation of the shortraker/rougheye rockfish management subgroup in the GOA in 1991. Historically, Gulf-wide catches of the shortraker/rougheye subgroup have been consistently around 1,500 to 2,000 mt in the years since 1992. Annual TACs have been the major determining factor of these catch amounts, as TACs have also ranged between approximately 1,500 and 2,000 mt over these years. Rougheye are caught in either bottom trawls or with longline gear, and about half came from each gear type in recent years (Shotwell et al. 2007). Nearly all the longline catch of rougheye appears to come as “true” bycatch in the sablefish or halibut longline fisheries. Rougheye and blackspotted rockfish are associated with soft to rocky habitats along the continental slope, although boulders and steeply sloping terrain also appear to be a desirable habitat feature (Krieger and Ito 1999). Trawling in such habitats often requires specialized fishing skills to avoid gear damage and to keep the trawl in the proper fishing configuration. One study estimated age at recruitment for rougheye rockfish to be 30 years (Nelson and Quinn 1987).

Since 2005, rougheye and blackspotted rockfish were assessed separately from shortraker rockfish and assigned their own values of acceptable biological catch and TAC in the GOA. Gulf-wide discard rates (percent of the total catch discarded within management categories) of fish in the shortraker/rougheye subgroup were available for the years 1991 through 2004, and range from approximately 10 percent to 42 percent. Beginning in 2005, discards for the rougheye rockfish complex are reported separately and range from 20 percent to 38 percent, which are relatively high when compared to other *Sebastes* species in the GOA (Shotwell et al. 2007).

In 2007, the Central Gulf of Alaska Rockfish Pilot Program was implemented to enhance resource conservation and improve economic efficiency for harvesters and processors who participate in the Central Gulf of Alaska rockfish fishery. This is a 5-year rationalization program that establishes cooperatives among trawl vessels and processors which receive exclusive harvest privileges for rockfish management groups. The program was revised and reimplemented in 2012. The primary rockfish management groups are northern, Pacific ocean perch, and pelagic shelf rockfish, while the secondary

species include rougheye and shortraker rockfish. This implementation impacts primary management groups but will also effect secondary groups with a maximum retained allowance. Potential effects of this program to rougheye rockfish include (1) changes in spatial distribution of fishing effort within the Central GOA, (2) improved at-sea and plant observer coverage for vessels participating in the rockfish fishery, (3) a higher potential to harvest 100 percent of the TAC in the Central GOA region, and (4) an extended fishing season lasting from May 1 through November 15. This should spread out the fishery in time and space, allowing for better prices for product and reducing the pressure of what was an approximately 2-week fishery in July.

D.15.3 Relevant Trophic Information

Rougheye rockfish in Alaska feed primarily on shrimps (especially pandalids), and various fish species such as myctophids are also consumed (Yang and Nelson 2000; Yang 2003). However, smaller juvenile rougheye rockfish (less than 12 inches [30 cm] fork length) in the GOA also consume a substantial amount of smaller invertebrates such as amphipods, mysids, and isopods (Yang and Nelson 2000). Recent food studies show the most common prey of rougheye as pandalid shrimp, euphausiids, and tanner crab (*Chionoecetes bairdi*). Other prey include octopuses and copepods (Yang et al. 2006). Predators of rougheye rockfish likely include halibut (*Hippoglossus stenolepis*), Pacific cod (*Gadus macrocephalus*), and sablefish (*Anoplopoma fimbria*).

D.15.4 Habitat and Biological Associations

Egg/Spawning: As with other *Sebastes* species, rougheye and blackspotted rockfish are presumed to be viviparous, where fertilization and incubation of eggs is internal and embryos receive at least some maternal nourishment. There have been no studies on fecundity of rougheye in Alaska. One study on their reproductive biology indicated that rougheye had protracted reproductive periods, and that parturition (larval release) may take place in December through April (McDermott 1994). There is no information as to when males inseminate females or if migrations for spawning/breeding occur.

Larvae: Information on larval rougheye and blackspotted rockfish is very limited. The larval stage is pelagic, but larval studies are hindered because the larvae at present can only be positively identified by genetic analysis, which is both expensive and labor-intensive.

Post-larvae and early young-of-the year: The post-larvae and early young-of-the-year stages also appear to be pelagic (Matarese et al. 1989, Kondzela et al. 2007). Genetic techniques have been used recently to identify a few post-larval rougheye rockfish from samples collected in epipelagic waters far offshore in the GOA (Kondzela et al. 2007), which is the only documentation of habitat preference for this life stage.

Juveniles: There is no information on when juvenile fish become demersal. Juvenile rougheye rockfish 6 to 16 inches (15 to 40 cm) fork length have been frequently taken in GOA bottom trawl surveys, implying the use of low relief, trawlable bottom substrates (Clausen et al. 2003). They are generally found at shallower, more inshore areas than adults and have been taken in a variety of locations, ranging from inshore fiords to offshore waters of the continental shelf. Studies using manned submersibles have found that large numbers of small, juvenile rockfish are frequently associated with rocky habitat on both the shallow and deep shelf of the GOA (Carlson and Straty 1981). Another submersible study on the GOA shelf observed juvenile red rockfish closely associated with sponges that were growing on boulders (Freese and Wing 2004). Although these studies did not specifically identify rougheye rockfish, it is reasonable to suspect that juvenile rougheye rockfish may be among the species that utilize this habitat as refuge during their juvenile stage.

Adults: Adult rougheye and blackspotted rockfish are demersal and known to inhabit particularly steep, rocky areas of the continental slope, with highest catch rates generally at depths of 984 to 1,312 feet (300 to 400 m) in longline surveys (Zenger and Sigler 1992) and at depths of 984 to 1,640 feet (300 to 500 m) in bottom trawl surveys and in the commercial trawl fishery (Ito 1999). Observations from a manned

submersible in this habitat indicate that the fish prefer steep slopes and are often associated with boulders and sometimes with *Primnoa* spp. coral (Krieger and Ito 1999, Krieger and Wing 2002). Within this habitat, rougheye rockfish tend to have a relatively even distribution when compared with the highly aggregated and patchy distribution of other rockfish such as Pacific ocean perch (*Sebastes alutus*) (Clausen and Fujioka 2007).

Habitat and Biological Associations: Rougheye and Blackspotted Rockfish

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	U	NA	NA	NA	NA	NA	NA	
Larvae	U	U	parturition: Dec–Apr	U	Pelagic	NA	U	
Post-larvae/ early juvenile	U	U	summer to ?	LSP, BSN	Epipelagic	NA	U	
Juveniles	up to 20 years of age	shrimp, mysids, amphipods, isopods	U	OCS, USP	D	U	U	
Adults	20 to >100 years of age	shrimp, euphausiids, myctophids, tanner crab	year-round?	USP	D	M, S, R, SM, CB, MS, G, C steep slopes and boulders	U	observed associated with <i>Primnoa</i> coral

D.15.5 Literature

- Archibald, C.P., W. Shaw, and B.M. Leaman. 1981. Growth and mortality estimates of rockfishes (Scorpaenidae) from B.C. coastal waters, 1977-79. Can. Tech. Rep. Fish. Aquat. Sci. 1048, 57 p.
- Carlson, H.R. and R.R. Straty. 1981. Habitat and nursery grounds of Pacific rockfish, *Sebastes* spp., in rocky coastal areas of southeastern Alaska. Marine Fisheries Review 43(7):13-19.
- Chilton, D.E., and R.J. Beamish. 1982. Age determination methods for fishes studied by the Groundfish Program at the Pacific Biological Station. Can. Spec. Publ. Fish. Aquat. Sci. 60, 102 p.
- Clausen, D. M., and J. T. Fujioka. 2007. Variability in trawl survey catches of Pacific ocean perch, shortraker rockfish, and rougheye rockfish in the Gulf of Alaska. In J. Heifetz, J. Dicosimo, A. J. Gharrett, M. S. Love, V. M. O'Connell, and R. D. Stanley (editors), Biology, assessment, and management of North Pacific rockfishes, p. 411-428. Alaska Sea Grant, Univ. of Alaska Fairbanks.
- Clausen, D.M., J.T. Fujioka, and J. Heifetz. 2003. Shortraker/rougheye and other slope rockfish. In Stock assessment and fishery evaluation report for the groundfish resources of the GOA, p. 531-572. Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.
- de Bruin, J., R. Gosden, C. Finch, and B. Leaman. 2004. Ovarian aging in two species of long-lived rockfish, *Sebastes aleutianus* and *S. alutus*. Biol. Reprod. 71: 1036-1042.
- Freese, J.F., B.L. Wing. 2004. Juvenile red rockfish, *Sebastes* spp., associations with sponges in the Gulf of Alaska. Mar. Fish. Rev. 65(3):38-42.
- Gharrett, A.J., A.P. Matala, E.L. Peterson, A.K. Gray, Z. Li, and J. Heifetz. 2005. Two genetically distinct forms of rougheye rockfish are different species. Trans. Am. Fish. Soc. 132:242-260.
- Gharrett, A.J., C.W. Mecklenburg, L.W. Seeb, L. Li, A.P. Matala, A.K. Gray, and J. Heifetz. 2006. Do genetically distinct rougheye rockfish sibling species differ phenotypically? Trans. Am. Fish. Soc. 135:792-800.

- Kondzela, C.M., A.W. Kendall, Z. Li, D.M. Clausen, and A.J. Gharrett. 2007. Preliminary identification of pelagic juvenile rockfishes collected in the Gulf of Alaska. In J. Heifetz, J. DiCosimo, A.J. Gharrett, M.S. Love, V.M. O'Connell, and R.D. Stanley (editors), Biology, assessment, and management of North Pacific rockfishes, p. 153-166. Alaska Sea Grant, Univ. of Alaska Fairbanks.
- Kramer, D.E., and V.M. O'Connell. 1988. A Guide to Northeast Pacific Rockfishes: Genera *Sebastes* and *Sebastolobus*. In: Alaska Sea Grant Advisory Bulletin, 25. In National Marine Fisheries Service 2001(a).
- Krieger, K.J., and D.H. Ito. 1999. Distribution and abundance of shortraker rockfish, *Sebastes borealis*, and rougheye rockfish, *Sebastes aleutianus*, determined from a manned submersible. Fish. Bull. 97: 264-272.
- Krieger, K.J., and B.L. Wing. 2002. Megafauna associations with deepwater corals (*Primnoa* spp.) in the GOA. Hydrobiologia 471: 83-90.
- Ito, D.H. 1999. Assessing shortraker and rougheye rockfishes in the GOA: addressing a problem of habitat specificity and sampling capability. PhD. Dissertation. Univ. Washington, Seattle. 205 p.
- Malecha, P. W., D. H. Hanselman, and J. Heifetz. 2007. Growth and mortality of rockfish (Scorpaenidae) from Alaskan waters. NOAA Tech. Memo. NMFS-AFSC-172. 61 p.
- Maloney, N. E. 2004. Sablefish, *Anoplopoma fimbria*, populations on Gulf of Alaska seamounts. Mar. Fish. Rev. 66(3): 1-12.
- Matarese, A.C., A.W. Kendall, Jr., D.M. Blood, and B.M. Vinter. 1989. Laboratory guide to early life history stages of northeast Pacific fishes. NOAA Tech. Rep. NMFS 80, 652 p.
- McDermott, S.F. 1994. Reproductive biology of rougheye and shortraker rockfish, *Sebastes aleutianus* and *Sebastes borealis*. Masters Thesis. Univ. Washington, Seattle. 76 p.
- Mecklenburg, C.W., T.A. Mecklenburg, and L.K. Thorsteinson. 2002. Fishes of Alaska. Am. Fish. Soc., Bethesda, Maryland. 1,037 p.
- Munk, K.M. 2001. Maximum ages of groundfishes off Alaska and British Columbia and considerations of age determination. Alaska Fish. Res. Bull. 8(1): 12-21.
- Nelson, B.D., and T.J. Quinn. 1987. Population parameters of rougheye rockfish (*Sebastes aleutianus*). In Proc. Int. Rockfish Symp. pp. 209-228. Univ. Alaska Sea Grant Report No. 87-2. Anchorage, AK.
- Orr, J.W. and S. Hawkins. 2008. Species of the rougheye rockfish complex: resurrection of *Sebastes melanostictus* (Matsubara, 1934) and a redescription of *Sebastes aleutianus* (Jordan and Evermann, 1898) (Teleostei: Scorpaeniformes). Fisheries Bulletin. 106: 111-134.
- Shotwell, S.K., D. Hanselman, and D. Clausen. 2007. Gulf of Alaska rougheye rockfish. In Stock assessment and fishery evaluation report for the groundfish fisheries of the Gulf of Alaska. North Pacific Fishery Management Council, 605 W 4th Avenue, Suite 306, Anchorage, AK 99510.
- Yang, M-S., and M.W. Nelson. 2000. Food habits of the commercially important groundfishes in the GOA in 1990, 1993, and 1996. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-112, 174 p.
- Yang, M-S. 2003. Food habits of the important groundfishes in the AI in 1994 and 1999. AFSC Proc. Rep 2003-07. 233 p. (Available from NMFS, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115).
- Yang, M-S., K. Dodd, R. Hibpsman, and A. Whitehouse. 2006. Food habits of groundfishes in the Gulf of Alaska in 1999 and 2001. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-164, 199 p.
- Zenger, H.H., Jr. and M.F. Sigler. 1992. Relative abundance of GOA sablefish and other groundfish based on National Marine Fisheries Service longline surveys, 1988-90. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-216, 103 pp.

D.16 Dusky rockfish (*Sebastes variabilis*)

Previously it was thought that there were two varieties of dusky rockfish, a dark colored variety inhabiting inshore, shallow waters, and a lighter colored variety inhabiting deeper water offshore. In 2004 these two varieties were designated as distinct species, the dark colored variety is now recognized as dark rockfish (*Sebastes ciliatus*) and the lighter colored variety is now recognized as dusky rockfish (*Sebastes variabilis*) (Orr and Blackburn 2004). In 2009 dark rockfish were removed from the GOA FMP to allow for more responsive management by the State of Alaska.

D.16.1 Life History and General Distribution

Dusky rockfish range from central Oregon through the North Pacific Ocean and Bering Sea in Alaska and Russia to Japan. The center of abundance for dusky rockfish appears to be the GOA (Reuter 1999). The species is much less abundant in the Aleutian Islands and Bering Sea (Reuter and Spencer 2006). Adult dusky rockfish have a very patchy distribution and are usually found in large aggregations at specific localities of the outer continental shelf. These localities are often relatively shallow offshore banks. Because the fish are taken with bottom trawls, they are presumed to be mostly demersal. Whether they also have a pelagic distribution is unknown, but there is no particular evidence of a pelagic tendency based on the information available at present. Most of what is known about dusky rockfish is based on data collected during the summer months from the commercial fishery or in research surveys. Consequently, there is little information on seasonal movements or changes in distribution for this species.

Life history information on dusky rockfish is extremely sparse. The fish are assumed to be viviparous, as are other *Sebastes*, with internal fertilization and incubation of eggs. Observations during research surveys in the GOA suggest that parturition (larval release) occurs in the spring and is probably completed by summer. Another, older source, however, lists parturition as occurring “after May.” Pre-extrusion larvae have been described, but field-collected larvae cannot be identified to species at present. Length of the larval stage, and whether a pelagic juvenile stage occurs, are unknown. There is no information on habitat and abundance of young juveniles (less than 25 cm fork length), as catches of these have been virtually nil in research surveys. Even the occurrence of older juveniles has been very uncommon in surveys, except for one year. In this latter instance, older juveniles were found on the continental shelf, generally at locations inshore of the adult habitat.

Dusky rockfish is a slow growing species, with a low rate of natural mortality estimated at 0.09. However, it appears to be faster growing than many other rockfish species. Maximum age is 51 to 59 years. Estimated age at 50 percent maturity for females is 11.3 years. No information on fecundity is available.

The approximate upper size limit of juvenile fish is 47 cm for females (size at 50 percent maturity is 43 cm); unknown for males, but presumed to be slightly smaller than for females based on what is commonly the case in other species of *Sebastes*.

D.16.2 Fishery

Dusky rockfish are mostly caught with bottom trawl gear and to a much lesser extent by jig gear. In 2007, the Central Gulf of Alaska Rockfish Pilot Program was implemented to enhance resource conservation and improve economic efficiency for harvesters and processors who participate in the Central Gulf of Alaska rockfish fishery. This is a 5-year rationalization program that establishes cooperatives among trawl vessels and processors which receive exclusive harvest privileges for rockfish management groups. The program was revised and reimplemented in 2012. The primary rockfish management groups are northern rockfish, Pacific ocean perch, and pelagic shelf rockfish. Potential effects of this program on Pacific ocean perch include (1) extended fishing season lasting from May 1 through November 15, (2)

changes in spatial distribution of fishing effort within the Central GOA, (3) Improved at-sea and plant observer coverage for vessels participating in the rockfish fishery, and (4) a higher potential to harvest 100 percent of the TAC in the Central GOA region. This program also makes dusky rockfish increasing available to jig and hook-and-line gear through a specific allocation of TAC.

A precise estimate of age at 50 percent recruitment is not available, but has been roughly estimated to be about 10 years based on length frequency information from the fishery. The fishery in the GOA in recent years has mostly occurred in the summer months, especially July, due to management regulations. Catches are concentrated at a number of relatively shallow, offshore banks of the outer continental shelf, especially the “W” grounds west of Yakutat, and Portlock Bank. Other fishing grounds include Albatross Bank, the “Snakehead” south of Kodiak Island, and Shumagin Bank. Outside of these banks, catches are generally sparse. Most of the trawl catch of dusky rockfish is taken at depths of 100 to 200 m offshore, while most of the catch by jig gear occurs in shallow, inshore waters.

D.16.3 Relevant Trophic Information

Although no comprehensive food study of dusky rockfish has been done, one smaller study in the GOA showed euphausiids to be the predominant food item of adults. Larvaceans, cephalopods, pandalid shrimp, and hermit crabs were also consumed.

Predators of dusky rockfish have not been documented, but likely include species that are known to consume rockfish in Alaska, such as Pacific halibut, sablefish, Pacific cod, and arrowtooth flounder.

D.16.4 Habitat and Biological Associations

Egg/Spawning: No information is known, except that parturition probably occurs in the spring, and may extend into summer.

Larvae: No information is known.

Juveniles: No information is known for small juveniles less than 25 cm fork length. Larger juveniles have been taken infrequently in bottom trawls at various localities of the continental shelf, usually inshore of the adult fishing grounds. A manned submersible study in the eastern Gulf observed juvenile (less than 40 cm) dusky rockfish associated with *Primnoa* spp. coral.

Adults: Commercial fishery and research survey data indicate that adult dusky rockfish are primarily found on offshore banks of the outer continental shelf at depths of 100 to 200 m. Type of substrate in this habitat has not been documented, but it may be rocky. During submersible dives on the outer shelf (40 to 50 m) in the eastern Gulf, adult dusky rockfish were observed in association with rocky habitats and in areas with extensive sponge beds where the fish were observed resting in large vase sponges (V. O’Connell, ADFG, personal communication). Dusky rockfish are the most highly aggregated of the rockfish species caught in GOA trawl surveys. Outside of these aggregations, the fish are sparsely distributed. Because the fish are generally taken only with bottom trawls, they are presumed to be mostly demersal. Whether they also have a pelagic distribution is unknown, but there is no evidence of a pelagic tendency based on the information available at present. There is no information on seasonal migrations. Dusky rockfish often co-occur with northern rockfish.

Habitat and Biological Associations: Dusky Rockfish

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	U	NA	U	NA	NA	NA	NA	NA
Larvae	U	U	spring–summer	U	P (assumed)	NA	U	U
Early Juveniles	U	U	all year	U	U	U	U	U
Late Juveniles	Up to 11 years	U	U	ICS, MCS, OCS	D	CB, R, G	U	observed associated with <i>Primnoa</i> coral
Adults	11 up to 51–59 years.	euphausiids	U, except that larval release may be in the spring in the GOA	OCS, USP	D	CB, R, G	U	observed associated with large vase-type sponges

D.16.5 Literature

- Ackley, D.R., and J. Heifetz. 2001. Fishing practices under maximum retainable bycatch rates in Alaska's groundfish fisheries. Alaska Fish. Res. Bull. 8(1): 22-44.
- Allen, M.J., and G.B. Smith. 1988. Atlas and zoogeography of common fishes in the BS and northeastern Pacific. U.S. Dep. Commer., NOAA Tech. Rept. NMFS 66, 151 p.
- Clausen, D.M., C.R. Lunsford, and J. Fujioka. 2002. Pelagic shelf rockfish. In Stock assessment and fishery evaluation report for the groundfish resources of the GOA, p.383-417. Council, 605 W. 4th. Ave., Suite 306, Anchorage, AK 99501-2252.
- Hanselman, D., P.D. Spencer, S.K. Shotwell, and R.R. Reuter. 2007b. Localized depletion of three Alaskan rockfish species. Proceedings of the 23rd Lowell Wakefield Fisheries Symposium: Biology, Assessment, and Management of North Pacific Rockfishes.
- Kendall, A.W. 1989. Additions to knowledge of *Sebastes* larvae through recent rearing. NWAFC Proc. Rept. 89-21. 46 p.
- Krieger, K.J., and B.L. Wing. 2002. Megafauna associations with deepwater corals (*Primnoa* spp.) in the GOA. Hydrobiologia 471: 83-90.
- Lunsford, C.R., S.K. Shotwell, D.H. Hanselman, and D.M. Clausen. 2008. Gulf of Alaska pelagic shelf rockfish. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 727-780, Appendix A. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage AK 99501.
- Malecha, P. W., D. H. Hanselman, and J. Heifetz. 2007. Growth and mortality of rockfish (*Scorpaenidae*) from Alaskan waters. NOAA Tech. Memo. NMFS-AFSC-172. 61 p.
- Martin, M.H., and D.M. Clausen. 1995. Data report: 1993 GOA bottom trawl survey. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-59. 217 p.
- Matarese, A.C., A.W. Kendall, Jr., D.M. Blood, and B.M. Vinter. 1989. Laboratory guide to early life history stages of northeast Pacific fishes. U.S. Dep. Commer. NOAA Tech. Rept. NMFS 80, 652 p.
- Orr, J.W., and J.E. Blackburn. 2004. The dusky rockfishes (Teleostei: Scorpaeniformes) of the North Pacific Ocean: resurrection of *Sebastes variabilis* (Pallas, 1814) and a redescription of *Sebastes ciliatus* (Tilesius, 1813). Fish Bull., U.S. 1002:328-348.
- Reuter, R.F. 1999. Describing dusky rockfish (*Sebastes ciliatus*) habitat in the GOA using historical data. M.S. Thesis, Calif. State Univ., Hayward CA. 83 p.

- Reuter, R.F., and P.D. Spencer. 2006. Chapter 14 Other Rockfish. *in* Stock Assessment and Fishery Evaluation Report for the groundfish resources of the Bering Sea and Aleutian Islands. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK, 99501. November 2006. pp. 925-948.
- Spencer, P., D. Hanselman, and M. Dorn. 2007. The effect of maternal age of spawning on estimation of Fmsy for Alaska Pacific ocean perch. In: Heifetz, J., DiCosimo J., Gharrett, A.J., Love, M.S, O'Connell, V.M, and Stanley, R.D. (eds.). Biology, Assessment, and Management of North Pacific Rockfishes. Alaska Sea Grant, University of Alaska Fairbanks. pp 513 – 533.
- Stark, J.W., and D.M. Clausen. 1995. Data report: 1990 GOA bottom trawl survey. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-49. 221 p.
- Westrheim, S.J. 1973. Preliminary information on the systematics, distribution, and abundance of the dusky rockfish, *Sebastes ciliatus*. J. Fish. Res. Bd. Can. 30: 1230-1234.
- Westrheim, S.J. 1975. Reproduction, maturation, and identification of larvae of some *Sebastes* (Scorpaenidae) species in the northeast Pacific Ocean. J. Fish. Res. Board Can. 32: 2399-2411.

D.17 Yelloweye rockfish (*Sebastes ruberrimus*) and other demersal rockfishes

Yelloweye rockfish (primary, described below), *Sebastes ruberrimus*
 Quillback rockfish, *Sebastes maliger*
 Rosethorn rockfish, *Sebastes helvomaculatus*
 Tiger rockfish, *Sebastes nigrocinctus*
 Canary rockfish, *Sebastes pinniger*
 China rockfish, *Sebastes nebulosus*
 Copper rockfish, *Sebastes caurinus*

D.17.1 Life History and General Distribution

These species are distributed from Ensenada, in northern Baja California, to Umnak Island and Unalaska Island, of the Aleutian Islands, in depths from 60 to 1,800 feet but commonly in 300 to 600 feet in rocky, rugged habitat (Allen and Smith 1988, Eschmeyer et al. 1983). Little is known about the young of the year and settlement. Young juveniles between 2.5 and 10 cm have been observed in areas of high and steep relief in depths deeper than 15 m. Subadult and adult fish are generally solitary, occurring in rocky areas and high relief with refuge space, particularly overhangs, caves, and crevices (O'Connell and Carlile 1993). Yelloweye are ovoviviparous. Parturition occurs in southeast Alaska between April and July with a peak in May (O'Connell 1987). Fecundity ranges from 1,200,000 to 2,700,000 eggs per season (Hart 1942, O'Connell, ADFG, personal communication). Yelloweye feed on a variety of prey, primarily fishes (including other rockfishes, herring, and sandlance) as well as caridean shrimp and small crabs. Yelloweye are a K-selected species with late maturation, slow growth, extreme longevity, and low natural mortality. They reach a maximum length of about 91 cm and growth slows considerably after age 30 years. Approximately 50 percent of females are mature at 45 cm and 22 years. Age of 50 percent maturity for males is 18 years and length is 43 cm. Natural mortality is estimated to be 0.02, and maximum age published is 118 years (O'Connell and Fujioka 1991, O'Connell and Funk 1987). However a 121-year-old specimen was harvested in the commercial fishery off Southeast Alaska in 2000.

D.17.2 Fishery

Demersal shelf rockfish are the target of a directed longline fishery and are the primary bycatch species in the longline fishery for Pacific halibut. They recruit into the fishery at about age 18 to 20 years at a length between 45 and 50 cm. The commercial fishery grounds are usually areas of rocky bottom with varying

degrees of vertical relief in water depths between 20 and 100 fathoms. The directed fishery now occurs between November and March both because of higher winter prices and limitations imposed due to the halibut individual fishing quota regulations.

D.17.3 Relevant Trophic Information

Yelloweye rockfish eat a large variety of organisms, primarily fishes including small rockfishes, herring, and sand lance as well as caridean shrimp and small crabs (Rosenthal et al. 1988). They also opportunistically consume lingcod eggs. Young rockfishes are in turn eaten by a variety of predators including lingcod, large rockfish, salmon, and halibut.

D.17.4 Habitat and Biological Associations

Early juveniles: Young juveniles between 2.5 (1 inch) and 10 cm (4 inches) have been observed in areas of high relief. This relief can be provided by the geology of an area such as vertical walls, fjord-like areas, and pinnacles, or by large invertebrates such as cloud sponges, *Farrea occa*, *Metridium farcimen*, and *Primnoa* coral. These observations were made in depths deeper than 13 m during the course of submersible research in the Eastern GOA (Southeast Alaska Groundfish Project, Alaska Department of Fish and Game, unpublished data).

Late juveniles/adults: Subadult (late juveniles) and adult fish are generally solitary, occurring in rocky areas and high relief with refuge spaces particularly overhangs, caves and crevices (O'Connell and Carlile 1993), and can co-occur with gorgonian corals (Krieger and Wing 2002). Not infrequently an adult yelloweye rockfish will cohabitate a cave or refuge space with a tiger rockfish. Habitat specific density data shows an increasing density with increasing habitat complexity: deep water boulder fields consisting of very large boulders have significantly higher densities than other rock habitats (O'Connell and Carlile 1993, O'Connell et al. 2007). Although yelloweye do occur over cobble and sand bottoms, generally this is when foraging and often these areas directly interface with a rock wall or outcrop.

Habitat and Biological Associations: Yelloweye Rockfish

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceano-graphic Features	Other
Eggs	NA	NA	NA	NA	NA	NA	NA	NA
Larvae	<6 mo	copepod	spring/ summer	U	N?	U	U	
Early Juveniles	to 10 years	U		ICS, MCS, OCS, BAY, IP	D	R, C	U	
Late Juveniles	10 to 18 years	U		ICS, MCS, OCS, BAY, IP	D	R, C	U	
Adults	at least 118 years	fish, shrimp, crab	parturition: Apr-Jul	ICS, MCS, OCS, USP, BAY, IP	D	R, C, CB	U	

Habitat and Biological Associations: Other Rockfishes.

Species	Range/Depth	Maximum Age	Trophic	Parturition	Known Habitat
Quillback	Kodiak Island to San Miguel Island, CA to 274 m (commonly 12–76 m)	At least 32 size at 50 percent maturity=30 cm	main prey = crustaceans, herring, sandlance	spring (Mar–Jun)	Juveniles have been observed at the margins of kelp beds, adults occur over rock bottom, or over cobble/sand next to reefs.
Copper	Shelikof St to central Baja, CA shallow to 183 m (commonly to 122 m)	At least 31 years size at 50 percent maturity =5 yr	crustaceans octopuses small fishes	Mar–Jul	Juveniles have been observed near eelgrass beds and in kelp, in areas of mixed sand and rock. Adults are in rocky bays and shallow coastal areas, generally less exposed than the other demersal shelf rockfish.
Tiger	Kodiak Is and Prince William Sound to Tanner-Cortes Banks, CA from 33 to 183 m	to 116 years	invertebrates, primarily crustaceans	early spring	Juveniles and adults in rocky areas: most frequently observed in boulder areas, generally under overhangs.
China	Kachemak Bay to San Miguel Island, CA to 128 m	to 72 years	invertebrates, brittle stars are significant component of diet	Apr–Jun	Juveniles have been observed in shallow kelp beds, adults in rocky reefs and boulder fields. Some indications that adults have a homesite.
Rosethorn	Kodiak Is to Guadalupe Is, Baja, CA to 25 m to 549 m	to 87 years mature 7–10 years		Feb–Sept (May)	observed over rocky habitats and in rock pavement areas with large sponge cover
Canary	Shelikof St to Cape Colnett, Baja, CA To 424 m (commonly to 137 m)	To 75 years size at 50 percent maturity = 9	macroplankton and small fishes		Occur over rocky and sand/cobble bottoms, often hovering in loose schools over soft bottom near rock outcrops. Schools often associate with schools of yellowtail and silvergrey.

D.17.5 Literature

- Allen, M.J., and G.B. Smith. 1988. Atlas and zoogeography of common fishes in the Bering Sea and Northeast Pacific. NOAA Tech. Rep. NMFS 66. Seattle.
- Eschmeyer, W.N., E.S. Herald, and H. Hammann. 1983. A field guide to Pacific fishes of North America from the Gulf of Alaska to Baja California. Boston: Houghton Mifflin.
- Hart, J.L. 1942. New Item. Red snapper fecundity. Fish. Res. Board. Can. Pac. Progr. Rep. 52: 18.
- Krieger, K.J. and B.L. Wing. 2002. Megafauna associations with deepwater corals (*Primnoa* spp.) in the Gulf of Alaska. Hydrobiologia. Vol. 471 (1-3): 83-90.
- O'Connell, V.M. 1987. Reproductive seasons for some *Sebastes* species in southeast Alaska. Alaska Department of Fish and Game Information Leaflet No. 263. Juneau, AK.
- O'Connell, V.M., and D.C. Carlile. 1993. Habitat-specific density of adult yelloweye rockfish *Sebastes ruberrimus* in the eastern GOA. Fishery Bull. 91:304-309.
- O'Connell, V.M., and J.T. Fujioka. 1991. Demersal Shelf Rockfishes. In Loh-Lee Low (ed.), Status of living marine resources off Alaska as assessed in 1991, p. 46-47. NOAA Tech. Memo. NMFS F/NWC-211, Northwest Fish. Sci. Cent., Auke Bay AK 95 P.
- O'Connell, V.M., and F.C. Funk. 1987. Age and growth of yelloweye rockfish (*Sebastes ruberrimus*) landed in southeast Alaska. In B.R. Melteff (ed.), Proceedings of the International Rockfish Symposium. p 171-185. Alaska Sea Grant Report No. 87-2.

O'Connell, V.M., C.K. Brylinsky, and H.G. Greene. 2007. The use of geophysical survey data in fisheries management: a case history from Southeast Alaska. In Mapping the Seafloor for Habitat Characterization. p 319-328. Geological Association of Canada Special paper 47.

Rosenthal, R.J., V. Moran-O'Connell, and M.C. Murphy. 1988. Feeding ecology of ten species of rockfishes (Scorpaenidae) from the GOA. Calif. Fish and Game 74(1):16-37.

D.18 Thornyhead rockfish (*Sebastolobus* spp.)

D.18.1 Life History and General Distribution

Thornyhead rockfish of the northeastern Pacific Ocean comprise two species, the shortspine thornyhead (*Sebastolobus alascanus*) and the longspine thornyhead (*S. altivelis*). The longspine thornyhead is not common in the GOA. The shortspine thornyhead is a demersal species which inhabits deep waters from 17 to 1,524 m along the Pacific rim from the Seas of Okhotsk and Japan in the western north Pacific, throughout the Aleutian Islands, Bering Sea slope, and GOA, and south to Baja California. This species is common throughout the GOA, eastern Bering Sea, and Aleutian Islands. The population structure of shortspine thornyheads, however, is not well defined. Thornyhead rockfish are slow-growing and long-lived with maximum age in excess of 50 years and maximum size greater than 75 cm and 2 kg. Shortspine thornyhead spawning takes place in the late spring and early summer, between April and July in the GOA. Thornyhead rockfish spawn a bi-lobed mass of fertilized eggs which floats in the water column. Juvenile shortspine thornyhead rockfish have an extended pelagic period of about 14 to 15 months and settle out at about 22 to 27 mm into relatively shallow benthic habitats between 100 and 600 m and then migrate deeper as they grow. Fifty percent of female shortspine thornyhead rockfish are sexually mature at about 21.5 cm.

D.18.2 Fishery

Trawl and longline gear are the primary methods of harvest. The bulk of the fishery occurs in late winter or early spring through the summer. In the past, this species was seldom the target of a directed fishery. Today thornyhead rockfish are one of the most valuable of the rockfish species, with most of the domestic harvest exported to Japan. Despite their high value, they are still managed using a "bycatch only" fishery status in the GOA because they are nearly always taken in fisheries directed at sablefish (*Anoplopoma fimbria*) and other rockfish (*Sebastes* spp.). The incidental catch of shortspine thornyhead rockfish in these fisheries has been sufficient to capture a substantial portion of the thornyhead quota established in recent years, so directed fishing on shortspine thornyhead rockfish exclusively is not permitted. Although the thornyhead fishery is conducted operationally as a "bycatch" fishery, the high value and desirability of shortspine thornyhead rockfish means they are still considered a "target" species for the purposes of management.

D.18.3 Relevant Trophic Information

Shortspine thornyhead rockfish prey mainly on epibenthic shrimp and fish. Yang (1993, 1996) showed that shrimp were the top prey item for shortspine thornyhead rockfish in the GOA, whereas, cottids were the most important prey item in the Aleutian Islands region. Differences in abundance of the main prey between the two areas might be the main reason for the observed diet differences. Shortspine thornyhead rockfish are consumed by a variety of piscivores, including arrowtooth flounder, sablefish, "toothed whales" (sperm whales), and sharks. Juvenile shortspine thornyhead rockfish are thought to be consumed almost exclusively by adult thornyhead rockfish.

D.18.4 Habitat and Biological Associations

Egg/Spawning: Eggs float in masses of various sizes and shapes. Frequently the masses are bilobed with the lobes 15 cm to 61 cm in length, consisting of hollow conical sheaths containing a single layer of eggs in a gelatinous matrix. The masses are transparent and not readily observed in the daylight. Eggs are 1.2 to 1.4 mm in diameter with a 0.2 mm oil globule. They move freely in the matrix. Complete hatching time is unknown but is probably more than 10 days.

Larvae: Three-day-old larvae are about 3 mm long and apparently float to the surface.

Juveniles: Juvenile shortspine thornyhead rockfish have an extended pelagic period of about 14 to 15 months and settle out at about 22 to 27 mm into relatively shallow benthic habitats between 100 and 600 m and then migrate deeper as they grow

Adults: Adults are demersal and can be found at depths ranging from about 90 to 1,500 m. Once in benthic habitats thornyhead rockfish associate with muddy substrates, sometimes near rocks or gravel, and distribute themselves evenly across this habitat, appearing to prefer minimal interactions with individuals of the same species. They have very sedentary habits and are most often observed resting on the bottom in small depressions. Groundfish species commonly associated with thornyhead rockfish include: arrowtooth flounder (*Atheresthes stomias*), Pacific ocean perch (*Sebastes alutus*), sablefish (*Anoplopoma fimbria*), rex sole (*Glyptocephalus zachirus*), Dover sole (*Microstomus pacificus*), shortraker rockfish (*Sebastes borealis*), roughey rockfish (*Sebastes aleutianus*), and grenadiers (family *Macrouridae*).

Habitat and Biological Associations: Thornyhead Rockfish

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	U	U	spawning: late winter and early spring	U	P	U	U	
Larvae	<15 months	U	early spring through summer	U	P	U	U	
Juveniles	> 15 months when settling to bottom occurs (?)	U shrimp, amphipods, mysids, euphausiids?	U	MCS, OCS, USP	D	M, S, R, SM, CB, MS, G	U	
Adults	U	shrimp, fish (cottids), small crabs		MCS, OCS, USP, LSP	D	M, S, R, SM, CB, MS, G	year-round?	

D.18.5 Literature

- Allen, M.J., and G.B. Smith. 1988. Atlas and zoogeography of common fishes in the BS and Northeastern Pacific. U.S. Dep. Commer., NOAA Tech. Rept. NMFS 66, 151 p.
- Aton, M. 1981. GOA bottomfish and shellfish resources. U.S. Dep. Commer. Tech. Memo. NMFS F/NWC-10, 51 p.
- Aydin, K., S. Gaichas, I. Ortiz, D. Kinzey, and N. Friday. *In press*. A comparison of the Bering Sea, Gulf of Alaska, and Aleutian Islands large marine ecosystems through food web modeling. NOAA Tech Memo.
- Archibald, C.P., W. Shaw, and B.M. Leaman. 1981. Growth and mortality estimates of rockfishes (Scorpaenidae) from B.C. coastal waters, 1977-79. Can. Tech. Rep. Fish. Aquat. Sci. 1048, 57 p.

- Cailliet, G.M., A.H. Andrews, E.J. Burton, D.L. Watters, D.E. Kline, and L.A. Ferry-Grahan. 2001. Age determination and validation studies of marine fishes; do deep-dwellers live longer? *Experimental Gerontology* 36: 739-764.
- Chilton, D.E., and R.J. Beamish. 1982. Age determination methods for fishes studied by the Groundfish Program at the Pacific Biological Station. *Can. Spec. Publ. Fish. Aquat. Sci.* 60, 102 p.
- Cooper, D.W., K.E. Pearson, and D.R. Gunderson. 2005. Fecundity of shortspine thornyhead (*Sebastolobus alascanus*) and longspine thornyhead (*S. altivelis*) (Scorpaenidae) from the northeastern Pacific Ocean, determined by stereological and gravimetric techniques. *Fish Bull* 103: 15-22.
- Gunderson, D.R. 1997. Trade-off between reproductive effort and adult survival in oviparous and viviparous fishes. *Canadian Journal of Fisheries and Aquatic Science* 54: 990-998.
- Heifetz, J., J.N. Ianelli, and D.M. Clausen. 1996. Slope rockfish. In *Stock assessment and fishery evaluation report for the groundfish resources of the GOA*, p. 230-270. Council, 605 West 4th Avenue, Suite 306, Anchorage, AK 99501.
- Ianelli, J.N., D.H. Ito, and M. Martin. 1996. Thornyheads (*Sebastolobus* sp.). In *Stock Assessment and fishery evaluation report for the groundfish resources of the GOA*, p. 303-330. Council, 605 West 4th Avenue, Suite 306, Anchorage, AK 99501.
- Jacobson, L.D. 1993. Thornyheads. In *Status of living marine resources off the Pacific coast of the United States for 1993*. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-26, 35-37 p.
- Kastelle, C.R., D.K. Kimura, and S.R. Jay. 2000. Using ²¹⁰Pb/²²⁶Ra disequilibrium to validate conventional ages in Scorpaenids (genera *Sebastes* and *Sebastolobus*). *Fisheries Research* 46: 299-312.
- Kline, D.E. 1996. Radiochemical age verification for two deep-sea rockfishes *Sebastolobus altivelis* and *S. alascanus*. M.S. Thesis, San Jose State University, San Jose CA, 124 pp.
- Kramer, D.E., and V.M. O'Connell. 1986. Guide to northeast Pacific rockfishes, Genera *Sebastes* and *Sebastolobus*. Marine Advisory Bulletin No. 25: 1-78. Alaska Sea Grant College Program, University of Alaska.
- Low, L.L. 1994. Thornyheads. In *Status of living marine resources off Alaska, 1993*. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-27, 56-57 p.
- Love, M.S., M. Yoklavich, and L. Thorsteinson. 2002. The rockfishes of the northeast Pacific. University of California Press, Berkeley CA, 405 p.
- Love, M.S., C.W. Mecklenberg, T.A. Mecklenberg, and L.K. Thorsteinson. 2005. Resource inventory of marine and estuarine fishes of the West Coast and Alaska: a checklist of north Pacific and Arctic Ocean species from Baja California to the Alaska-Yukon Border. U.S. Department of the Interior, U.S. Geological Survey, Biological Resources Division, Seattle, Washington, 98104, OCS Study MMS 2005-030 and USGS/NBII 2005-001.
- Miller, P. P. 1985. Life history study of the shortspine thornyhead, *Sebastolobus alascanus*, at Cape Ommaney, south-eastern Alaska. M.S. Thesis, Univ. Alaska, Fairbanks, AK, 61 p.
- Sigler, M.F., and H.H. Zenger, Jr. 1994. Relative abundance of GOA sablefish and other groundfish based on the domestic longline survey, 1989. NOAA Tech. Memo. NMFS-AFSC-40.
- Pearson, K.E., and D.R. Gunderson, 2003. Reproductive biology and ecology of shortspine thornyhead rockfish (*Sebastolobus alascanus*) and longspine thornyhead rockfish (*S. altivelis*) from the northeastern Pacific Ocean. *Environ. Biol. Fishes* 67:11-136.
- Wolotira, R.J., Jr., T.M. Sample, S.F. Noel, and C.R. Iten. 1993. Geographic and bathymetric distributions for many commercially important fishes and shellfishes off the west coast of North America, based on research survey and commercial catch data, 1912-84. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-6, 184 p.
- Yang, M-S. 1993. Food habits of the commercially important groundfishes in the GOA in 1990. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-22, 150 p.
- Yang, M-S. 1996. Diets of the important groundfishes in the AI in summer 1991. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-60, 105 p.

D.19 Atka mackerel (*Pleurogrammus monopterygius*)

D.19.1 Life History and General Distribution

Atka mackerel are distributed from the GOA to the Kamchatka Peninsula, and they are most abundant along the Aleutian Islands. Adult Atka mackerel occur in large localized aggregations usually at depths less than 200 m and generally over rough, rocky, and uneven bottom near areas where tidal currents are swift. Associations with corals and sponges have been observed for Aleutian Islands Atka mackerel. Adults are semi-demersal, displaying strong diel behavior with vertical movements away from the bottom occurring almost exclusively during the daylight hours, presumably for feeding, and little to no movement at night. Spawning is demersal in moderately shallow waters (down to bottom depths of 144 m) and peaks in June through September, but may occur intermittently throughout the year. Female Atka mackerel deposit eggs in nests built and guarded by males on rocky substrates or on kelp in shallow water. Eggs develop and hatch at depth in 40 to 45 days, releasing planktonic larvae that have been found up to 800 km from shore. Little is known of the distribution of young Atka mackerel before their appearance in trawl surveys and the fishery at about age 2 to 3 years. R-traits are as follows: young age at maturity (approximately 50 percent are mature at age 3.6), fast growth rates, high natural mortality (mortality equals 0.3), and young average and maximum ages (about 5 and 14 years, respectively). K-selected traits indicate low fecundity (only about 30,000 eggs/female/year, large egg diameters [1 to 2 mm] and male nest-guarding behavior).

The approximate upper size limit of juvenile fish is estimated at 35 cm.

D.19.2 Fishery

The directed fishery is conducted with bottom trawls in the Aleutian Islands, at depths between about 70 and 300 m, in trawlable areas on rocky, uneven bottom, along edges, and in the lee of submerged hills during periods of high current. The fishery generally catches fish ages 3 to 11 years old. Currently, the fishery occurs on reefs west of Kiska Island, south and west of Amchitka Island, in Tanaga Pass and near the Delarof Islands, and south of Seguam and Umnak Islands. Historically the fishery occurred east into the GOA as far as Kodiak Island (through the mid 1980s), but is no longer conducted there. Directed fishing for Atka mackerel in the GOA is prohibited by Steller sea lion protection measures. Atka mackerel are taken as bycatch in the Shumagin (610) and Kodiak (620) areas in the rockfish fisheries

D.19.3 Relevant Trophic Information

Atka mackerel are important food for Steller sea lions in the Aleutian Islands, particularly during summer, and for other marine mammals (minke whales, Dall's porpoise, and northern fur seals). Juveniles are eaten by thick billed murres, tufted puffins, and short-tailed shearwaters. The main groundfish predators are Pacific halibut, arrowtooth flounder, and Pacific cod. Adult Atka mackerel consume a variety of prey, but principally calanoid copepods and euphausiids. Predation on Atka mackerel eggs by cottids and other hexagrammids is prevalent during the spawning season as is cannibalism by other Atka mackerel.

D.19.4 Habitat and Biological Associations

Egg/Spawning: Adhesive eggs are deposited in nests built and guarded by males on rocky substrates or on kelp in moderately shallow water.

Larvae/Juveniles: Planktonic larvae have been found up to 800 km from shore, usually in the upper water column (neuston), but little is known of the distribution of Atka mackerel until they are about 2 years old and start to appear in the fishery and surveys.

Adults: Adults occur in localized aggregations usually at depths less than 200 m and generally over rough, rocky, and uneven bottom near areas where tidal currents are swift. Associations with corals and sponges

have been observed for Aleutian Islands Atka mackerel. Adults are semi-demersal/pelagic during much of the year, but the males become demersal during spawning; females move between nesting and offshore feeding areas.

Habitat and Biological Associations: Atka mackerel

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	40 to 45 days	NA	summer	IP, ICS	D	GR, R, K	U	develop 3–20 °C; optimum 9–13 °C
Larvae	up to 6 mos	U copepods?	fall–winter	U	U N?	U	U	2–12 °C; optimum 5–7 °C
Juveniles	½ to 2 years of age	U copepods & euphausiids?	all year	U	U	U	U	3–5 °C
Adults	3+ years of age	Copepods, euphausiids, meso-pelagic fish (myctophids)	spawning (May–Oct) non-spawning (Nov–Apr) tidal/diurnal, year-round?	ICS and MCS, IP MCS and OCS, IP ICS, MCS, OCS, I	P, D (males) semidemersal (females) semidemersal / D (all sexes): D when currents high/day, semidemersal slack tides/night	GR, R, K	F, E	3–5 °C all stages >17 ppt only

D.19.5 Literature

- Allen, M.J., and G.B. Smith. 1988. Atlas and zoogeography of common fishes in the BS and Northeastern Pacific. U.S. Dep. Commerce., NOAA Tech. Rept. NMFS 66, 151 p.
- Bailey, K.M., J.F. Piatt, T.C. Royer, S.A. Macklin, R.K. Reed, M. Shima, R.C. Francis, A.B. Hollowed, D.A. Somerton, R.D. Brodeur, W.J. Ingraham, P.J. Anderson, and W.S. Wooster. 1995. ENSO events in the northern Gulf of Alaska, and effects on selected marine fisheries. Calif. Coop. Oceanic Fish. Invest. Rep. 36:78-96.
- Boldt, J.L. (Ed). 2005. Ecosystem indicators for the North Pacific and their implications for stock assessment: Proceedings of first annual meeting of NOAA's Ecological Indicators research program. AFSC Processed Rep.2005-04, Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115.
- Byrd, G.V., J.C. Williams, and R. Walder. 1992. Status and biology of the tufted puffin in the AI, Alaska, after a ban on salmon driftnets. U.S. Fish and Wildlife Service, Alaska Maritime National Wildlife Refuge, AI Unit, PSC 486, Box 5251, FPO AP 96506_5251, Adak, Alaska.
- Coon, C. 2007a. Groundfish bottom trawl fishing effort in the Gulf of Alaska, Bering Sea and Aleutian Islands. In J.L. Boldt (Ed.) Ecosystem Considerations for 2008. September 2007 DRAFT Appendix C of the BSAI\GOA Stock Assessment and Fishery Evaluation Reports. North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage, AK 99501.
- Coon, C. 2007b. Pot fishing effort in the Gulf of Alaska, Bering Sea, and Aleutian Islands. In J.L. Boldt (Ed.) Ecosystem Considerations for 2008. September 2007 DRAFT Appendix C of the BSAI\GOA Stock Assessment and Fishery Evaluation Reports. North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage, AK 99501.
- Coon, C. 2007c. Hook and Line (Longline) fishing effort in the Gulf of Alaska, Bering, Sea and Aleutian Islands. In J.L. Boldt (Ed.) Ecosystem Considerations for 2008. September 2007 DRAFT Appendix C of the

- BSAI\GOA Stock Assessment and Fishery Evaluation Reports. North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage, AK 99501.
- Doyle, M.J., W.C. Rugen, and R.D. Brodeur. 1995. Neustonic ichthyoplankton in the western GOA during spring. *Fishery Bulletin* 93: 231-253.
- Francis, R.C., and S.R. Hare. 1994. Decadal scale regime shifts in the large marine ecosystems of the northeast Pacific: A case for historical science. *Fish. Oceanogr.* 3(1):279-291.
- Fritz, L.W. 1993. Trawl locations of walleye pollock and Atka mackerel fisheries in the BS, AI, and GOA from 1977-1992. AFSC Processed Report 93-08, NMFS, 7600 Sand Point Way, NE, Seattle, WA 98115. 162 pp.
- Fritz, L.W., and S.A. Lowe. 1998. Seasonal distributions of Atka mackerel (*Pleurogrammus monopterygius*) in commercially-fished areas of the Aleutian Islands and Gulf of Alaska. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-92, 29 p.
- Gorbunova, N.N. 1962. Razmnozhenie i razvitiye ryb semeistva terpugovykh (Hexagrammidae) (Spawning and development of greenlings (family Hexagrammidae). Tr. Inst. Okeanol., Akad. Nauk SSSR 59:118-182. In Russian. (Trans. by Isr. Program Sci. Trans., 1970, p. 121-185 in T.S. Rass (editor), Greenlings: taxonomy, biology, interoceanic transplantation; available from the U.S. Dep. Commer., Natl. Tech. Inf. Serv., Springfield, VA., as TT 69_55097).
- Hare, S.R., and N.J. Mantua. 2000. Empirical evidence for North Pacific regime shifts in 1977 and 1989. *Prog. Oceanogr.* 47:103-145.
- Hollowed, A.B., S.R. Hare, and W.S. Wooster. 2001. Pacific Basin climate variability and patterns of Northeast Pacific marine fish production. *Prog. Oceanogr.* 49:257-282.
- Kajimura, H. 1984. Opportunistic feeding of the northern fur seal *Callorhinus ursinus*, in the eastern north Pacific Ocean and eastern Bering Sea. NOAA Tech. Rept. NMFS SSRF-779. USDOC, NOAA, NMFS, 49 pp.
- Kendall, A.W., and J.R. Dunn. 1985. Ichthyoplankton of the continental shelf near Kodiak Island, Alaska. U.S. Department of Commerce, NOAA Technical Report NMFS 20, 89 p.
- Kendall, A.W., Jr., J.R. Dunn, and R.J. Wolotira, Jr. 1980. Zooplankton, including ichthyoplankton and decapod larvae, of the Kodiak shelf. NWAFC Processed Rept. 80-8, AFSC-NMFS, 7600 Sand Point Way, NE, Seattle, WA 98115. 393 p.
- Lauth, R.R., and D. M. Blood. *In press*. Embryonic development and incubation period of Atka mackerel (*Pleurogrammus monopterygius*). Oct 2007 US Fish. Bull.
- Lauth, R.R., J. Guthridge, D. Nichol, S. W. McEntire, and N. Hillgruber. *In press*. Timing of mating and brooding periods of Atka mackerel (*Pleurogrammus monopterygius*) in the North Pacific Ocean. Oct 2007 US Fish. Bull.
- Lauth, R. R., S. W. McEntire, and H. H. Zenger. 2007. Geographic distribution, depth range, and description of Atka mackerel (*Pleurogrammus monopterygius*) nesting habitat in Alaska. *Alaska Fish. Res. Bull.* 12:164-185.
- Lee, J.U. 1985. Studies on the fishery biology of the Atka mackerel *Pleurogrammus monopterygius* (Pallas) in the north Pacific Ocean. *Bull. Fish. Res. Dev. Agency*, 34, pp.65-125.
- Levada, T.P. 1979. Comparative morphological study of Atka mackerel. Pac. Sci. Res. Inst. Fish. Oceanogr. (TINRO), Vladivostok, U.S.S.R., Unpublished manuscript.
- Lowe, S.A., and L.W. Fritz. 1996. Atka mackerel. *In* Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the BSAI Regions as Projected for 1997. Council, 605 West 4th Avenue, Suite 306, Anchorage, AK 99501.
- Malecha, P.W., R.P. Stone, and J. Heifetz. 2005. Living substrate in Alaska: Distribution, abundance, and species associations. Pages 289-299 *in* P.W. Barnes and J.P. Thomas, editors. Benthic habitats and the effects of fishing. American Fisheries Society, Symposium 41, Bethesda, Maryland.

- Martin, M. 2005. Gulf of Alaska Survey Bottom Temperature Analysis. In J.L. Boldt (Ed.) Ecosystem Considerations for 2006. Appendix C of the BSAI\GOA Stock Assessment and Fishery Evaluation Reports. North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage, AK 99501.
- McDermott, S.F., and S.A. Lowe. 1997. The reproductive cycle and sexual maturity of Atka mackerel (*Pleurogrammus monopterygius*) in Alaskan waters. Fishery Bulletin 95: 321-333.
- McDermott, S.F., K.E. Pearson and D.R. Gunderson. 2007. Annual fecundity, batch fecundity, and oocyte atresia of Atka mackerel (*Pleurogrammus monopterygius*) in Alaskan waters. Fish Bull. 105:19-29.
- Merrick, R.L., M.K. Chumbley, and G.V. Byrd. 1997. Diet diversity of Steller sea lions (*Eumetopias jubatus*) and their population decline in Alaska: a potential relationship. Can. J. Fish. Aquat. Sci. 54:1342-1348.
- Morris, B.F. 1981. An assessment of the living marine resources of the central BS and potential resource use conflicts between commercial fisheries and Petroleum development in the Navarin Basin, Proposed sale No. 83. Anchorage, AK: USDOC, NOAA, NMFS, Environmental Assessment Division.
- Musienko, L.N. 1970. Razmnozheine i razvitie ryb Beringova morya (Reproduction and development of BS fishes). Tr. Vses. Nauchno-issled. Inst. Morsk. Rybn. Koz. Okeanogr. 70: 161-224 In P.A. Moiseev (ed.), Soviet fisheries investigations in the northeastern Pacific, Pt. 5, Avail. Natl. Tech. Info. Serv., Springfield, VA as TT 74-50127.
- Nichol, D.G., and D.A. Somerton. 2002. Diurnal vertical migration of the Atka mackerel *Pleurogrammus monopterygius* as shown by archival tags. Mar Ecol Prog Ser 239: 193-207.
- NMFS. 1995. Status review of the United States Steller sea lion (*Eumetopias jubatus*) population. National Marine Mammal Laboratory, Alaska Fishery Science Center, NMFS, 7600 Sand Point Way, NE, Seattle, WA 98115.
- National Marine Fisheries Service (NMFS). 2004. Website: Resources Assessment and Conservation Engineering Field Videos—Underwater Habitat Footage, Alaska Fisheries Science Center. http://www.afsc.noaa.gov/race/media/videos/vids_habitat.htm.
- Orlov, A.M. 1996. The role of mesopelagic fishes in feeding of Atka mackerel in areas of the North Kuril islands. Publ. Abstract in Role of forage fishes in marine ecosystems. Symposium held Nov 1996, AK Sea Grant, U. Alaska, Fairbanks.
- Rugen, W.C. 1990. Spatial and temporal distribution of larval fish in the western GOA, with emphasis on the period of peak abundance of walleye pollock (*Theragra chalcogramma*) larvae. NWAFC Processed Rept 90-01, AFSC-NMFS, 7600 Sand Point Way, NE, Seattle, WA 98115. 162 p.
- Sinclair E.H., and T.K. Zeppelin. 2002. Seasonal and spatial differences in diet in the western stock of Steller sea lions (*Eumetopias jubatus*). Journal of Mammalogy 83(4).
- Sinclair, E., J.W. Testa, and L. Fritz. 2006. Marine Mammals. In J.L. Boldt (Ed.) Ecosystem Considerations for 2007. Appendix C of the BSAI\GOA Stock Assessment and Fishery Evaluation Reports. North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage, AK 99501.
- Springer, A.M., J.F. Piatt, V.P. Shuntov, G.B. Van Vliet, V.L. Vladimirov, A.E. Kuzin, and A.S. Perlov. 1999. Marine birds and mammals of the Pacific subarctic gyres. Prog. Oceanogr. 43:443-487.
- Stone, R.P. 2006. Coral habitat in the Aleutian Islands of Alaska: depth distribution, fine-scale species associations, and fisheries interactions. Coral Reefs 25:229-238.
- Waldron, K.D. 1978. Ichthyoplankton of the EBS, 11 February-16 March 1978. REFM Report, AFSC, NMFS, 7600 Sand Point Way, NE, Seattle, WA 98115. 33 p.
- Waldron, K.D., and B.M. Vinter. 1978. Ichthyoplankton of the EBS. Final Report (RU 380), Environmental Assessment of the Alaskan continental shelf, REFM, AFSC, NMFS, 7600 Sand Point Way, NE, Seattle, WA 98115. 88 p.
- Wolotira, R.J., Jr., T.M. Sample, S.F. Noel, and C.R. Iten. 1993. Geographic and bathymetric distributions for many commercially important fishes and shellfishes off the west coast of North America, based on research

- survey and commercial catch data, 1912-84. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-6, 184 p.
- Winship, A.J., and A.W. Trites. 2003. Prey consumption of Steller sea lions (*Eumetopias jubatus*) off Alaska: How much prey do they require? Fish. Bull. 101:147-167.
- Yang, M. S. 1993. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990. NOAA Technical Memorandum, NMFS-AFSC-22, U.S. Department of Commerce, NOAA. p. 150.
- Yang, M-S. 1996. Diets of the important groundfishes in the Aleutian Islands in summer 1991. NOAA Technical Memorandum, NMFS-AFSC-60, U.S. Department of Commerce, NOAA. p. 105.
- Yang, M-S. 1999. The trophic role of Atka mackerel, *Pleurogrammus monopterygius*, in the Aleutian Islands area. Fishery Bulletin 97(4):1047-1057.
- Yang, M-S. 2003. Food habits of the important groundfishes in the Aleutian Islands in 1994 and 1997. AFSC Processed Rep.2003-07, Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115. p. 233.
- Yang, M-S., K. Dodd, R. Hibpshman, and A. Whitehouse. 2006. Food habits of groundfishes in the Gulf of Alaska in 1999 and 2001. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-164, 199 p.
- Yang, M-S., and M.W. Nelson. 2000. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990, 1993, and 1996. NOAA Technical Memorandum, NMFS-AFSC-112, U.S. Department of Commerce, NOAA. p. 174.
- Zolotov, O.G. 1993. Notes on the reproductive biology of *Pleurogrammus monopterygius* in Kamchatkan waters. J. of Ichthy. 33(4), pp. 25-37.

D.20 Skates (*Rajidae*)

The species representatives for skates are:

- Alaska skate (*Bathyraja parmifera*)
- Aleutian skate (*Bathyraja aleutica*)
- Bering skate (*Bathyraja interrupta*)

D.20.1 Life History and General Distribution:

Skates (*Rajidae*) that occur in the BSAI and GOA are grouped into two genera: *Bathyraja* sp., or soft-nosed species (rostral cartilage slender and snout soft and flexible), and *Raja* sp., or hard-nosed species (rostral cartilage is thick making the snout rigid). Skates are oviparous; fertilization is internal, and eggs (one to five or more in each case) are deposited in horny cases for incubation. Adults and juveniles are demersal and feed on bottom invertebrates and fish. Big skates (*Raja binoculata*) and longnose skates (*Raja rhina*) are the most abundant skates in the GOA. Most of the biomass for these two species is located in the Central GOA (NMFS statistical areas 620 and 630). Depth distributions from surveys show that big skates are found primarily from 0 to 100 m; longnose skates are found primarily from 100 to 200 m, although they are found at all depths shallower than 300 m. Below 200 m depth, *Bathyraja* sp. skates are dominant. Little is known of their habitat requirements for growth or reproduction, nor of any seasonal movements. BSAI skate biomass estimate more than doubled between 1982 and 1996 from bottom trawl surveys; it may have decreased in the GOA and remained stable in the Aleutian Islands in the 1980s.

Approximate upper size limit of juvenile fish is unknown.

D.20.2 Fishery

Until 2003, skates were not a target of groundfish fisheries of BSAI or GOA, but were caught as bycatch (13,000 to 17,000 mt per year in the BSAI from 1992 to 1995; 1,000 to 2,000 mt per year in the GOA) principally by the longline Pacific cod and bottom trawl pollock and flatfish fisheries; almost all were discarded. Skate bycatches in the eastern Bering Sea groundfisheries ranged between 1 and 4 percent of the annual eastern Bering Sea trawl survey biomass estimates from 1992 to 1995.

Starting in 2003, a directed fishery for skates developed in the GOA centered around Kodiak Island. It is prosecuted primarily on longline vessels less than 60 feet long, with some additional targeting by trawlers using large mesh nets. The primary target species appeared to be *R. binoculata*, followed by *R. rhina*, but this is difficult to determine given that there is almost no observer coverage of the fishery. Directed fishing for skates has been prohibited in the GOA since 2005. There continues to be substantial incidental catch; the official 2008 estimate for all skates gulfwide was 2,351 mt. There is also undocumented catch in the individual fishing quota halibut fisheries.

D.20.3 Relevant Trophic Information

Skates feed on bottom invertebrates (crustaceans, molluscs, and polychaetes) and fish.

D.20.4 Habitat and Biological Associations

Egg/Spawning: Skates deposit eggs in horny cases on shelf and slope.

Juveniles and Adults: After hatching, juveniles probably remain in shelf and slope waters, but distribution is unknown. Adults found across wide areas of shelf and slope; surveys found most skates at depths less than 500 m in the GOA and eastern Bering Sea, but greater than 500 m in the Aleutian Islands. In the GOA, most skates found between 4 and 7 °C, but data are limited.

Habitat and Biological Associations: Skates

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	U	NA	U	MCS, OCS, USP	D	U	U	
Larvae	NA	NA	NA	NA	NA	NA	NA	
Juveniles	U	invertebrates, small fish	all year	MCS, OCS, USP	D	U	U	
Adults	U	invertebrates, small fish	all year	MCS, OCS, USP	D	U	U	

D.20.5 Literature

- Allen, M.J., and G.B. Smith. 1988. Atlas and zoogeography of common fishes in the BS and Northeastern Pacific. U.S. Dep. Commerce., NOAA Tech. Rept. NMFS 66, 151 p.
- Eschmyer, W.N., and E.S. Herald. 1983. A field guide to Pacific coast fishes, North America. Houghton Mifflin Co., Boston. 336 p.
- Fritz, L.W. 1996. Other species *In* Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the BSAI Regions as Projected for 1997. Council, 605 West 4th Avenue, Suite 306, Anchorage, AK 99501.
- Hart, J.L. 1973. Pacific fishes of Canada. Fisheries Res. Bd. Canada Bull. 180. Ottawa. 740 p.

Ormseth, O.A. and B. Matta. 2009. Gulf of Alaska Skates. In: Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska Region. North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage, AK 99501.

Teshima, K., and T.K. Wilderbuer. 1990. Distribution and abundance of skates in the EBS, AI region, and the GOA. Pp. 257-267 in H.L. Pratt, Jr., S.H. Gruber, and T. Taniuchi (eds.), *Elasmobranchs as living resources: advances in the biology, ecology, systematics and the status of the fisheries*. U.S. Dep. Commerce., NOAA Technical Report 90.

D.21 Squids (*Cephalopoda*, *Teuthida*)

The species representatives for squids are:

Gonaditae:	red or magistrate armhook squid (<i>Berryteuthis magister</i>)
Onychoteuthidae:	boreal clubhook squid (<i>Onychoteuthis banksii borealjaponicus</i>) giant or robust clubhook squid (<i>Moroteuthis robusta</i>)
Sepiolidae:	eastern Pacific bobtail squid (<i>Rossia pacifica</i>)

D.21.1 Life History and General Distribution:

Squids are members of the molluscan class *Cephalopoda*, along with octopus, cuttlefish, and nautiloids. In the BSAI and GOA, gonatid and onychoteuthid squids are generally the most common, along with chiroteuthids. All cephalopods are stenohaline, occurring only at salinities less than 30 ppt. Fertilization is internal, and development is direct ("larval" stages are only small versions of adults). The eggs of inshore neritic species are often enveloped in a gelatinous matrix attached to rocks, shells, or other hard substrates, while the eggs of some offshore oceanic species are extruded as large, sausage-shaped drifting masses. Little is known of the seasonality of reproduction, but most species probably breed in spring through early summer, with eggs hatching during the summer. Most small squid are generally thought to live only 2 to 3 years, but the giant *Moroteuthis robusta* clearly lives longer.

B. magister is widely distributed in the boreal north Pacific from California, throughout the Bering Sea, to Japan in waters 30 to 1,500 m deep; adults are most often found at mesopelagic depths or near the bottom on the shelf, rising to the surface at night; juveniles are widely distributed across shelf, slope, and abyssal waters in mesopelagic and epipelagic zones, and they rise to the surface at night. Juveniles and adults migrate seasonally, moving northward and inshore in summer, and southward and offshore in winter, particularly in the western north Pacific. The approximate upper size limit of juvenile fish is 20 cm mantle length (ML) for males and 25 cm ML for females; both are at approximately 1 year of age. Maximum size for females is 50 cm ML; for males, maximum size is 40 cm ML. Spermatophores are transferred into the mantle cavity of the female, and eggs are laid on the bottom on the upper slope (200 to 800 m). Fecundity is estimated at 10,000 eggs per female. Spawning of eggs occurs from February to March in Japan, but apparently year-round in the Bering Sea. Eggs hatch after 1 to 2 months of incubation; development is direct. Adults are gregarious prior to and most die after mating.

O. banksii borealjaponicus, an active, epipelagic species, is distributed in the north Pacific from the Sea of Japan, throughout the Aleutian Islands and south to California, but is absent from the Sea of Okhotsk and is not common in the Bering Sea. Juveniles can be found over shelf waters at all depths and near shore. Adults apparently prefer the upper layers over slope and abyssal waters; they are diel migrators and gregarious. Development includes a larval stage; maximum size is about 55 cm.

M. robusta, a giant squid, lives near the bottom on the continental slope and mesopelagically over abyssal waters; it is rare on the shelf. It is distributed in all oceans and is found in the Bering Sea, Aleutian Islands, and GOA. Mantle length can be up to 2.5 m long (at least 7 m with tentacles), but most are about 2 m long.

R. pacifica is a small (maximum length with tentacles of less than 20 cm) demersal, neritic and shelf, boreal species, distributed from Japan to California in the North Pacific and in the Bering Sea in waters of about 20 to 300 m depth. Less is known about *R. pacifica*, but other *Rossia* spp. deposit demersal egg masses.

D.21.2 Fishery

Squids are not currently a target of groundfish fisheries of the BSAI or GOA. A Japanese fishery catching up to 9,000 mt of squid annually existed until the early 1980s for *B. magister* in the Bering Sea and *O. banksii borealjaponicus* in the Aleutian Islands. Since 1990, annual squid bycatch has been about 1,000 mt or less in the BSAI and between 30 to 150 mt in the GOA; in the BSAI, almost all squid bycatch is in the midwater pollock fishery near the continental shelf break and slope, while in the GOA, trawl fisheries for rockfish and pollock (again mostly near the edge of the shelf and on the upper slope) catch most of the squid bycatch.

D.21.3 Relevant Trophic Information

The principal prey items of squid are small forage fish pelagic crustaceans (e.g., euphausiids and shrimp) and other cephalopods; cannibalism is not uncommon. After hatching, small planktonic zooplankton (copepods) are eaten. Squid are preyed upon by marine mammals, seabirds, and, to a lesser extent by fish, and they occupy an important role in marine food webs worldwide. Perez (1990) estimated that squids comprise over 80 percent of the diets of sperm whales, bottlenose whales, and beaked whales and about half of the diet of Dall's porpoise in the eastern Bering Sea and Aleutian Islands. Seabirds (e.g., kittiwakes, puffins, murre) on island rookeries close to the shelf break (e.g., Buldir Island, Pribilof Islands) are also known to feed heavily on squid (Hatch et al. 1990, Byrd et al. 1992, Springer 1993). In the GOA, only about 5 percent or less of the diets of most groundfish consisted of squid (Yang 1993). However, squid play a larger role in the diet of salmon (Livingston and Goiney 1983).

D.21.4 Habitat and Biological Associations for *B. magister*

Egg/Spawning: Eggs are laid on the bottom on the upper slope (200 to 800 m); incubate for 1 to 2 months.

Young Juveniles: Distributed epipelagically (top 100 m) from the coast to open ocean.

Old Juveniles and Adults: Distributed mesopelagically (most from 150 to 500 m) on the shelf (possibly only in the summer), but mostly in outer shelf/slope waters (to lesser extent over the open ocean). They migrate to slope waters to mate and spawn demersally.

Habitat and Biological Associations: *Berryteuthis magister* (red squid)

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	1 to 2 months	NA	varies	USP, LSP	D	M, SM, MS	U	
Young juveniles	4 to 6 months	zooplankton	varies	all shelf, slope, BSN	P, N	NA	UP, F?	
Older Juveniles and Adults	1 to 2 years (may be up to 4 years)	euphausiids, shrimp, small forage fish, and other cephalopods	summer winter	all shelf, USP, LSP, BSN, OS, USP, LSP, BSN	semipelagic, P	UP, F?	U	euhaline waters, 2–4 °C

D.21.5 Literature

- Arkhipkin, A.I., V.A. Bizikov, V.V. Krylov, and K.N. Nesis. 1996. Distribution, stock structure, and growth of the squid *Berryteuthis magister* (Berry, 1913) (Cephalopoda, Gonatidae) during summer and fall in the western BS. Fish. Bull. 94: 1-30.
- Akimushkin, I.I. 1963. Cephalopods of the seas of the U.S.S.R. Academy of Sciences of the U.S.S.R., Institute of Oceanology, Moscow. Translated from Russian by Israel Program for Scientific Translations, Jerusalem 1965. 223 p.
- Byrd, G.V., J.C. Williams, and R. Walder. 1992. Status and biology of the tufted puffin in the AI, Alaska, after a ban on salmon driftnets. U.S. Fish and Wildlife Service, Alaska Maritime National Wildlife Refuge, AI Unit, PSC 486, Box 5251, FPO AP 96506-5251, Adak, Alaska.
- Fritz, L.W. 1996. Other species *In* Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the BSAI Regions as Projected for 1997. Council, 605 West 4th Avenue, Suite 306, Anchorage, AK.
- Hatch, S.A., G.V. Byrd, D.B. Irons, and G.L. Hunt, Jr. 1990. Status and ecology of kittiwakes in the North Pacific. Proc. Pacific Seabird Group Symposium, Victoria, B.C., 21-25 February 1990.
- Livingston, P.A., and B.J. Goiney, Jr. 1983. Food habits literature of North Pacific marine fishes: a review and selected bibliography. U.S. Dep. Commerce., NOAA Tech. Memo. NMFS F/NWC-54, 81 p.
- Nesis, K.N. 1987. Cephalopods of the world. TFH Publications, Neptune City, NJ, USA. 351 pp.
- Perez, M. 1990. Review of marine mammal population and prey information for BS ecosystem studies. U.S. Dep. Commerce., NOAA Tech. Memo. NMFS F/NWC-186, 81 p.
- Sobolevsky, Ye. I. 1996. Species composition and distribution of squids in the western BS. Pp. 135-141 *In* O.A. Mathisen and K.O. Coyle (eds.), Ecology of the BS: a review of Russian literature. Alaska Sea Grant Rept 96-01, U. Alaska, Fairbanks, AK 99775.
- Springer, A. 1993. Report of the seabird working group. pp. 14-29 *In* Is it food? Addressing marine mammal and seabird declines: a workshop summary. Alaska Sea Grant Report 93-01, Univ. Alaska, Fairbanks, AK, 99775.
- Yang, M.S. 1993. Food habits of the commercially important groundfishes in the GOA in 1990. U.S. Dep. Commerce., NOAA Tech. Memo. NMFS-AFSC-22, 150 p.

D.22 Sculpins (Cottidae)

The species representatives for sculpins are:

- Yellow Irish lord (*Hemilepidotus jordani*)
- Red Irish lord (*Hemilepidotus hemilepidotus*)

Butterfly sculpin (*Hemilepidotus papilio*)
Bigmouth sculpin (*Hemitripterus bolini*)
Great sculpin (*Myoxocephalus polyacanthocephalus*)
Plain sculpin (*Myoxocephalus jaok*)

D.22.1 Life History and General Distribution

Cottidae (sculpins) is a large circumboreal family of demersal fishes inhabiting a wide range of habitats in the north Pacific Ocean and Bering Sea. Most species live in shallow water or in tidepools, but some inhabit the deeper waters (to 1,000 m) of the continental shelf and slope. Most species do not attain a large size (generally 10 to 15 cm), but those that live on the continental shelf and are caught by fisheries can be 30 to 50 cm; the cabezon is the largest sculpin and can be as long as 100 cm. Most sculpins spawn in the winter. All species lay eggs, but in some genera, fertilization is internal. The female commonly lays demersal eggs amongst rocks where they are guarded by males. Egg incubation duration is unknown; larvae were found across broad areas of the shelf and slope all year-round in ichthyoplankton collections from the southeast Bering Sea and GOA. Larvae exhibit diel vertical migration (near surface at night and at depth during the day). Sculpins generally eat small invertebrates (e.g., crabs, barnacles, mussels), but fish are included in the diet of larger species; larvae eat copepods. The approximate upper size limit of juvenile fish is unknown.

Yellow Irish lords: They are distributed from subtidal areas near shore to the edge of the continental shelf (down to 200 m) throughout the Bering Sea, Aleutian Islands, and eastward into the GOA as far as Sitka, Alaska. They grow up to 40 cm in length. Twelve to 26 mm larvae have been collected in spring on the western GOA shelf.

Red Irish lords: They are distributed from rocky, intertidal areas to about 100 m depth on the middle continental shelf (most shallower than 50 m), from California (Monterey Bay) to Kamchatka and throughout the Bering Sea and GOA. They are rarely over 30 cm in length and spawn masses of pink eggs in shallow water or intertidally. Larvae were 7 to 20 mm long in spring in the western GOA.

Butterfly sculpins: They are distributed primarily in the western north Pacific and northern Bering Sea, from Hokkaido, Japan, Sea of Okhotsk, and Chukchi Sea, to the southeast Bering Sea and in the Aleutian Islands. They are found at depths of 20 to 250 m; most frequent 50 to 100 m.

Bigmouth sculpin: They are distributed in deeper waters offshore, between about 100 to 300 m in the Bering Sea and Aleutian Islands, and throughout the GOA. They are up to 70 cm in length.

Great sculpin: They are distributed from the intertidal area to 200 m, but may be most common on sand and muddy/sand bottoms in moderate depths (50 to 100 m). They are up to 80 cm in length. They are found throughout the Bering Sea, Aleutian Islands, and GOA, but may be less common east of Prince William Sound. *Myoxocephalus* spp. larvae ranged in length from 9 to 16 mm in spring ichthyoplankton collections in the western GOA.

Plain sculpin: They are distributed throughout the Bering Sea and GOA (not common in the Aleutian Islands) from intertidal areas to depths of about 100 m, but most common in shallow waters (less than 50 m). They are up to 50 cm in length. *Myoxocephalus* spp. larvae ranged in length from 9 to 16 mm in spring ichthyoplankton collections in the western GOA.

D.22.2 Fishery

Sculpins are not a target of groundfish fisheries of the GOA, but sculpin bycatch (which comprises 75 percent of the other species complex biomass) has ranged from 500 to 1,600 mt per year in the GOA. Bycatch occurs principally in bottom trawl fisheries for flatfish, Pacific cod, and rockfish, and in the Pacific cod pot fishery; in 2007 about 20 percent of sculpins were retained. Since 2006 sculpin bycatch

has increased due to the capture of large sculpins in the shallow water flatfish fishery (Reuter and TenBrink 2008). Bycatch of sculpin species is about 5 percent of total sculpin biomass in the GOA.

D.22.3 Relevant Trophic Information

Sculpins feed on bottom invertebrates (e.g., crabs, barnacles, mussels, and other molluscs); larger species eat fish.

D.22.4 Habitat and Biological Associations

Egg/Spawning: Lay demersal eggs in nests guarded by males; many species in rocky shallow waters near shore.

Larvae: Distributed pelagically and in neuston across broad areas of shelf and slope, but predominantly on inner and middle shelf; have been found year-round.

Juveniles and Adults: Sculpins are demersal fish and live in a broad range of habitats from rocky intertidal pools to muddy bottoms of the continental shelf and in rocky, upper slope areas. Most commercial bycatch occurs on middle and outer shelf areas used by bottom trawlers for Pacific cod and flatfish.

Habitat and Biological Associations: Sculpins

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	U	NA	winter?	BCH, ICS (MCS-OCS?)	D	R (others?)	U	
Larvae	U	copepods	all year?	ICS-MCS, OCS, US	N,P	NA?	U	
Juveniles and Adults	U	bottom invertebrates (crabs, molluscs, barnacles) and small fish	all year	BCH, ICS, MCS, OCS, USP	D	R, S, M, SM	U	

D.22.5 Literature

- Allen, M.J., and G.B. Smith. 1988. Atlas and zoogeography of common fishes in the BS and Northeastern Pacific. U.S. Dep. Commerce., NOAA Tech. Rept. NMFS 66, 151 p.
- Doyle, M.J., W.C. Rugen, and R.D. Brodeur. 1995. Neustonic ichthyoplankton in the western GOA during spring. Fishery Bulletin 93: 231-253.
- Eschmyer, W.N., and E.S. Herald. 1983. A field guide to Pacific coast fishes, North America. Houghton Mifflin Co., Boston. 336 p.
- Fritz, L.W. 1996. Other species *In* Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the BSAI Regions as Projected for 1997. Council, 605 West 4th Avenue, Suite 306, Anchorage, AK 99501.
- Hart, J.L. 1973. Pacific fishes of Canada. Fisheries Res. Bd. Canada Bull. 180. Ottawa. 740 p.
- Kendall, A.W., Jr., and J.R. Dunn. 1985. Ichthyoplankton of the continental shelf near Kodiak Island, Alaska. U.S. Dep. Commerce., NOAA Tech. Rept NMFS 20, 89 p.
- Kendall, A.W., Jr., J.R. Dunn, and R.J. Wolotira, Jr. 1980. Zooplankton, including ichthyoplankton and decapod larvae, of the Kodiak shelf. NWAFC Processed Rept. 80-8, AFSC-NMFS, 7600 Sand Point Way, NE, Seattle, WA 98115. 393 p.

- Reuter, R.F. and T. TenBrink. 2008. Assessment of Sculpin stocks in the Gulf of Alaska. *In* Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the GOA as Projected for 2009. North Pacific Fishery Management Council, Anchorage AK.
- Rugen, W.C. 1990. Spatial and temporal distribution of larval fish in the western GOA, with emphasis on the period of peak abundance of walleye pollock (*Theragra chalcogramma*) larvae. NWAFC Processed Rept 90-01, AFSC-NMFS, 7600 Sand Point Way, NE, Seattle, WA 98115. 162 p.
- Waldron, K.D. 1978. Ichthyoplankton of the EBS, 11 February-16 March 1978. REFM Report, AFSC, NMFS, 7600 Sand Point Way, NE, Seattle, WA 98115. 33 p.
- Waldron, K.D., and B.M. Vinter. 1978. Ichthyoplankton of the EBS. Final Report (RU 380), Environmental Assessment of the Alaskan continental shelf, REFM, AFSC, NMFS, 7600 Sand Point Way, NE, Seattle, WA 98115. 88 p.

D.23 Sharks

The species representatives for sharks are:

Lamnidae:	Salmon shark (<i>Lamna ditropis</i>)
Squalidae:	Sleeper shark (<i>Somniosus pacificus</i>)
	Spiny dogfish (<i>Squalus acanthias</i>)

D.23.1 Life History and General Distribution

Sharks of the order Squaliformes, which includes the two families Lamnidae and Squalidae, are the higher sharks with five gill slits and two dorsal fins. The Lamnidae are large, aplacental, viviparous (with small litters, one to four pups, and embryos nourished by yolk sac, oophagy, and/or intrauterine cannibalism), widely migrating sharks, which are highly aggressive predators (salmon and white sharks). The Lamnidae are partly warm-blooded; the heavy trunk muscles are warmer than water for greater power and efficiency. Salmon sharks are distributed epipelagically along the shelf (can be found in shallow waters) from California through the GOA (where they occur all year and are probably most abundant in Alaska waters), the Bering Sea, and off Japan. In groundfish fishery and survey data, they occur chiefly on outer shelf/upper slope areas in the Bering Sea, but near the coast to the outer shelf in the GOA, particularly near Kodiak Island. They are not commonly seen in the Aleutian Islands. They are believed to eat primarily fish, including salmon, sculpins, and gadids and can be up to 3 m in length.

The Pacific sleeper shark is distributed from California around the Pacific rim to Japan and in the Bering Sea principally on the outer shelf and upper slope (but has been observed nearshore). It is generally demersal (but also seen near surface). Other members of the Squalidae are aplacental viviparous, but fertilization and development of sleeper sharks are not known. Adults are up to 8 m in length. They are omnivorous predators of flatfish, cephalopods, rockfish, crabs, seals, and salmon; they may also prey on pinnipeds. In groundfish fishery and survey data, they occur chiefly on outer shelf/upper slope areas in the Bering Sea, but near coast to the outer shelf in the GOA, particularly near Kodiak Island.

Spiny dogfish are widely distributed through the Atlantic, Pacific, and Indian Oceans. In the north Pacific, they may be most abundant in the GOA, but also occur in the Bering Sea. They are pelagic species and are found at surface and to depths of 700 m; they are mostly found at 200 m or less on shelf and neritic; they are often found in aggregations. They are aplacental viviparous, with litter size proportional to the size of the female. Litter size ranges from 2 to 23 and averages 10. Gestation may be 22 to 24 months. Young are 24 to 30 cm at birth, with growth initially rapid, then it slows dramatically. Maximum adult size is about 1.6 m and 10 kg; maximum age is 80+ years. Fifty percent of females are mature at 97 cm and 35 years old; males are mature at 74 cm and 21 years old. Females give birth in shallow coastal waters, usually from September to January. Dogfish eat a wide variety of foods, including fish (smelts,

herring, sand lance, and other small schooling fish), crustaceans (crabs, euphausiids, shrimp), and cephalopods (octopus). Tagging experiments indicate local indigenous populations in some areas and widely migrating groups in others. They may move inshore in summer and offshore in winter.

The approximate upper size limit of juvenile fish is unknown for salmon sharks and sleeper sharks; for spiny dogfish, it is 94 cm for females, and 72cm for males.

D.23.2 Fishery

Sharks are not a target of groundfish fisheries of BSAI or GOA, but shark bycatch has ranged from 187 to 1,603 mt per year in the BSAI from 1997 to 2008; 409 to 1,603 mt per year in the GOA principally by pelagic trawl fishery for pollock, longline fisheries for Pacific cod and sablefish, and bottom trawl fisheries for pollock, flatfish, and cod; almost all are discarded. Little is known of shark biomass in BSAI or GOA.

D.23.3 Relevant Trophic Information

Sharks are top level predators in the GOA; the only likely predator would be larger fish preying on young/small sharks. Spiny dogfish tend to be opportunistic and generalist feeders (Tribuzio et al. 2008), feeding more on invertebrates (such as shrimp and hermit crabs) when young and having a more varied diet when older, including fish species (forage fish, rockfish, and some salmon). Salmon shark feed primarily on squid and larger fish species (e.g., pollock and salmon). Pacific sleeper shark diet is less well known; a study by Sigler et al. (2006) found squid to be a major component, but also found flesh from grey whale and harbor seal in the stomachs. However, results were inconclusive as to whether the prey was scavenged or hunted.

D.23.4 Habitat and Biological Associations

Egg/Spawning: Salmon sharks and spiny dogfish are aplacental viviparous; reproductive strategy of sleeper sharks is not known. Spiny dogfish give birth in shallow coastal waters, while salmon sharks probably give birth offshore and pelagic.

Juveniles and Adults: Spiny dogfish are widely dispersed throughout the water column on shelf in the GOA, and along outer shelf in the eastern Bering Sea; apparently they are not as commonly found in the Aleutian Islands and are not commonly found at depths greater than 200 m.

Salmon sharks are found throughout the GOA, but are less common in the eastern Bering Sea and Aleutian Islands; they are epipelagic and are found primarily over shelf/slope waters in the GOA and on the outer shelf in the eastern Bering Sea.

Sleeper sharks are widely dispersed on shelf/upper slope in the GOA and along the outer shelf/upper slope only in the eastern Bering Sea; they are generally demersal and may be less commonly found in the Aleutian Islands.

Habitat and Biological Associations: Sharks

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs and Larvae								
Juveniles and Adults:								
Salmon shark	U	fish (salmon, sculpins and gadids)	all year	ICS, MCS, OCS, US in GOA	P	NA	U	
Sleeper shark	U	omnivorous; flatfish, cephalopods, rockfish, crabs, seals, salmon, pinnipeds	all year	ICS, MCS, OCS, US in GOA	D	U	U	
Spiny dogfish	80+ years	fish (smelts, herring, sand lance, and other small schooling fish), crustaceans (crabs, euphausiids, shrimp), and cephalopods (octopus)	all year	ICS, MCS, OCS in GOA give birth ICS in fall/winter?	P	U	U	euhaline 4–16 °C

D.23.5 Literature

- Allen, M.J., and G.B. Smith. 1988. Atlas and zoogeography of common fishes in the BS and Northeastern Pacific. U.S. Dep. Commerce., NOAA Tech. Rept. NMFS 66, 151 p.
- Eschmeyer, W.N., and E.S. Herald. 1983. A field guide to Pacific coast fishes, North America. Houghton Mifflin Co., Boston. 336 p.
- Fritz, L.W. 1996. Other species *In* Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the BSAI Regions as Projected for 1997. Council, 605 West 4th Avenue, Suite 306, Anchorage, AK 99501.
- Hart, J.L. 1973. Pacific fishes of Canada. Fisheries Res. Bd. Canada Bull. 180. Ottawa. 740 p.
- Sigler M.F., L. Hulbert, C. R. Lunsford, N. Thompson, K. Burek, G. Corry-Crowe, and A. Hirons. 2006. Diet of Pacific sleeper shark, a potential Steller sea lion predator, in the north-east Pacific Ocean. Fish Biol. 69:392-405.
- Tribuzio, C.A., C. Rodgveller, J. Heifetz, D. Courtney, and K.J. Goldman. 2008. Assessment of the shark stocks in the Gulf of Alaska. *In* Stock Assessment and Fishery Evaluation Report for the groundfish resources of the Gulf of Alaska. Compiled by the Plan Team for the fishery resources of the Gulf of Alaska. North Pacific Fisheries Management Council, Anchorage, AK.

D.24 Octopuses

There are at least seven species of octopuses currently identified from the GOA, including one species of genus *Octopus* that has not been fully described (*Octopus sp. A*, Connors and Jorgensen 2008). The species most abundant at depths less than 200 m is the giant Pacific octopus *Enteroctopus dofleini* (formerly *Octopus dofleini*). Several species are found primarily in deeper waters along the shelf break and slope, including, *Benthoctopus leioderma* and the cirrate octopus *Opisthoteuthis cf californiana*. *Octopus californicus* is reported from the eastern GOA at depths ranging from 100 to 1,000 m. *Japetella diaphana* and bathypelagic finned species *Vampyroteuthis infernalis* are found in pelagic waters of the GOA. Preliminary evidence (Connors and Jorgensen 2008, Connors et al. 2004) indicates that octopus

taken as incidental catch in groundfish fisheries are primarily *Enteroctopus dofleini*. This species has been extensively studied in British Columbia and Japan, and is used as the primary indicator for the assemblage. Species identification of octopuses in the Bering Sea and GOA has changed since the previous essential fish habitat review and is still developing. The state of knowledge of octopuses in the GOA, including the true species composition, is very limited.

D.24.1 Life History and General Distribution

Octopus are members of the molluscan class Cephalopoda, along with squid, cuttlefish, and nautiloids. The octopuses (order Octopoda) have only eight appendages or arms and unlike other cephalopods, they lack shells, pens, and tentacles. There are two groups of Octopoda, the cirrate and the incirrate. The cirrate have cirri and are by far less common than the incirrate which contain the more traditional forms of octopus. Octopuses are found in every ocean in the world and range in size from less than 20 cm (total length) to over 3 m (total length); the latter is a record held by *Enteroctopus dofleini*.

In the GOA, octopuses are found from subtidal waters to deep areas near the outer slope. The highest diversity is along the shelf break region of the GOA, although, unlike the Bering Sea, there is a high abundance of octopuses on the shelf. While octopuses were observed throughout the GOA, they are more commonly observed in the Central and Western GOA (statistical areas 610, 620, and 630) than in the Eastern GOA. The greatest number of observations is clustered around the Shumagin Islands and Kodiak Island. These spatial patterns are influenced by the distribution of fishing effort. Alaska Fisheries Science Center survey data also show the presence of octopus throughout the GOA but also indicate highest biomass in areas 610 and 630. Octopuses were caught at all depths ranging from shallow inshore areas (mostly pot catches) to trawl and longline catches on the continental slope at depths to nearly 1,000 m. The majority of octopus caught with pots in the GOA came from 40 to 60 fathoms (70 to 110 m); catches from longline vessels tended to be in deeper waters of 200 to 400 fathoms (360 to 730 m). The distribution of octopuses between state waters (within three miles of shore) and federal waters remains unknown. *Enteroctopus dofleini* in Japan undergo seasonal depth migrations associated with spawning; it is unknown whether similar migrations occur in Alaskan waters.

In general, octopus life spans are either 1 to 2 years or 3 to 5 years depending on species. Life histories of six of the seven species in the Bering Sea are largely unknown. *Enteroctopus dofleini* has been studied in waters of northern Japan and western Canada, but reproductive seasons and age/size at maturity in Alaskan waters are still undocumented. General life histories of the other six species are inferred from what is known about other members of the genus.

E. dofleini is sexually mature after approximately three years. In Japan, females weigh between 10 to 15 kg at maturity while males are 7 to 17 kg (Kanamaru and Yamashita 1967). *E. dofleini* in the Bering Sea may mature at larger sizes given the more productive waters in the Bering Sea. *E. dofleini* in Japan move to deeper waters to mate during July through October and move to shallower waters to spawn during October through January. There is a 2-month lag time between mating and spawning. This time may be necessary for the females to consume extra food to last the seven months required for hatching of the eggs, during which time the female guards and cleans the eggs but does not feed. *E. dofleini* is a terminal spawner, females die after the eggs hatch while males die shortly after mating. While females may have 60,000 to 100,000 eggs in their ovaries, only an average of 50,000 eggs are laid (Kanamaru 1964). Hatchlings are approximately 3.5 mm. Mottet (1975) estimated survival to 6 mm at 4 percent, while survival to 10 mm was estimated to be 1 percent; mortality at the 1 to 2 year stage was also estimated to be high (Hartwick 1983). Since the highest mortality occurs during the larval stage it is likely that ocean conditions have the largest effect on the number of *E. dofleini* in the Bering Sea and large fluctuations in numbers of *E. dofleini* should be expected.

Octopus californicus is a medium-sized octopus, maximum total length of approximately 40 cm. Very little is known about this species of octopus. It is collected between 100 and 1,000 m. It is believed to

spawn 100 to 500 eggs. Hatchlings are likely benthic; hatchling size is unknown. The female likely broods the eggs and dies after hatching.

Octopus sp. A is a small-sized species, maximum total length less than 10 cm. This species has only recently been identified in the GOA and its full taxonomy has not been determined. *Octopus sp. A* is likely a terminal spawner with a life-span of 12 to 18 months. The eggs of *Octopus sp. A* are likely much larger than those of *O. rubescens*, as benthic larvae are often bigger; they could take up to six months or more to hatch. Females have 80 to 90 eggs.

Benthoctopus leioderma is a medium-sized species, maximum total length approximately 60 cm. Its life span is unknown. It occurs from 250 to 1,400 m and is found throughout the shelf break region. It is a common octopus and often occurs in the same areas where *E. dofleini* are found. The eggs are brooded by the female but mating and spawning times are unknown. They are thought to spawn under rock ledges and crevices. The hatchlings are benthic.

Opisthoteuthis californiana is a cirrate octopus. It has fins and cirri (on the arms). It is common in the GOA but would not be confused with *E. dofleini*. It is found from 300 to 1,100 m and likely common over the abyssal plain. Other details of its life history remain unknown.

Japetella diaphana is a small pelagic octopus. Little is known about members of this family. This is not a common octopus in the GOA and would not be confused with *E. dofleini*.

V. infernalis is a relatively small (up to about 40 cm total length) bathypelagic species, living at depths well below the thermocline; they may be most commonly found at 700 to 1,500 m. They are found throughout the world's oceans. Eggs are large (3 to 4 mm in diameter) and are shed singly into the water. Hatched juveniles resemble adults, but with different fin arrangements, which change to the adult form with development. Little is known of their food habits, longevity, or abundance.

D.24.2 Fishery

There is no federally managed directed fishery for octopus in the GOA. The State of Alaska allows directed fishing for octopus in state waters under a commissioner's permit. One processor in Kodiak purchases incidentally-caught octopus, primarily for halibut bait. Recent increases in market value have increased retention of incidentally-caught octopus in the GOA). Catches in federal waters are incidental, chiefly in the pot fishery for Pacific cod and bottom trawl fisheries for cod and flatfish, but sometimes in the pelagic trawl pollock fishery. Total incidental catch has ranged between an estimated 200 and 400 mt in the BSAI and 80 and 300 mt in the GOA. Most of the bycatch occurs on the outer continental shelf (100 to 200 m depth), chiefly in the western GOA around Kodiak Island and south of the Alaska peninsula in the Sanak-Shumagin region. The North Pacific Fishery Management Council is currently considering dividing the GOA "other species" category into several subgroups for separate management; one of these subgroups would be octopus (all species).

D.24.3 Relevant Trophic Information

Octopuses are eaten by pinnipeds (principally Steller sea lions, and spotted, bearded, and harbor seals) and a variety of fishes, including Pacific halibut and Pacific cod (Yang 1993). When small, octopods eat planktonic and small benthic crustaceans (mysids, amphipods, copepods). As adults, octopuses eat benthic crustaceans (crabs) and molluscs (clams). Large octopus are also able to catch and eat benthic fishes; the Seattle aquarium has documented a giant Pacific octopus preying on a 4-foot dogfish.

D.24.4 Habitat and Biological Associations

Egg/Spawning: Occurs on shelf; *E. dofleini* lays strings of eggs in cave or den in boulders or rubble, which are guarded by the female until hatching. The exact habitat needs and preferences for denning are unknown.

Larvae: Pelagic for *Enteroctopus dofleini*, demersal for other octopus species.

Young Juveniles: Are semi-demersal; are widely dispersed on shelf, upper slope.

Old Juveniles and Adults: Are demersal; are widely dispersed on shelf and upper slope, preferentially among rocks, cobble, but also on sand/mud.

Habitat and Biological Associations: *Enteroctopus dofleini*, *Octopus gilbertianus*

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	U (1 to 2 months?)	NA	spring–summer?	U (ICS, MCS?)	D, P*	R, G?	U	euhaline waters
Young juveniles	U	zooplankton	summer–fall	U (ICS, MCS, OCS, USP?)	D, SD	U	U	euhaline waters
Older Juveniles and Adults	U (3–5 yrs for <i>E. dofleini</i> ; 1–2 yrs for other species?)	crustaceans, mollusks, fish	all year	ICS, MCS, OCLS, USP	D?	R, G, S, MS	U	euhaline waters

* Larvae is pelagic for *Enteroctopus dofleini*, demersal for other octopus species.

D.24.5 Literature

- Akimushkin, I.I. 1963. Cephalopods of the seas of the U.S.S.R. Academy of Sciences of the U.S.S.R., Institute of Oceanology, Moscow. Translated from Russian by Israel Program for Scientific Translations, Jerusalem 1965. 223 p.
- Alaska Department of Fish and Game (2004). Annual management report of the commercial and subsistence shellfish fisheries of the Aleutian Islands, Bering Sea, and the westward region's shellfish observer program, 2003. Regional Information Report No. 4K04-43
- Aydin, K., S. Gaichas, I. Ortiz, D. Kinzey, and N. Friday. 2008. A comparison of the Bering Sea, Gulf of Alaska, and Aleutian Islands large marine ecosystems through food web modeling. NOAA Tech Memo.
- Caddy, J.F. 1979. Preliminary analysis of mortality, immigration, and emigration on *Illex* population on the Scotian Shelf. ICNAF Res. Doc. 79/VI/120, Ser. No. 5488.
- Caddy, J.F. 1983. The cephalopods: factors relevant to their population dynamics and to the assessment and management of stocks. Pages 416-452 In J.F. Caddy, ed. Advances in assessment of world cephalopod resources. FAO Fisheries Tech. Paper 231.
- Caddy, J.F. 2004. Current usage of fisheries indicators and reference points, and their potential application to management of fisheries for marine invertebrates. Can. J Fish. Aquat. Sci. 61:1307-1324.
- Caddy, J.F. and P.G. Rodhouse. 1998. Cephalopod and groundfish landings: evidence for ecological change in global fisheries? Rev. Fish Biology and Fisheries 8:431-444.
- Charnov e.L. and D. Berrigan. 1991. Evolution of life history parameters in animals with indeterminate growth, particularly fish. Evol. Ecol. 5:63-68.
- Connors, M. E., P. Munro, and S. Neidetcher (2004). Pacific cod pot studies 2002-2003. AFSC Processed Report 2004-04. June 2004
- Connors, M.E. and E. Jorgensen. 2005. Octopus Complex in the Gulf of Alaska. In: Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska. North Pac. Fish. Mgmt. Council, Anchorage, AK,

- Conners, M.E. and E. Jorgensen. 2006. Octopus Complex in the Gulf of Alaska. In: Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska. North Pac. Fish. Mgmt. Council, Anchorage, AK,
- Conners, M.E. and E. Jorgensen. 2007. Octopus Complex in the Gulf of Alaska. In: Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska. North Pac. Fish. Mgmt. Council, Anchorage, AK,
- Conners, M.E. and E. Jorgensen. 2008. Octopus Complex in the Gulf of Alaska. In: Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska. North Pac. Fish. Mgmt. Council, Anchorage, AK,
- Fritz, L.W. 1996. Other species In Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions as Projected for 1997. North Pacific Fishery Management Council, 605 West 4th Avenue, Suite 306, Anchorage, AK 99501.
- Fritz, L. 1997. Summary of changes in the Bering Sea Aleutian Islands squid and other species assessment. (in) Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. N. Pacific Fish. Management Council, Anchorage, AK.
- Gaichas, S. 2004. Other Species (in) Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea / Aleutian Islands regions. N. Pacific Fish. Management Council, Anchorage, AK.
- Hatanaka, H. 1979. Studies on the fisheries biology of common octopus off the northwest coast of Africa. Bull Far Seas Reserarch Lab 17:13-94.
- Hartwick, B. 1983. *Octopus dofleini*. In Cephalopod Life Cycles Vol. I. P.R. Boyle eds. 277-291.
- Hartwick, E.B., R.F. Ambrose, and S.M.C. Robinson. 1984. Dynamics of shallow-water populations of *Octopus dofleini*. Mar. Biol. 82:65-72.
- Hartwick, E.B, and I. Barriga (1997) *Octopus dofleini*: biology and fisheries in Canada (in) Lang, M. A. and F.G. Hochberg (eds.) (1997). Proceedings of the Workshop on the Fishery and market potential of octopus in California. Smithsonian Institutions: Washington. 192 p.
- Hoenig, J.N. 1983. Empirical Use of Longevity Data to Estimate Mortality Rates. Fishery Bulletin V. 82 No. 1, pp. 898-903.
- Iverson, S.J., K.J. Frost, and S.L.C. Lang. 2002. Fat content and fatty acid composition of forage fish and invertebrates in Prince William Sound, Alaska: factors contributing to among and within species variability. Marine Ecol. Prog. Ser. 241:161-181.
- Kanamaru, S. 1964. The octopods off the coast of Rumoi and the biology of mizudako. Hokkaido Marine Research Centre Monthly Report 21(4&5):189-210.
- Kanamaru, S. and Y. Yamashita. 1967. The octopus mizudako. Part 1, Ch. 12. Investigations of the marine resources of Hokkaido and developments of the fishing industry, 1961 – 1965.
- Livingston, P.L., Aydin, K.Y., J. Boldt., S. Gaichas, J. Ianelli, J. Jurado-Molina, and I. Ortiz. 2003. Ecosystem Assessment of the Bering Sea/Aleutian Islands and Gulf of Alaska Management Regions. In: Stock assessment and fishery evaluation report for the groundfish resources or the Bering Sea/Aleutian Islands regions. North. Pac. Fish. Mgmt. Council, Anchorage, AK.
- Osako, M. and . Murata. 1983. Stock assessment of cephalopod resources in the northwestern Pacific. Pages55-144 In J.F. Caddy, ed. Advances in assessment of world cephalopod resources. FAO Fisheries Tech. Paper 231.
- Merrick, R.L., M.K. Chumbley, and G.V. Byrd, 1997. Diet diversity of Steller sea lions (*Eumetpias jubatus*) and their population decline in Alaska: a potential relationship. Can J. Fish. Aquat. Sci. 54: 1342-1348.
- Mottet, M. G. 1975. The fishery biology of *Octopus dofleini*. Washington Department of Fisheries Technical Report No. 16, 39 pp.
- National Research Council. 1998. Improving fish stock assessments. National Academy Press, Washington, D.C.
- Nesis, K.N. 1987. Cephalopods of the world. TFH Publications, Neptune City, NJ, USA. 351 pp.

- Paust, B.C. 1988. Fishing for octopus, a guide for commercial fishermen. Alaska Sea Grant Report No. 88-3, 48 pp.
- Paust, B.C. 1997. *Octopus dofleini*: Commercial fishery in Alaska (in) Lang, M. A. and F.G. Hochberg (eds.) (1997). Proceedings of the Workshop on the Fishery and market potential of octopus in California. Smithsonian Institutions: Washington. 192 p.
- Perez, M. 1990. Review of marine mammal population and prey information for Bering Sea ecosystem studies. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS F/NWC-186, 81 p.
- Perry, R.I., C.J. Walters, and J.A. Boutillier. 1999. A framework for providing scientific advice for the management of new and developing invertebrate fisheries. Rev. Fish Biology and Fisheries 9:125-150.
- Punt, A.E. 1995. The performance of a production-model management procedure. Fish. Res. 21:349-374.
- Rikhter, V.A. and V.N. Efanov, 1976. On one of the approaches to estimation of natural mortality of fish populations. ICNAF Res.Doc., 79/VI/8, 12p.
- Rooper, C.F.E., M.J. Sweeny, and C.E. Nauen. 1984. FAO Species catalogue vol. 3 cephalopods of the world. FAO Fisheries Synopsis No. 125, Vol. 3.
- Sato, R. and H. Hatanaka. 1983. A review of assessment of Japanese distant-water fisheries for cephalopods. Pages 145-203 In J.F. Caddy, ed. Advances in assessment of world cephalopod resources. FAO Fisheries Tech. Paper 231.
- Scheel, D. 2002. Characteristics of habitats used by *Enteroctopus dofleini* in Prince William Sound and Cook Inlet, Alaska. Marine Ecology 23(3):185-206.
- Sigler M.F., L. Hulbert, C. R. Lunsford, N. Thompson, K. Burek, G. Corry-Crowe, and A. Hirons. 2006. Diet of Pacific sleeper shark, a potential Steller sea lion predator, in the north-east Pacific Ocean. Fish Biol. 69:392-405.
- Sinclair, E.H. and T.K. Zeppelin. 2002. Seasonal and spatial differences in diet in the western stock of Steller sea lions (*Eumetopias jubatus*). J Mammology 83:973-990.
- Wakabayashi, K, R.G. Bakkala, and M. S. Alton. 1985. Methods of the U.S.-Japan demersal trawl surveys (in) R.G. Bakkala and K. Wakabayashi (eds.), Results of cooperative U.S. - Japan groundfish investigations in the Bering Sea during May - August 1979. International North Pacific Fisheries Commission Bulletin 44.
- Walters, G. E. Report to the fishing industry on the results of the 2004 Eastern Bering Sea Groundfish Survey. AFSC Process Report 2005-03. Feb 2005.
- Wilson, J.R. and A.H. Gorham (1982). Alaska underutilized species Volume II: Octopus. Alaska Sea Grant Report 82-3. May 1982. 64 p.
- Yang, M.S. 1993. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-AFSC-22, 150 p.

D.25 Capelin (*osmeridae*)

The species representative for capelin is *Mallotus villosus*.

D.25.1 Life History and General Distribution

Capelin are a short-lived marine (neritic), pelagic, filter-feeding schooling fish with a circumpolar distribution that includes the entire coastline of Alaska and the Bering Sea, and south along British Columbia to the Strait of Juan de Fuca. In the North Pacific, capelin grow to a maximum of 25 cm and 5 years of age. Capelin, which are a type of smelt, spawn at ages 2 to 4 in spring and summer (May to August; earlier in south, later in north) when about 11 to 17 cm on coarse sand and fine gravel beaches, especially in Norton Sound, northern Bristol Bay, along the Alaska Peninsula, and near Kodiak. Age at 50 percent maturity is 2 years. Fecundity is 10,000 to 15,000 eggs per female. Eggs hatch in 2 to 3 weeks.

Most capelin die after spawning. Larvae and juveniles are distributed on the inner-mid shelf in summer (rarely found in waters deeper than about 200 m), and juveniles and adults congregate in fall in mid-shelf waters east of the Pribilof Islands, west of St. Matthew and St. Lawrence Islands, and north into the Gulf of Anadyr. They are distributed along the outer shelf and under the ice edge in winter. Larvae, juveniles, and adults have diurnal vertical migrations following scattering layers; at night they are near the surface and at depth during the day. Smelts are captured during trawl surveys, but their patchy distribution both in space and time reduces the validity of biomass estimates.

The approximate upper size limit of juvenile fish is 13 cm.

D.25.2 Fishery

Capelin are not a target species in groundfish fisheries of BSAI or GOA, but are caught as bycatch (up to several hundred tons per year in the 1990s) principally during the yellowfin sole trawl fishery in Kuskokwim and Togiak Bays in spring in the BSAI; almost all are discarded. Small local coastal fisheries occur in spring and summer.

D.25.3 Relevant Trophic Information

Capelin are important prey for marine birds and mammals as well as other fish. Surface feeding (e.g., gulls and kittiwakes), as well as shallow and deep diving piscivorous birds (e.g., murre and puffins) largely consume small schooling fishes such as capelin, eulachon, herring, sand lance, and juvenile pollock (Hunt et al. 1981a). Both pinnipeds (Steller sea lions, northern fur seals, harbor seals, and ice seals) and cetaceans (such as harbor porpoise and fin, sei, humpback, and beluga whales) feed on smelts, which may provide an important seasonal food source near the ice-edge in winter, and as they assemble nearshore in spring to spawn (Frost and Lowry 1987, Wespestad 1987). Smelts are also found in the diets of some commercially exploited fish species, such as Pacific cod, walleye pollock, arrowtooth flounder, Pacific halibut, sablefish, Greenland turbot, and salmon throughout the North Pacific Ocean and the Bering Sea (Allen 1987, Yang 1993, Livingston, in prep.).

D.25.4 Habitat and Biological Associations

Egg/Spawning: Spawn adhesive eggs (about 1 mm in diameter) on fine gravel or coarse sand (0.5 to 1 mm grain size) beaches intertidally to depths of up to 10 m in May through July in Alaska (later to the north in Norton Sound). Hatching occurs in 2 to 3 weeks. Most intense spawning when coastal water temperatures are 5 to 9 °C.

Larvae: After hatching, 4 to 5 mm larvae remain on the middle-inner shelf in summer; distributed pelagically; centers of distribution are unknown, but have been found in high concentrations north of Unimak Island, in the western GOA, and around Kodiak Island.

Juveniles: In fall, juveniles are distributed pelagically in mid-shelf waters (50 to 100 m depth; -2 to 3 °C), and have been found in highest concentrations east of the Pribilof Islands, west of St. Matthew and St. Lawrence Islands, and north into the Gulf of Anadyr.

Adults: Found in pelagic schools in inner-mid shelf in spring and fall, feed along semi-permanent fronts separating inner, mid, and outer shelf regions (approximately 50 and 100 m). In winter, found in concentrations under ice-edge and along mid-outer shelf.

Habitat and Biological Associations: Capelin

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	2 to 3 weeks to hatch	na	May–August	BCH (to 10 m)	D	S,CB		5–9 °C peak spawning
Larvae	4 to 8 months?	copepods, phytoplankton	summer/fall/ winter	ICS, MCS	N, P	U NA?	U	
Juveniles	1.5+ years, up to age 2	copepods, euphausiids	all year	ICS, MCS	P	U NA?	U F?; Ice edge in winter	
Adults	2 years, ages 2–4+	copepods, euphausiids, polychaetes, small fish	spawning (May–August) non-spawning (Sep–Apr)	BCH (to 10 m) ICS, MCS, OCS	D, SD P	S, CB NA?	F; Ice edge in winter	-2–3 °C peak distributions in EBS?

D.25.5 Literature

- Allen, M.J. 1987. Demersal fish predators of pelagic forage fishes in the southeastern BS. Pp. 29-32. *In* Forage fishes of the southeastern BS. Proceedings of a Conference, November 1986, Anchorage, AK. U.S. Dept Interior, Minerals Management Service, OCS Study MMS 87-0017.
- Allen, M.J., and G.B. Smith. 1988. Atlas and zoogeography of common fishes in the BS and Northeastern Pacific. U.S. Dep. Commerce., NOAA Tech. Rept. NMFS 66, 151 p.
- Crawford, T.W. 1981. Vertebrate prey of *Phocoenoides dalli* (Dall's porpoise), associated with the Japanese high seas salmon fishery in the North Pacific Ocean. M.S. Thesis, Univ. Washington, Seattle, 72 p.
- Doyle, M.J., W.C. Rugen, and R.D. Brodeur. 1995. Neustonic ichthyoplankton in the western GOA during spring. Fishery Bulletin 93: 231-253.
- Eschmyer, W.N., and E.S. Herald. 1983. A field guide to Pacific coast fishes, North America. Houghton Mifflin Co., Boston. 336 p.
- Fritz, L.W. 1996. Other species *In* Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the BSAI Regions as Projected for 1997. Council, 605 West 4th Avenue, Suite 306, Anchorage, AK 99501.
- Fritz, L.W., V.G. Wespestad, and J.S. Collie. 1993. Distribution and abundance trends of forage fishes in the BS and GOA. Pp. 30-44. *In* Is It Food: Addressing marine mammal and seabird declines. Workshop Summary. Alaska Sea Grant College Program Rept. No. AK-SG-93-01, Univ. Alaska, Fairbanks, AK 99775-5040.
- Frost, K.J., and L. Lowry. 1987. Marine mammals and forage fishes in the southeastern BS. Pp. 11-18 *In* Forage fishes of the southeastern BS. Proceedings of a Conference, November 1986, Anchorage, AK. U.S. Dept Interior, Minerals Management Service, OCS Study MMS 87-0017.
- Hart, J.L. 1973. Pacific fishes of Canada. Fisheries Res. Bd. Canada Bull. 180. Ottawa. 740 p.
- Hunt, G.L., Jr., B. Burgeson, and G.A. Sanger. 1981a. Feeding ecology of seabirds of the EBS. Pp 629-647 *In* D.W. Hood and J.A. Calder (eds.), The EBS Shelf: Oceanography and Resources, Vol. II. U.S. Dept. Commerce., NOAA, OCSEAP, Office of Marine Pollution Assessment, Univ. WA Press, Seattle, WA.
- Hunt, G.L., Jr., Z. Eppley, B. Burgeson, and R. Squibb. 1981b. Reproductive ecology, foods and foraging areas of seabirds nesting on the Pribilof Islands, 1975-79. Environmental Assessment of the Alaskan Continental Shelf, Final Reports of Principal Investigators, RU-83, U.S. Dept. Commerce., NOAA, OCSEAP, Boulder, CO.
- Kawakami, T. 1980. A review of sperm whale food. Sci. Rep. Whales Res. Inst. Tokyo 32: 199-218.

- Kendall, A.W., Jr., and J.R. Dunn. 1985. Ichthyoplankton of the continental shelf near Kodiak Island, Alaska. U.S. Dep. Commerce., NOAA Tech. Rept NMFS 20, 89 p.
- Kendall, A.W., Jr., J.R. Dunn, and R.J. Wolotira, Jr. 1980. Zooplankton, including ichthyoplankton and decapod larvae, of the Kodiak shelf. NWAFC Processed Rept. 80-8, AFSC-NMFS, 7600 Sand Point Way, NE, Seattle, WA 98115. 393 p.
- Livingston, P.A. In prep. Groundfish utilization of walleye pollock (*Theragra chalcogramma*), Pacific herring (*Clupea pallasii*) and capelin (*Mallotus villosus*) resources in the GOA. In preparation.
- Morris, B.F., M.S. Alton, and H.W. Braham. 1983. Living marine resources of the GOA: a resource assessment for the GOA/Cook Inlet Proposed Oil and Gas Lease Sale 88. U.S. Dept. Commerce., NOAA, NMFS.
- Murphy, E.C., R.H. Day, K.L. Oakley, and A.A. Hoover. 1984. Dietary changes and poor reproductive performances in glaucous-winged gulls. Auk 101: 532-541.
- Naumenko, E.A. 1996. Distribution, biological condition, and abundance of capelin (*Mallotus villosus socialis*) in the BS. Pp. 237-256 In O.A. Mathisen and K.O. Coyle (eds.), Ecology of the BS: a review of Russian literature. Alaska Sea Grant Report No. 96-01, Alaska Sea Grant College Program, U. Alaska, Fairbanks, AK 99775-5040. 306 p.
- Ormseth, O.A., Connors, L., Guttormsen M., and J. Vollenweider. 2008. Forage fishes in the Gulf of Alaska. In: Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska Region. North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage, AK 99501.
- Pahlke, K.A. 1985. Preliminary studies of capelin *Mallotus villosus* in Alaska waters. Alaska Dept. Fish Game, Info. Leaf. 250, 64 p.
- Perez, M.A., and M.A. Bigg. 1986. Diet of northern fur seals, *Callorhinus ursinus*, off western North America. Fish. Bull., U.S. 84: 957-971.
- Pitcher, K.W. 1980. Food of the harbor seal, *Phoca vitulina richardsi*, in the GOA. Fish. Bull., U.S. 78: 544-549.
- Rugen, W.C. 1990. Spatial and temporal distribution of larval fish in the western GOA, with emphasis on the period of peak abundance of walleye pollock (*Theragra chalcogramma*) larvae. NWAFC Processed Rept 90-01, AFSC-NMFS, 7600 Sand Point Way, NE, Seattle, WA 98115. 162 p.
- Waldron, K.D. 1978. Ichthyoplankton of the EBS, 11 February-16 March 1978. REFM Report, AFSC, NMFS, 7600 Sand Point Way, NE, Seattle, WA 98115. 33 p.
- Waldron, K.D., and B.M. Vinter. 1978. Ichthyoplankton of the EBS. Final Report (RU 380), Environmental Assessment of the Alaskan continental shelf, REFM, AFSC, NMFS, 7600 Sand Point Way, NE, Seattle, WA 98115. 88 p.
- Wespestad, V.G. 1987. Population dynamics of Pacific herring (*Clupea palasii*), capelin (*Mallotus villosus*), and other coastal pelagic fishes in the EBS. Pp. 55-60 In Forage fishes of the southeastern BS. Proceedings of a Conference, November 1986, Anchorage, AK. U.S. Dept Interior, Minerals Management Service, OCS Study MMS 87-0017.
- Yang, M.S. 1993. Food habits of the commercially important groundfishes in the GOA in 1990. U.S. Dept. Commerce., NOAA Tech. Memo. NMFS-AFSC-22. 150 pp.

D.26 Eulachon (*osmeridae*)

The species representative for eulachon is the candlefish (*Thaleichthys pacificus*).

D.26.1 Life History and General Distribution

Eulachon are a short-lived anadromous, pelagic schooling fish distributed from the Pribilof Islands in the eastern Bering Sea, throughout the GOA, and south to California. Eulachon are consistently found pelagically in Shelikof Strait (hydroacoustic surveys in late winter-spring) and between Unimak Island

and the Pribilof Islands (bycatch in groundfish trawl fisheries) from the middle continental shelf to over the slope. In the North Pacific, eulachon, which are a type of smelt, grow to a maximum of 23 cm and 5 years of age. They spawn at ages 3 to 5 years in spring and early summer (April to June) when they are about 14 to 20 cm in rivers on coarse sandy bottom. Their age at 50 percent maturity is 3 years. Fecundity equals approximately 25,000 eggs per female. Eggs adhere to sand grains and other substrates on river bottom. Eggs hatch in 30 to 40 days at 4 to 7 °C. Most eulachon die after first spawning. Larvae drift out of rivers and develop at sea. Smelts are captured during trawl surveys, but their patchy distribution both in space and time reduces the validity of biomass estimates.

The approximate upper size limit of juvenile fish is 14 cm.

D.26.2 Fishery

Eulachon and candlefish are not target species in groundfish fisheries of the BSAI or GOA, but are caught as bycatch (ranging from at least 18 to 850 mt from 2003 to 2009; observers have only consistently identified smelts to species since 2005) principally by midwater pollock fisheries in Shelikof Strait (GOA), on the east side of Kodiak (GOA), and between the Pribilof Islands and Unimak Island on the outer continental shelf and slope (eastern Bering Sea); almost all are discarded. Small local coastal fisheries occur in spring and summer and eulachon are a very important subsistence resource for coastal Alaska residents.

D.26.3 Relevant Trophic Information

Eulachon may be important prey for marine birds and mammals as well as other fish. Surface feeding (e.g., gulls and kittiwakes), as well as shallow and deep diving piscivorous birds (e.g., murres and puffins) largely consume small schooling fishes such as capelin, eulachon, herring, sand lance, and juvenile pollock (Hunt et al. 1981a, Sanger 1983). Both pinnipeds (Steller sea lions, northern fur seals, harbor seals, and ice seals) and cetaceans (such as harbor porpoise and fin, sei, humpback, and beluga whales) feed on smelts, which may provide an important seasonal food source near the ice-edge in winter, and as they assemble nearshore in spring to spawn (Frost and Lowry 1987, Wespestad 1987). Smelts are also found in the diets of some commercially exploited fish species, such as Pacific cod, walleye pollock, arrowtooth flounder, Pacific halibut, sablefish, Greenland turbot, and salmon throughout the North Pacific Ocean and the Bering Sea (Allen 1987; Yang 1993; Livingston, in prep.).

D.26.4 Habitat and Biological Associations

Egg/Spawning: Anadromous; return to spawn in spring (May to June) in rivers; demersal eggs adhere to bottom substrate (e.g., sand, cobble). Hatching occurs in 30 to 40 days.

Larvae: After hatching, 5 to 7 mm larvae drift out of river and develop pelagically in coastal marine waters; centers of distribution are unknown.

Juveniles and Adults: Distributed pelagically in mid-shelf to upper slope waters (50 to 1,000 m water depth), and have been found in highest concentrations between the Pribilof Islands and Unimak Island on the outer shelf, and in Shelikof Strait east of the Pribilof Islands, west of St. Matthew and St. Lawrence Islands, and north into the Gulf of Anadyr.

Habitat and Biological Associations: Eulachon (Candlefish)

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	30 to 40 days	NA	April–June	Rivers, FW	D	S (CB?)		4–8 °C for egg development
Larvae	1 to 2 months?	copepods, phytoplankton, mysids, larvae	summer/fall	ICS?	P?	U NA?	U	
Juveniles	2.5+ years, up to age 3	copepods, euphausiids	all year	MCS, OCS, USP	P	U NA?	U F?	
Adults	3 years		spawning May–June	Rivers, FW	D	S (CB?)		
	ages 3 to 5+	copepods, euphausiids	non-spawning (July–Apr)	MCS, OCS, USP	P	NA?	F?	

D.26.5 Literature

- Allen, M.J. 1987. Demersal fish predators of pelagic forage fishes in the southeastern BS. Pp. 29-32 *In* Forage fishes of the southeastern BS. Proceedings of a Conference, November 1986, Anchorage, AK. U.S. Dept Interior, Minerals Management Service, OCS Study MMS 87-0017.
- Crawford, T.W. 1981. Vertebrate prey of *Phocoenoides dalli* (Dall's porpoise), associated with the Japanese high seas salmon fishery in the North Pacific Ocean. M.S. Thesis, Univ. Washington, Seattle, 72 p.
- Fritz, L.W., V.G. Wespestad, and J.S. Collie. 1993. Distribution and abundance trends of forage fishes in the BS and GOA. Pp. 30-44 *In* Is It Food: Addressing marine mammal and seabird declines. Workshop Summary. Alaska Sea Grant College Program Rept. No. AK-SG-93-01, Univ. Alaska, Fairbanks, AK 99775-5040.
- Frost, K.J., and L. Lowry. 1987. Marine mammals and forage fishes in the southeastern BS. Pp. 11-18 *In* Forage fishes of the southeastern BS. Proceedings of a Conference, November 1986, Anchorage, AK. U.S. Dept Interior, Minerals Management Service, OCS Study MMS 87-0017.
- Hart, J.L. 1973. Pacific fishes of Canada. Fisheries Res. Bd. Canada Bull. 180. Ottawa. 740 p.
- Hunt, G.L., Jr., B. Burgeson, and G.A. Sanger. 1981a. Feeding ecology of seabirds of the EBS. Pp 629-647 *In* D.W. Hood and J.A. Calder (eds.), The EBS Shelf: Oceanography and Resources, Vol. II. U.S. Dept. Commerce., NOAA, OCSEAP, Office of Marine Pollution Assessment, Univ. WA Press, Seattle, WA.
- Hunt, G.L., Jr., Z. Eppley, B. Burgeson, and R. Squibb. 1981b. Reproductive ecology, foods and foraging areas of seabirds nesting on the Pribilof Islands, 1975-79. Environmental Assessment of the Alaskan Continental Shelf, Final Reports of Principal Investigators, RU-83, U.S. Dept. Commerce., NOAA, OCSEAP, Boulder, CO.
- Kawakami, T. 1980. A review of sperm whale food. Sci. Rep. Whales Res. Inst. Tokyo 32: 199-218.
- Livingston, P.A. In prep. Groundfish utilization of walleye pollock (*Theragra chalcogramma*), Pacific herring (*Clupea pallasii*) and capelin (*Mallotus villosus*) resources in the GOA. In preparation.
- Morris, B.F., M.S. Alton, and H.W. Braham. 1983. Living marine resources of the GOA: a resource assessment for the GOA/Cook Inlet Proposed Oil and Gas Lease Sale 88. U.S. Dept. Commerce., NOAA, NMFS.
- Perez, M.A., and M.A. Bigg. 1986. Diet of northern fur seals, *Callorhinus ursinus*, off western North America. Fish. Bull., U.S. 84: 957-971.
- Pitcher, K.W. 1980. Food of the harbor seal, *Phoca vitulina richardsi*, in the GOA. Fish. Bull., U.S. 78: 544-549.
- Sanger, G.A. 1983. Diets and food web relationships of seabirds in the GOA and adjacent marine regions. Outer Continental Shelf Environmental Assessment Program, Final Reports of Principal Investigators 45: 631-771.
- Wespestad, V.G. 1987. Population dynamics of Pacific herring (*Clupea pallasii*), capelin (*Mallotus villosus*), and other coastal pelagic fishes in the EBS. Pp. 55-60 *In* Forage fishes of the southeastern BS. Proceedings of a

- Conference, November 1986, Anchorage, AK. U.S. Dept Interior, Minerals Management Service, OCS Study MMS 87-0017.
- Yang, M.S. 1993. Food habits of the commercially important groundfishes in the GOA in 1990. U.S. Dept. Commerce., NOAA Tech. Memo. NMFS-AFSC-22. 150 pp.

Maps of Essential Fish Habitat

Maps of essential fish habitat are included in this section for the following species (life stage is indicated in parentheses):

Figures E-1 to E-3	Walleye pollock (eggs, larvae, late juveniles/adults)
Figures E-4 to E-6	Pacific cod (eggs, larvae, late juveniles/adults)
Figures E-7 to E-9	Sablefish (eggs, larvae, late juveniles/adults)
Figures E-10 to E-12	Yellowfin sole (eggs, larvae, late juveniles/adults)
Figures E-13 and E-14	Northern rock sole (larvae, late juveniles/adults)
Figures E-13 and E-15	Southern rock sole (larvae, late juveniles/adults)
Figures E-16 to E-18	Alaska plaice (eggs, larvae, late juveniles/adults)
Figures E-19 to E-21	Rex sole (eggs, larvae, late juveniles/adults)
Figures E-22 to E-24	Dover sole (eggs, larvae, late juveniles/adults)
Figures E-25 to E-27	Flathead sole (eggs, larvae, late juveniles/adults)
Figures E-28 and E-29	Arrowtooth flounder (larvae, late juveniles/adults)
Figure E-30 and E-31	Pacific ocean perch (larvae, late juveniles/adults)
Figures E-30 and E-32	Northern rockfish (larvae, late juveniles/adults)
Figures E-30 and E-33	Shortraker rockfish (larvae, late juveniles/adults)
Figures E-30 and E-34	Blackspotted and roughey rockfish (larvae, late juveniles/adults)
Figures E-30 and E-35	Dusky rockfish (larvae, adults)
Figures E-30 and E-36	Yelloweye rockfish (larvae, juveniles/adults)
Figures E-30 and E-37	Thornyhead rockfish (larvae, late juveniles/adults)
Figures E-38 to E-40	Atka mackerel (eggs, larvae, late juveniles/adults)
Figure E-41	Skates (adults)
Figure E-42	Squid species (late juveniles/adults)
Figure E-43	Sculpin species (juveniles/adults)

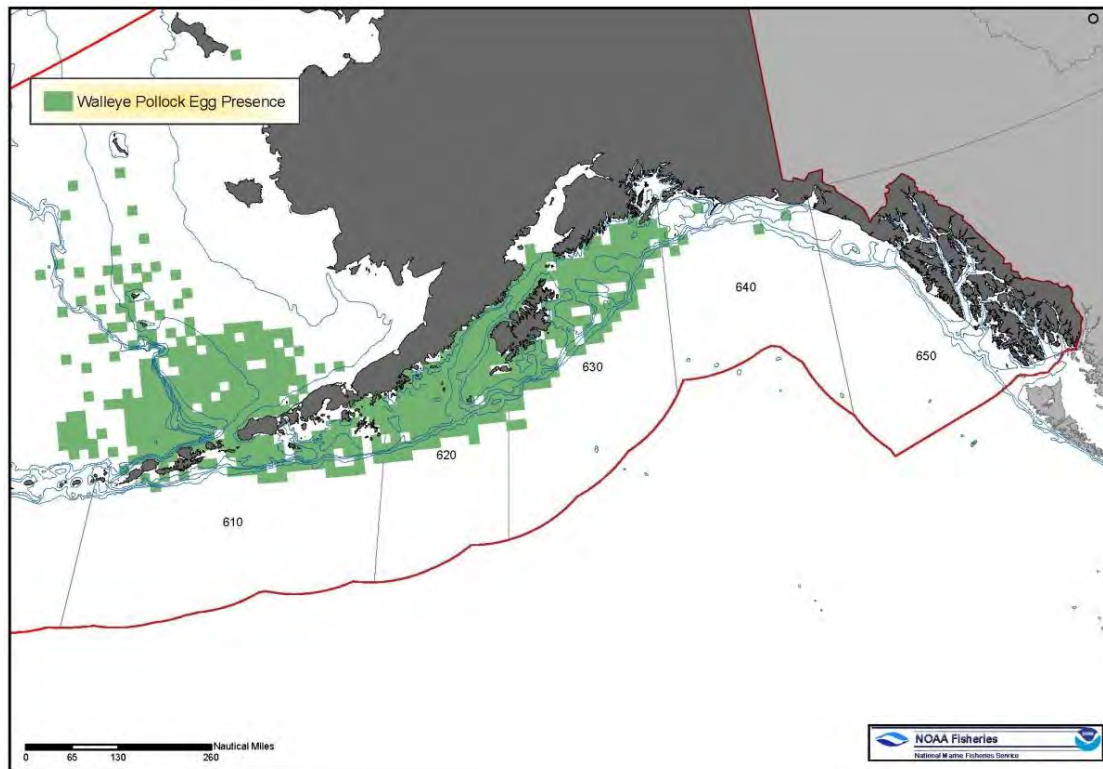
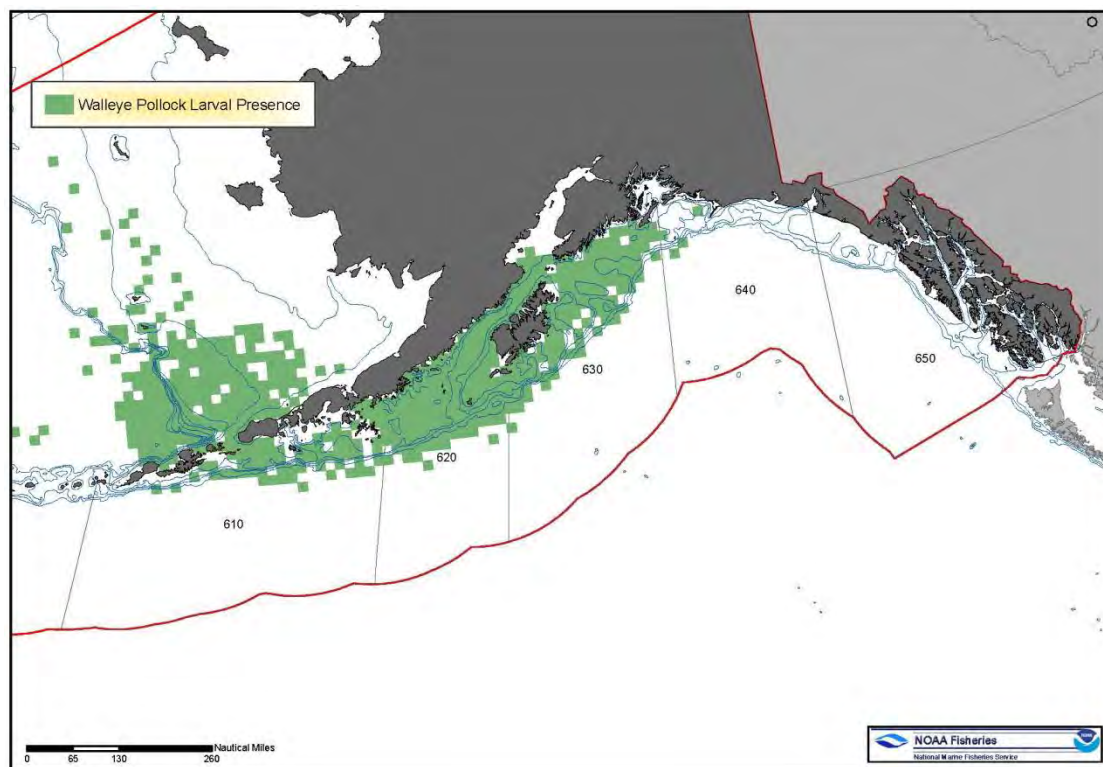
Figure E- 1 EFH Distribution – GOA Walleye Pollock (Eggs)**Figure E- 2 EFH Distribution – GOA Walleye Pollock (Larvae)**

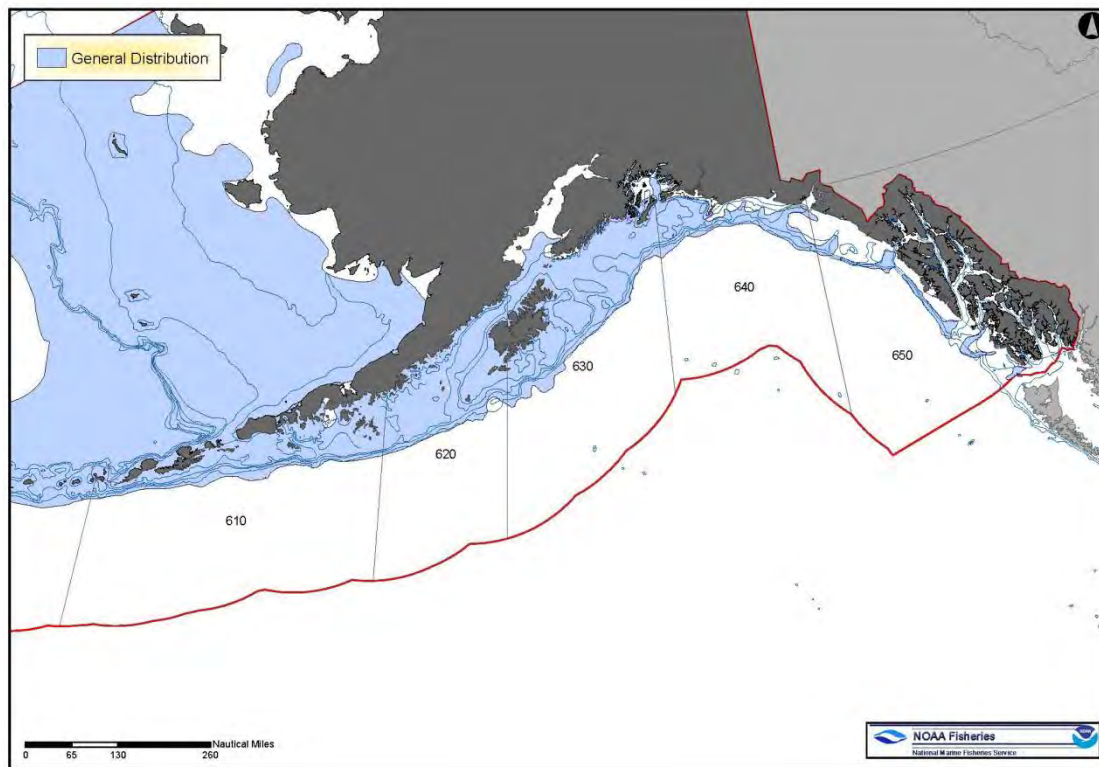
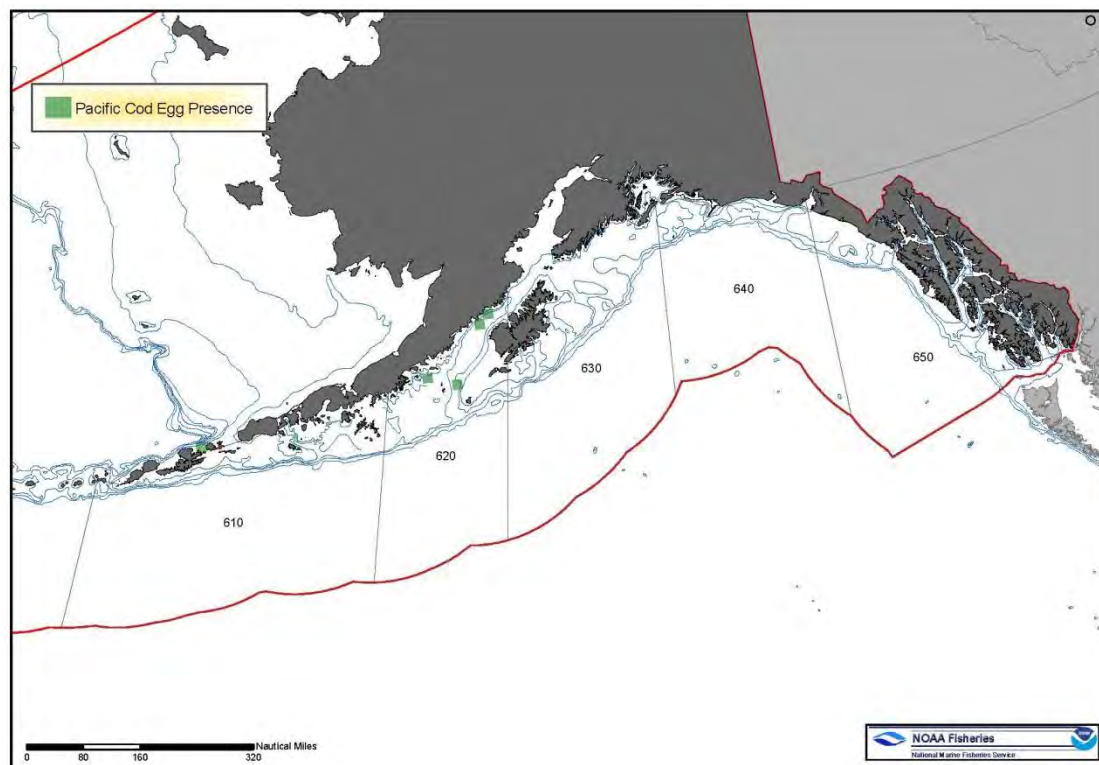
Figure E- 3 EFH Distribution – GOA Walleye Pollock (Late Juveniles/Adults)**Figure E- 4 EFH Distribution – GOA Pacific Cod (Eggs)**

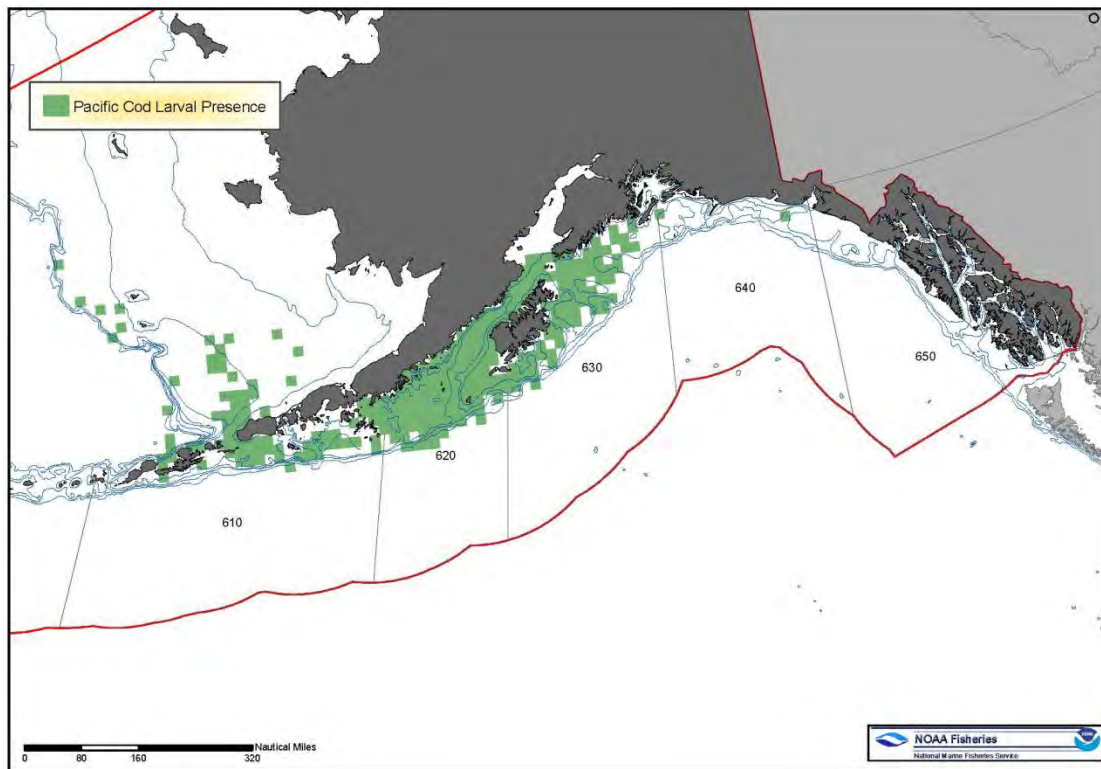
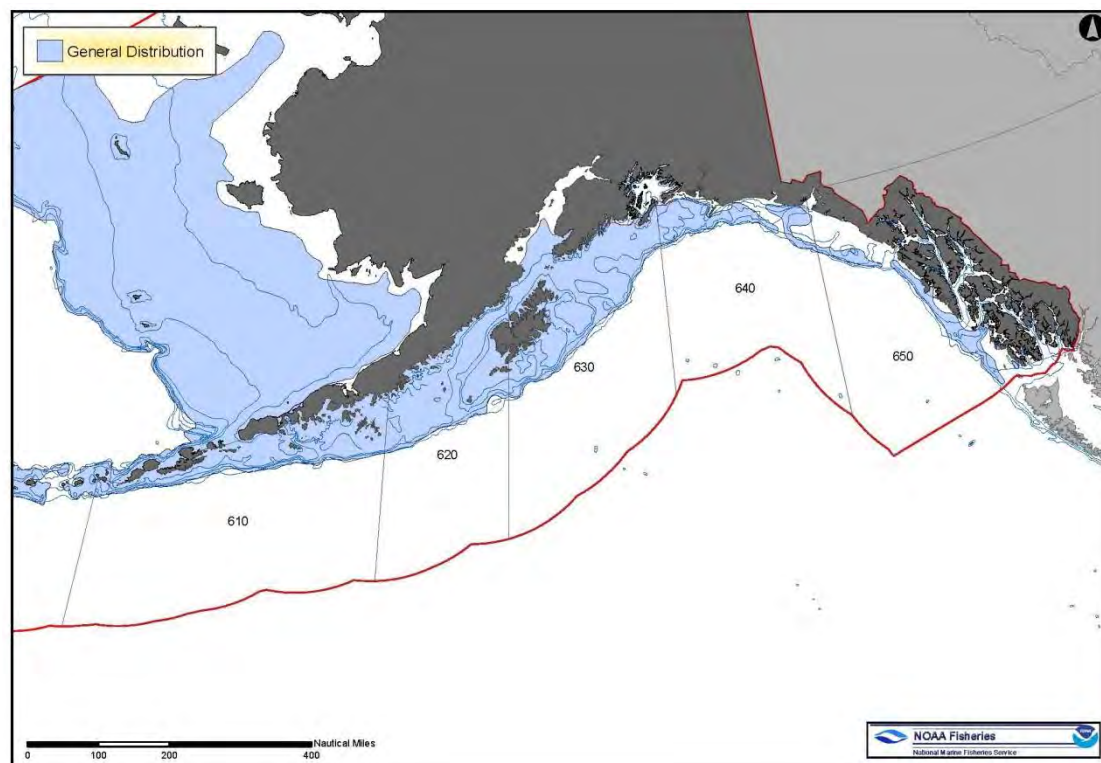
Figure E- 5 EFH Distribution – GOA Pacific Cod (Larvae)**Figure E- 6 EFH Distribution – GOA Pacific Cod (Late Juveniles/Adults)**

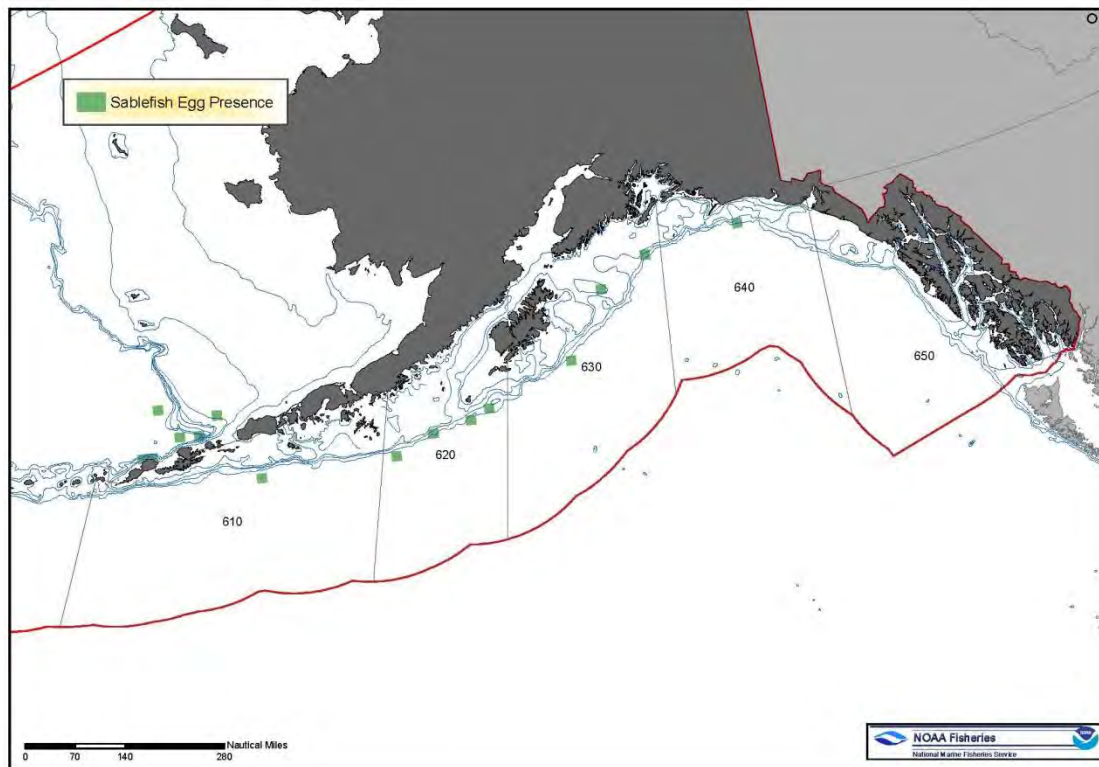
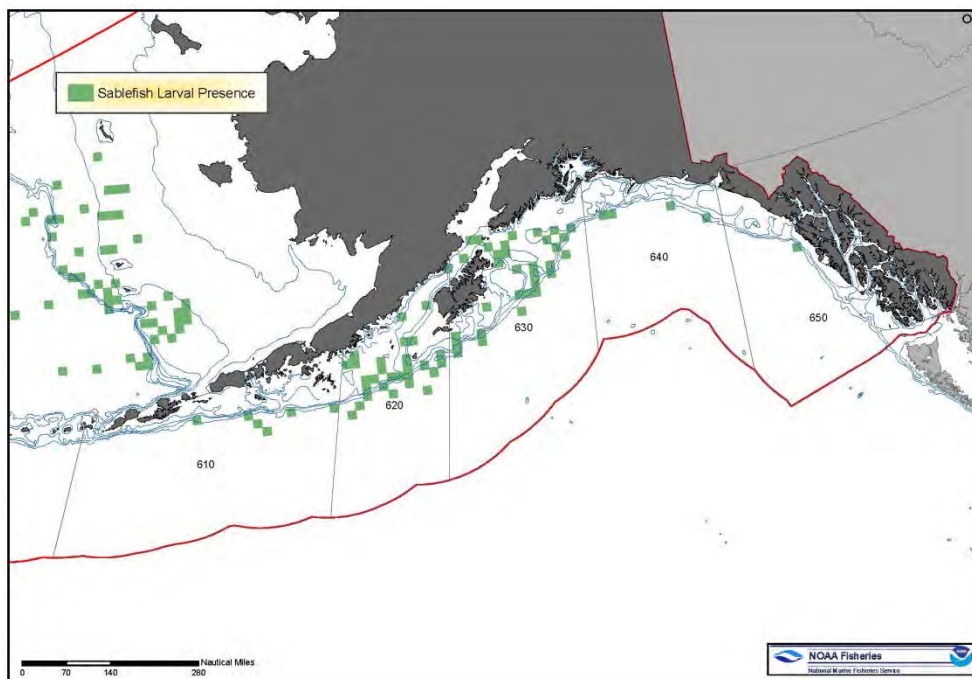
Figure E- 7 EFH Distribution – GOA Sablefish (Eggs)**Figure E- 8 EFH Distribution – GOA Sablefish (Larvae)**

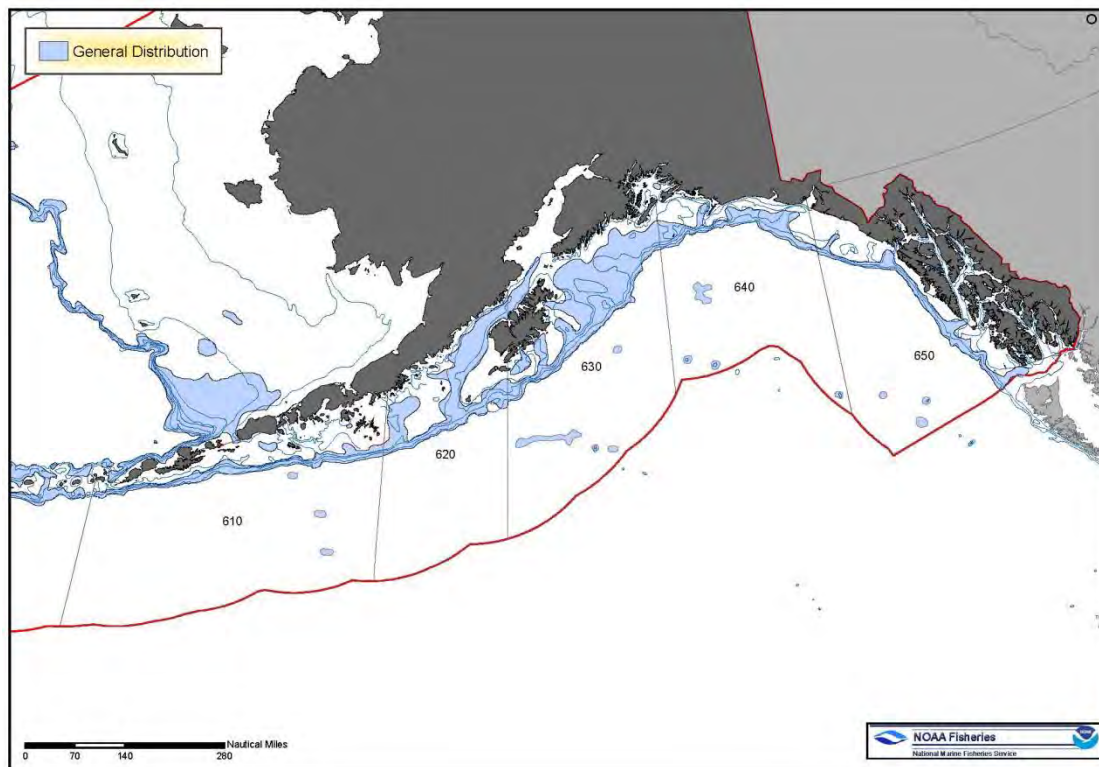
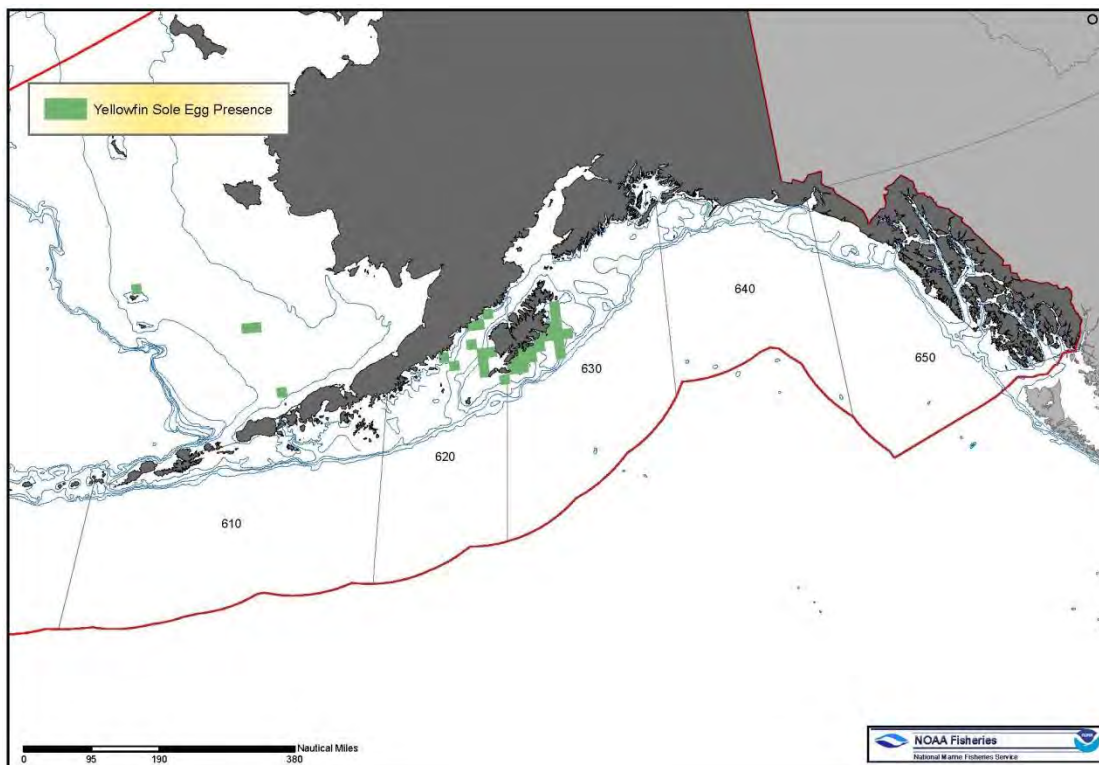
Figure E- 9 EFH Distribution – GOA Sablefish (Late Juveniles/Adults)**Figure E- 10 EFH Distribution – GOA Yellowfin Sole (Eggs)**

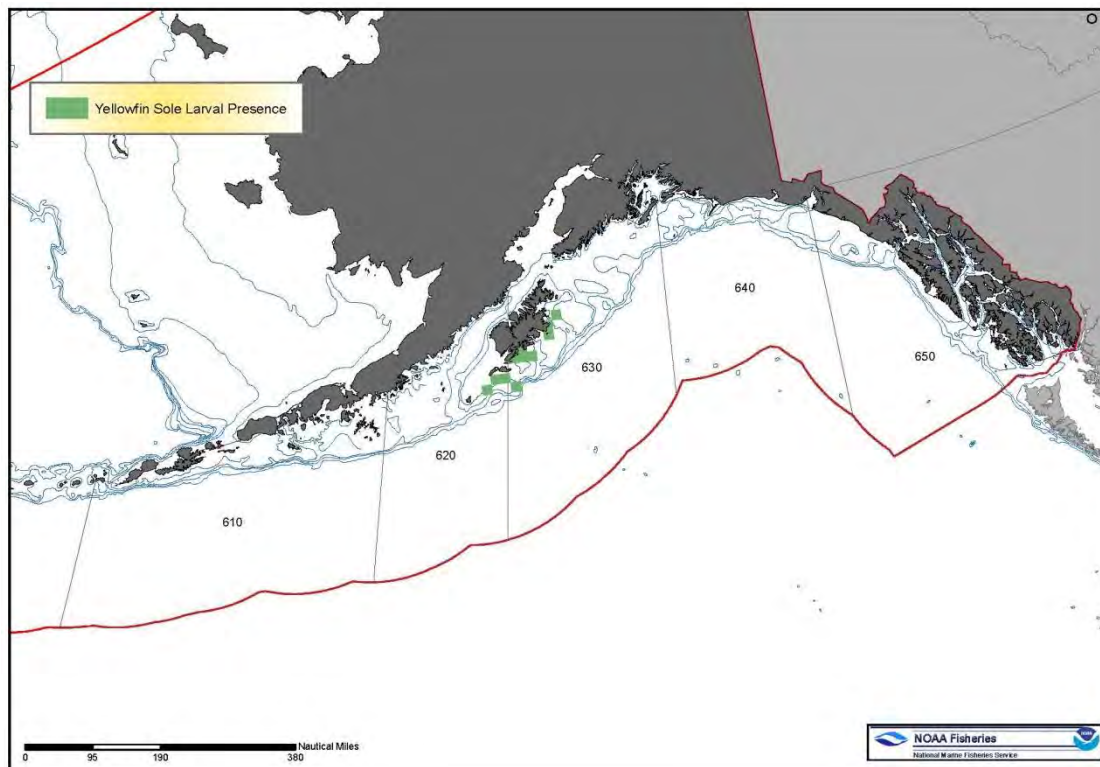
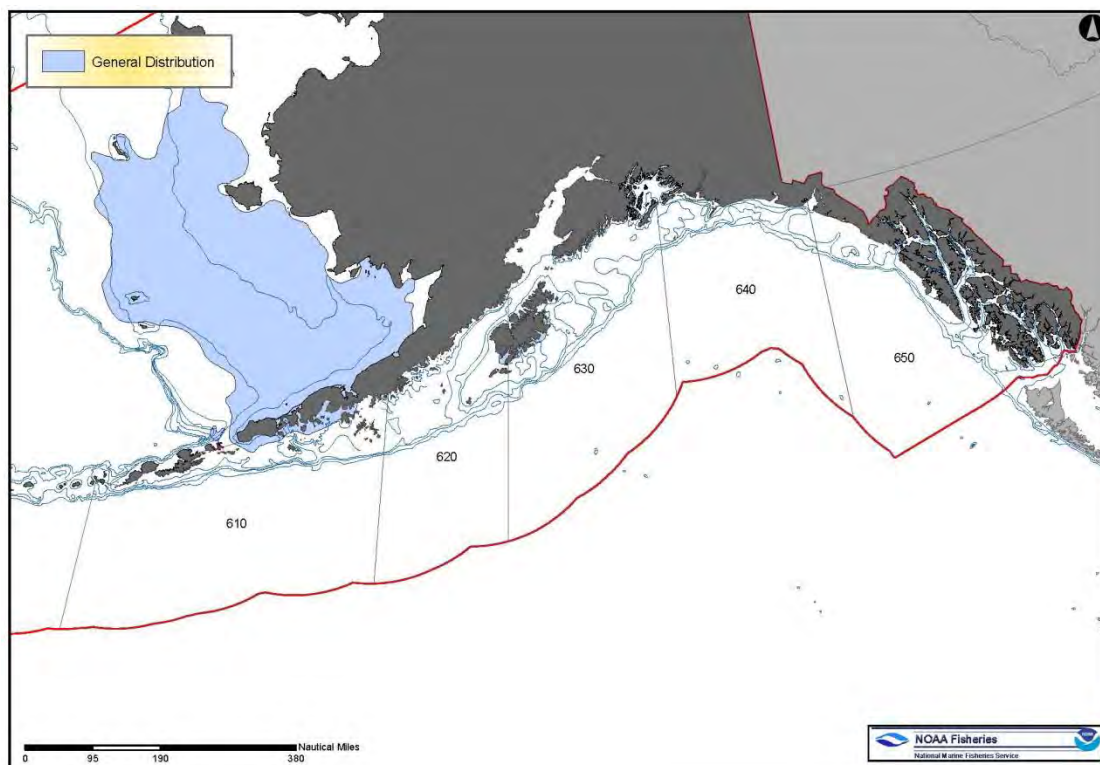
Figure E- 11 EFH Distribution – GOA Yellowfin Sole (Larvae)**Figure E- 12 EFH Distribution – GOA Yellowfin Sole (Late Juveniles/Adults)**

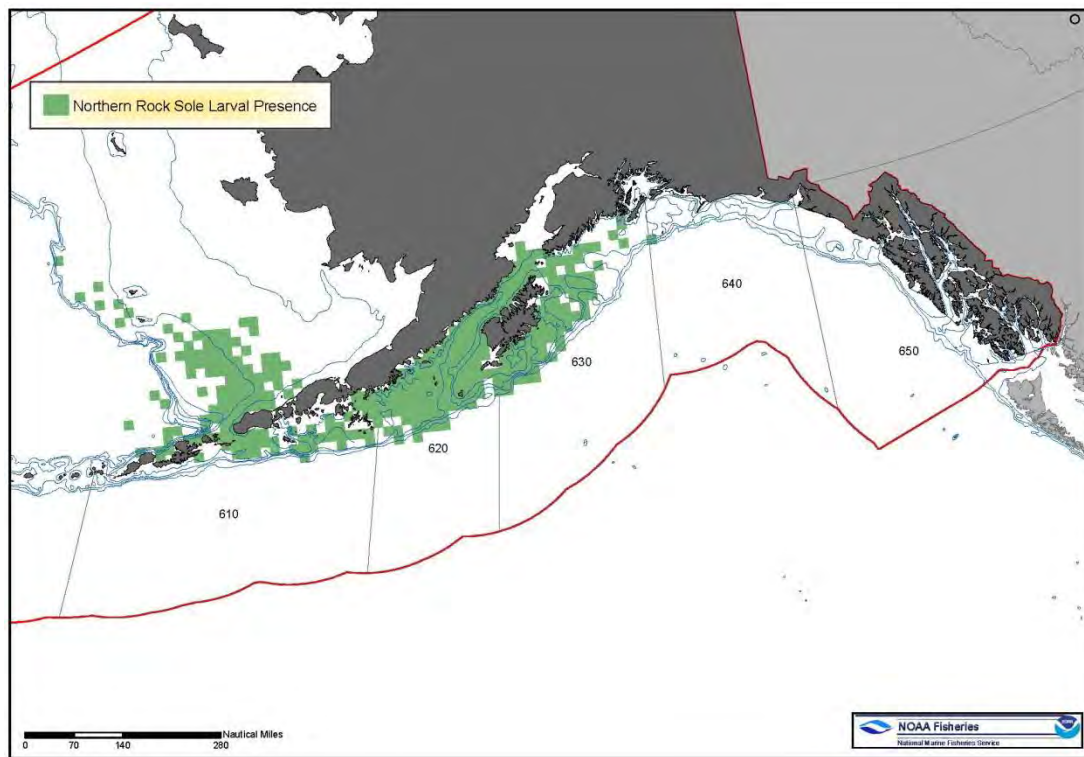
Figure E- 13 EFH Distribution – GOA Rock Sole (Larvae)**Figure E- 14 EFH Distribution – GOA Northern Rock Sole (Late Juveniles/Adults)**

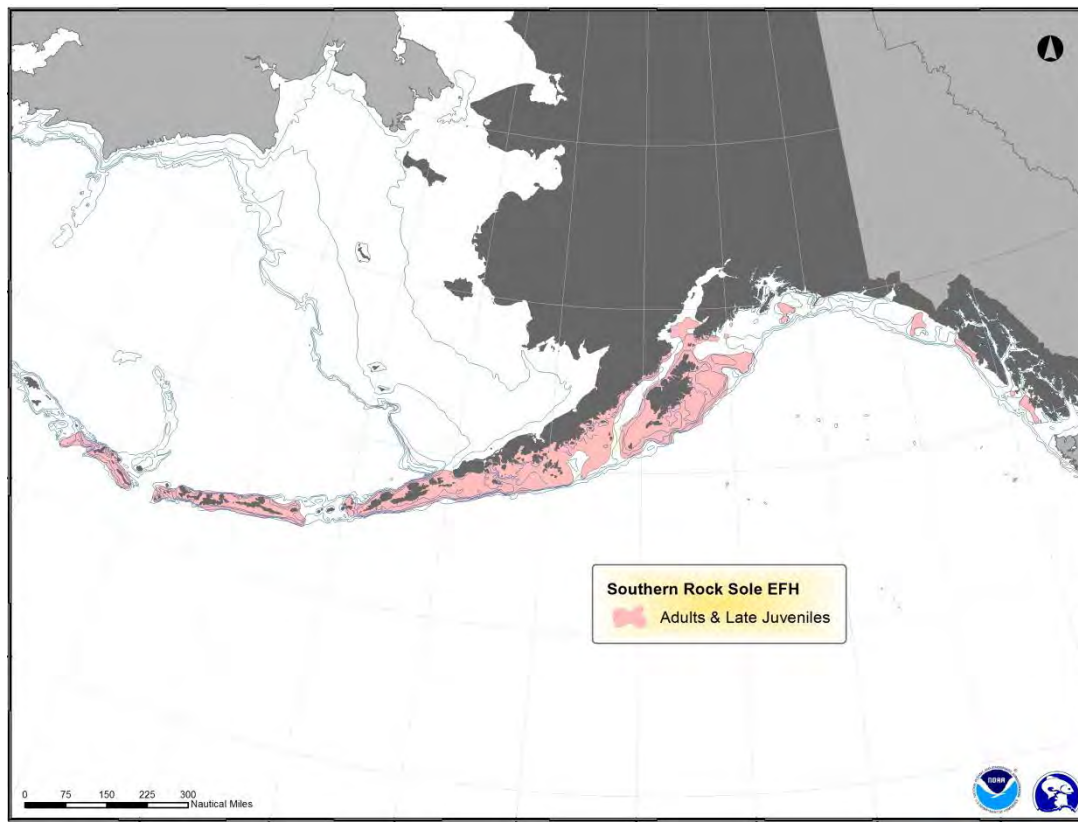
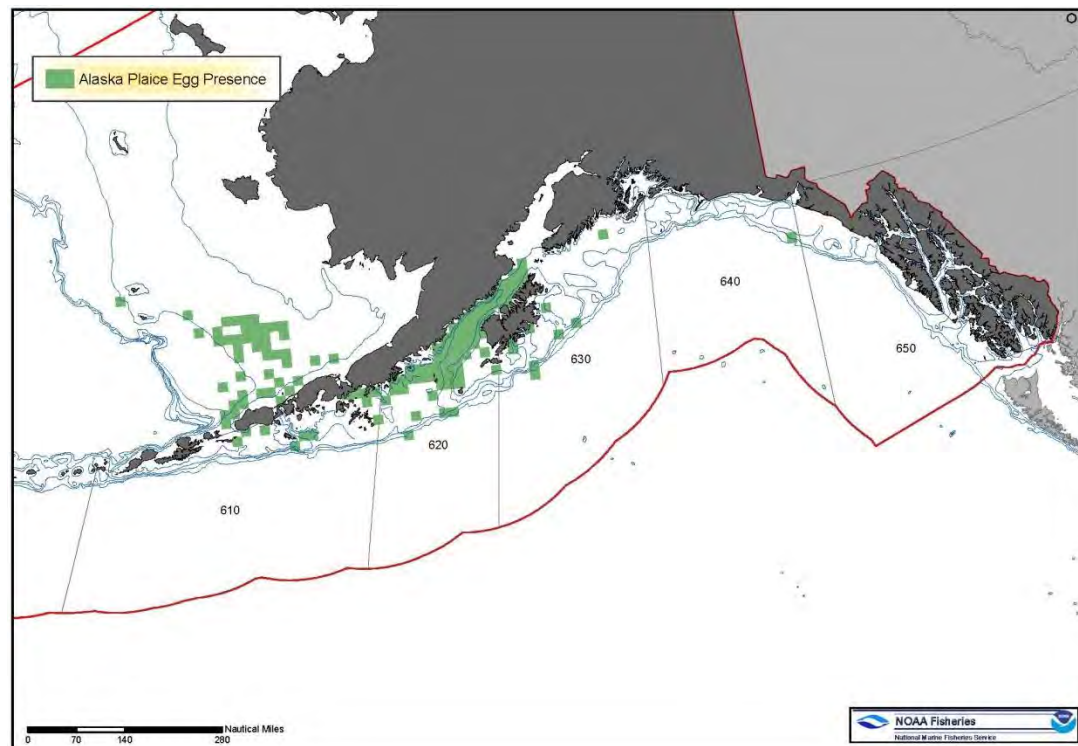
Figure E- 15 EFH Distribution – GOA Southern Rock Sole (Late Juveniles/Adults)**Figure E- 16 EFH Distribution – GOA Alaska Plaice (Eggs)**

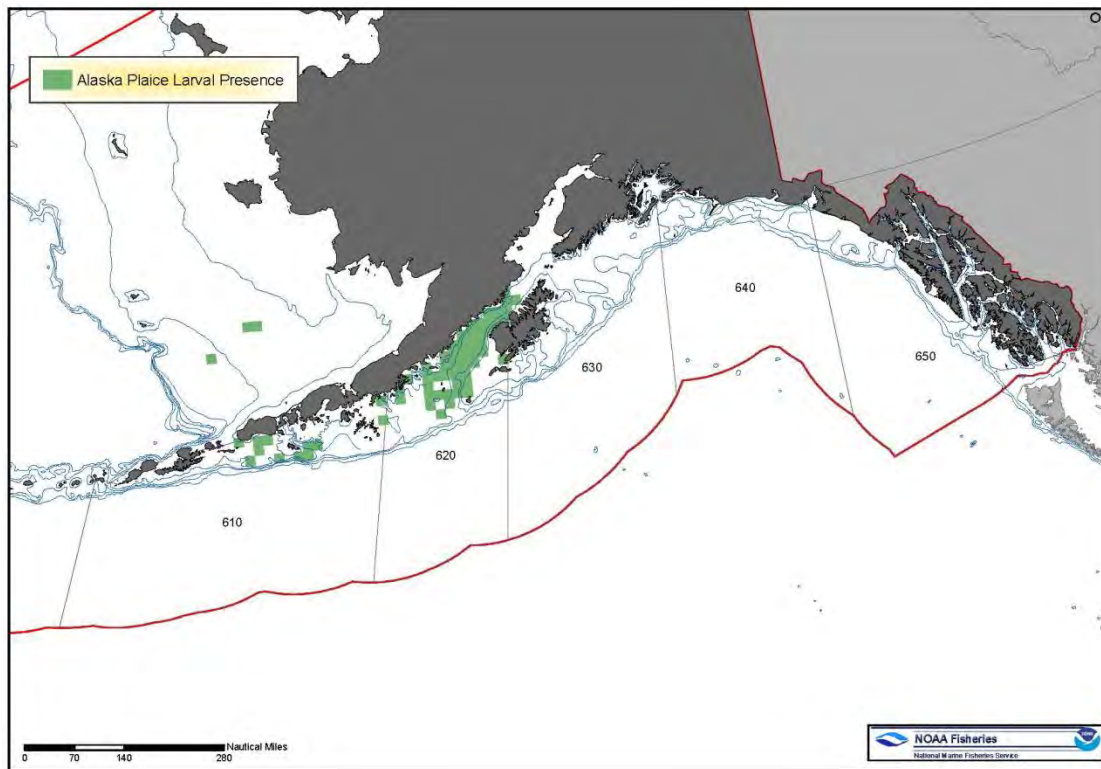
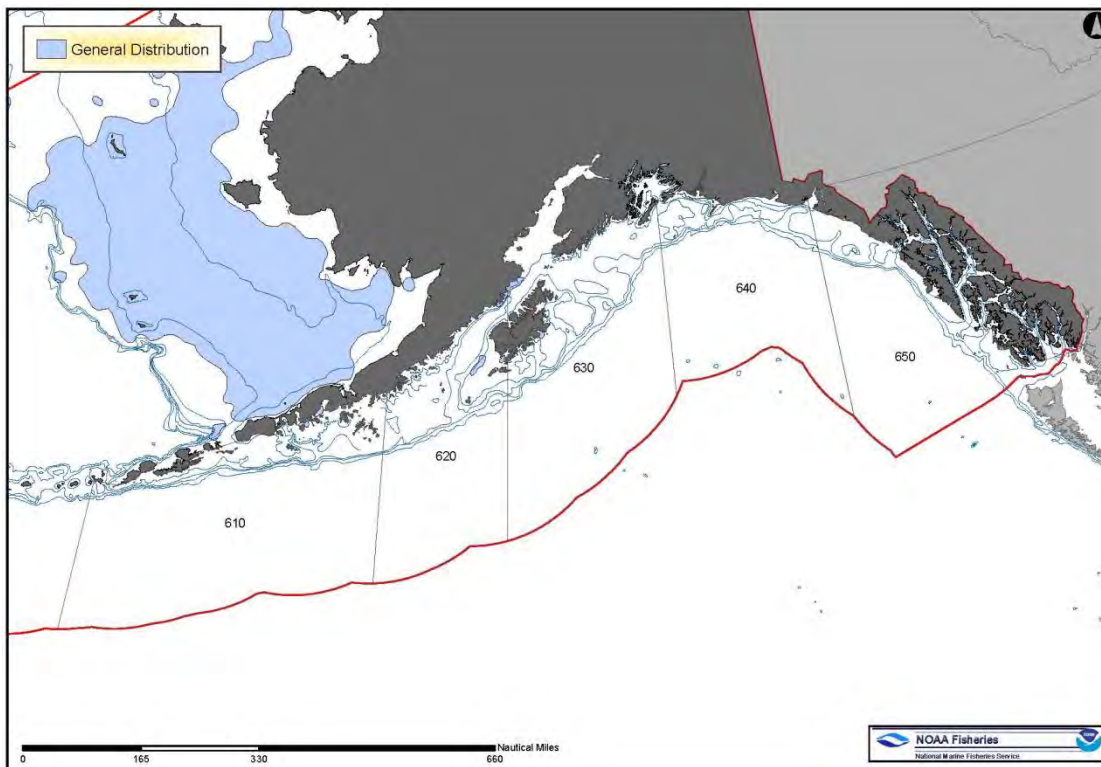
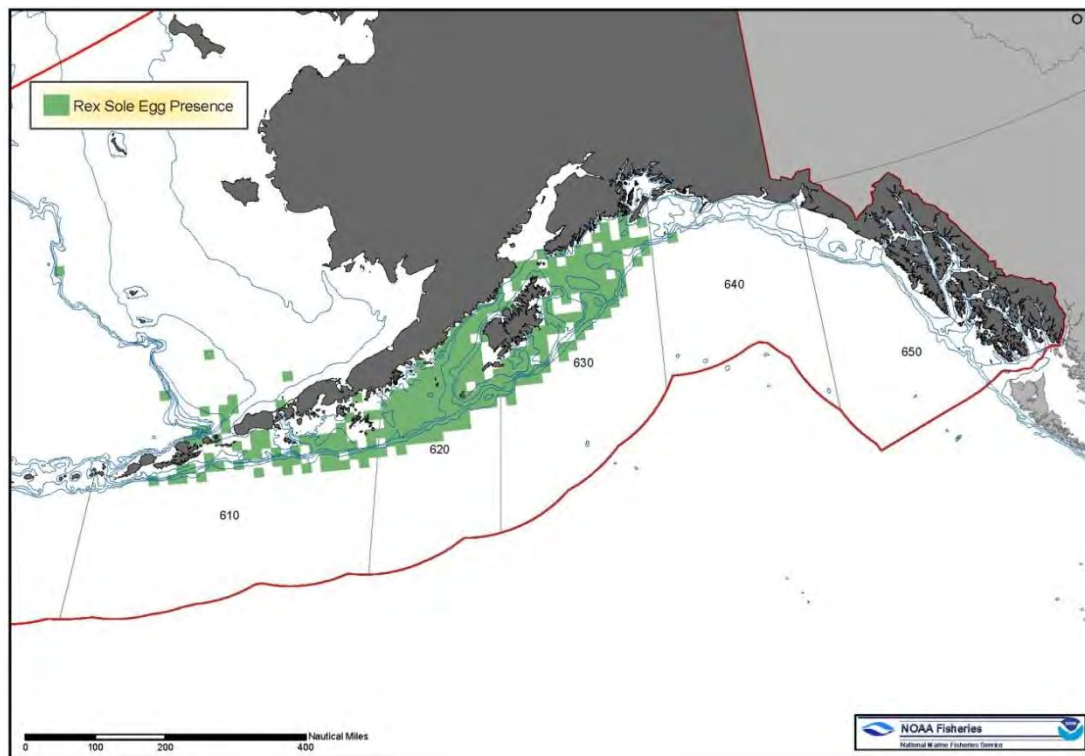
Figure E- 17 EFH Distribution – GOA Alaska Plaice (Larvae)**Figure E- 18 EFH Distribution – GOA Alaska Plaice (Late Juveniles/Adults)**

Figure E- 19 EFH Distribution – GOA Rex Sole (Eggs)**Figure E- 20 EFH Distribution – GOA Rex Sole (Larvae)**

Note, EFH distribution includes both green boxes and black crosses.

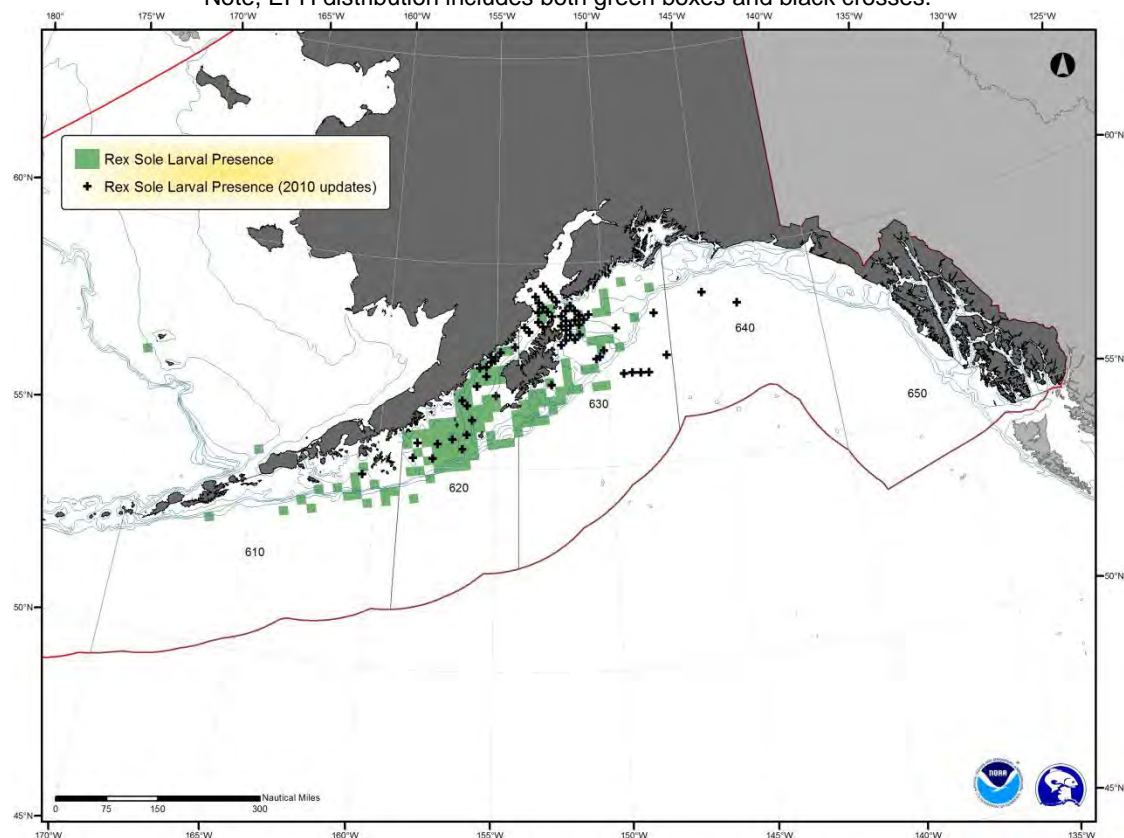


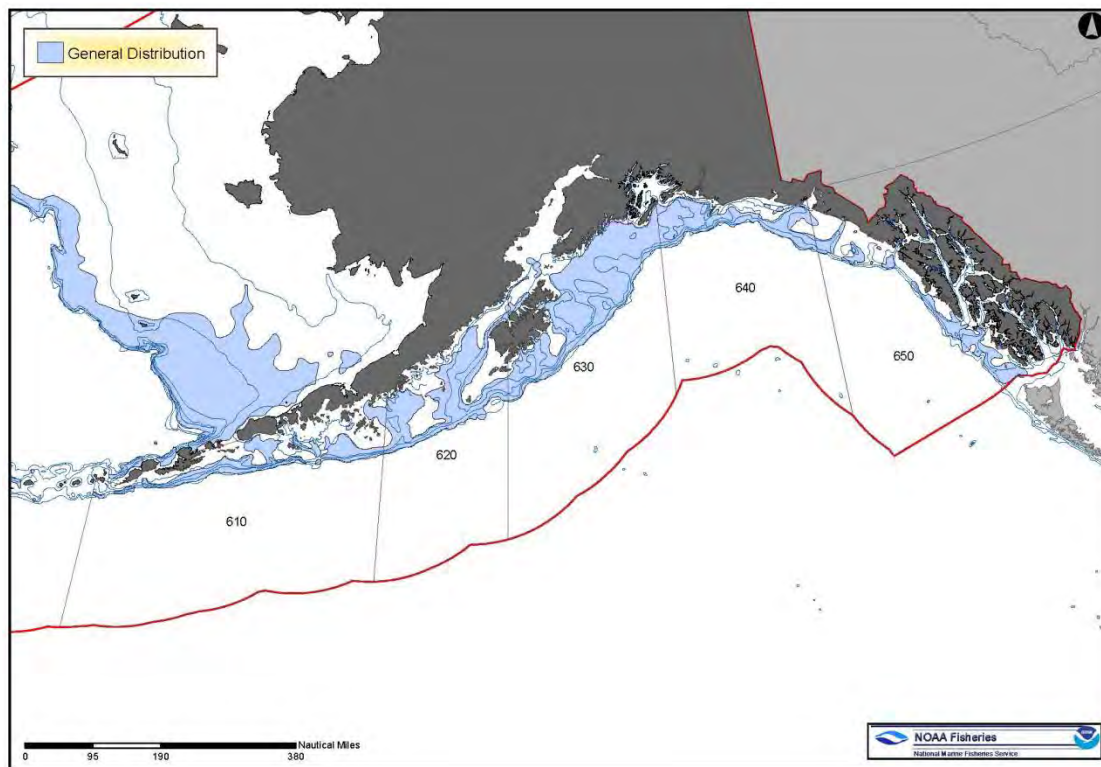
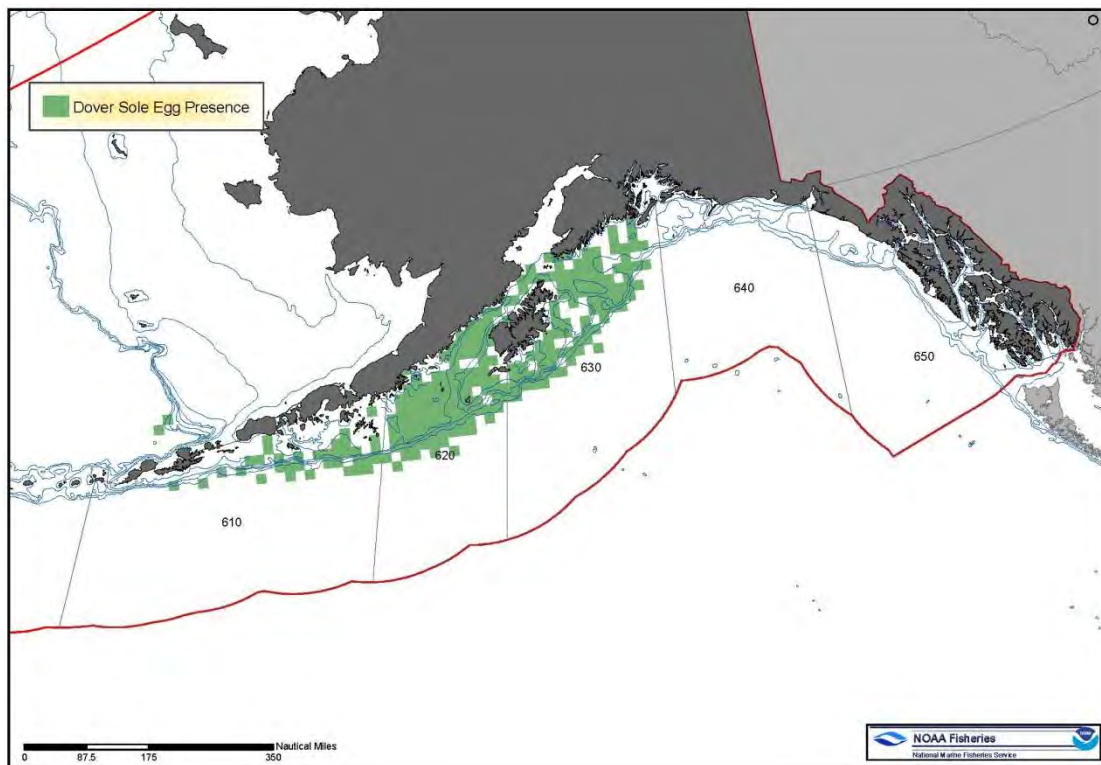
Figure E- 21 EFH Distribution – GOA Rex Sole (Late Juveniles/Adults)**Figure E- 22 EFH Distribution – GOA Dover Sole (Eggs)**

Figure E- 23 EFH Distribution – GOA Dover Sole (Larvae)

Note, EFH distribution includes both green boxes and black crosses.

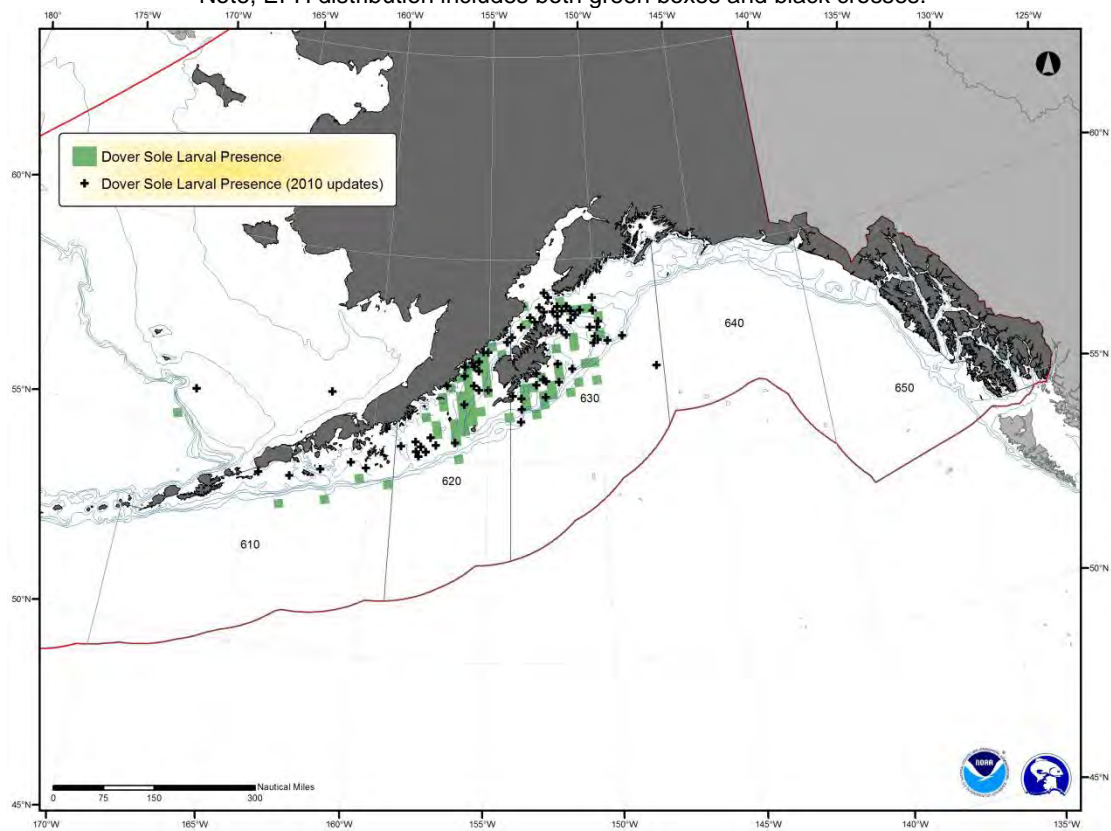
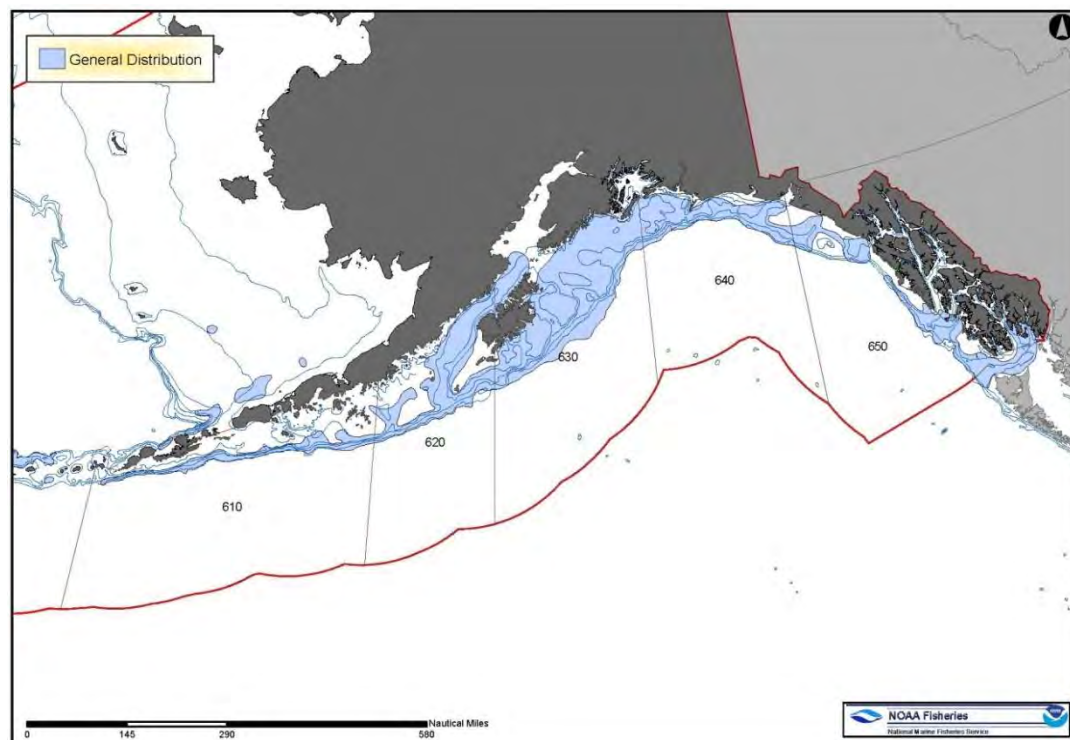
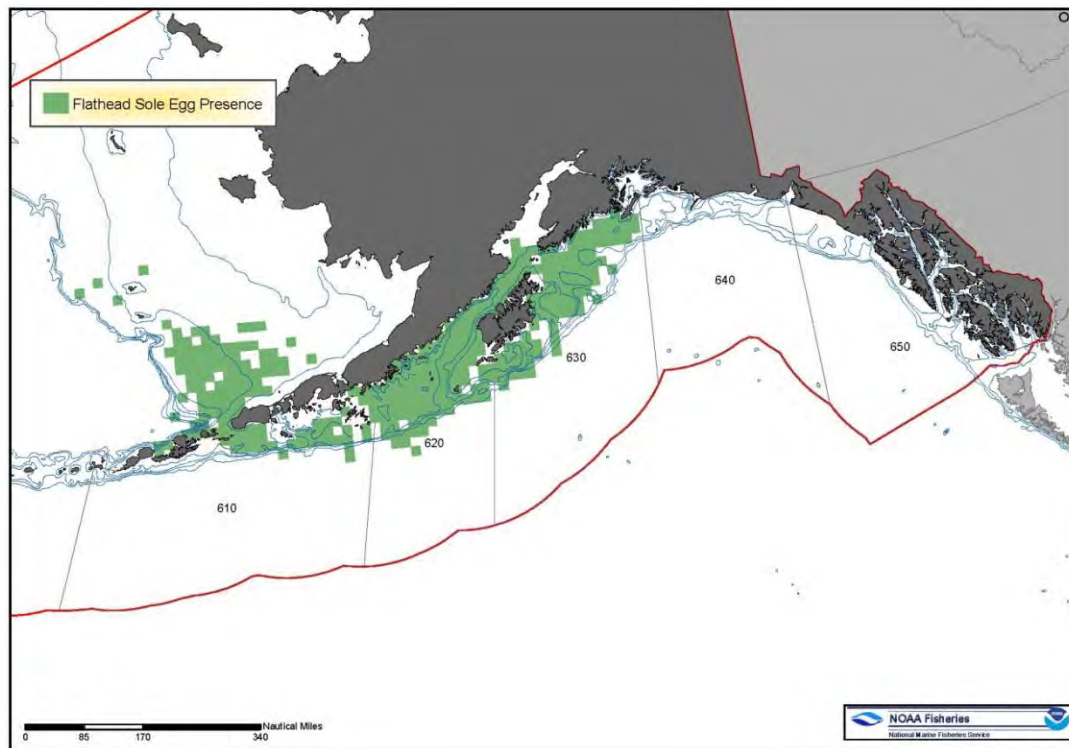
**Figure E- 24 EFH Distribution – GOA Dover Sole (Late Juveniles/Adults)**

Figure E- 25 EFH Distribution – GOA Flathead Sole (Eggs)**Figure E- 26 EFH Distribution – GOA Flathead Sole (Larvae)**

Note, EFH distribution includes both green boxes and black crosses.

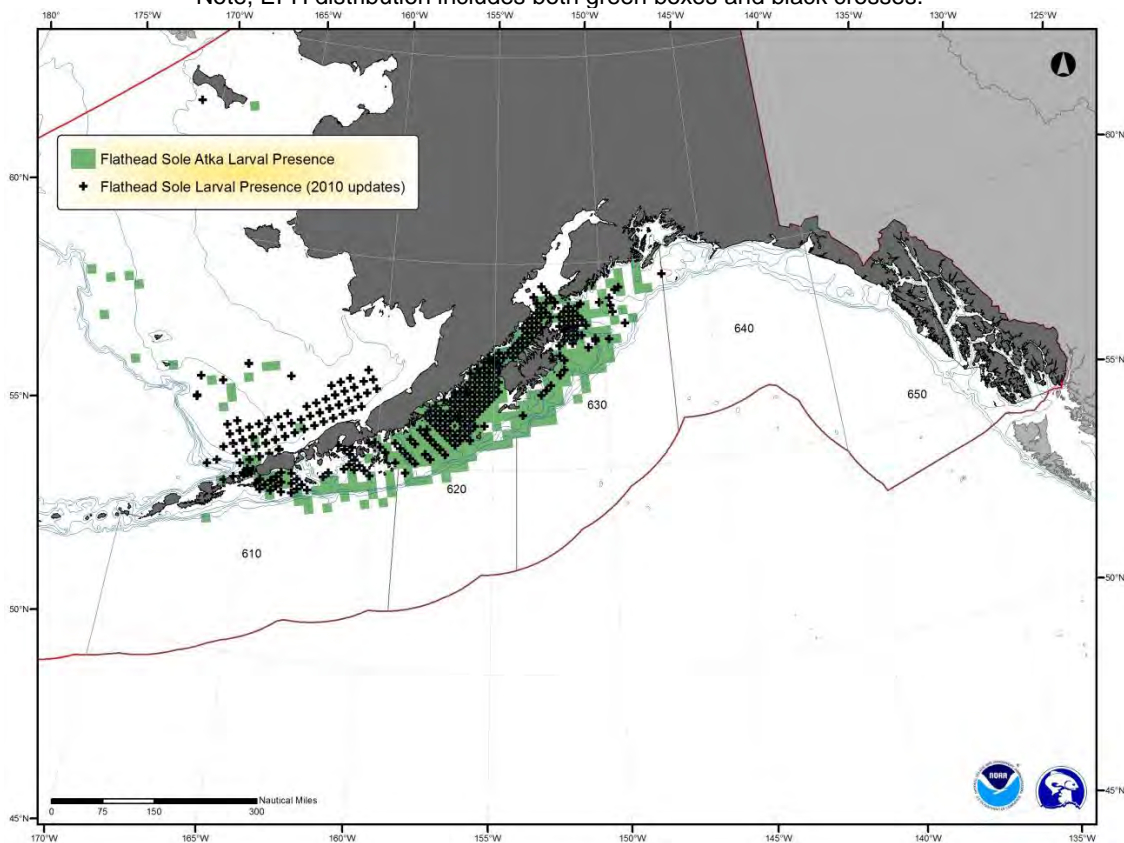


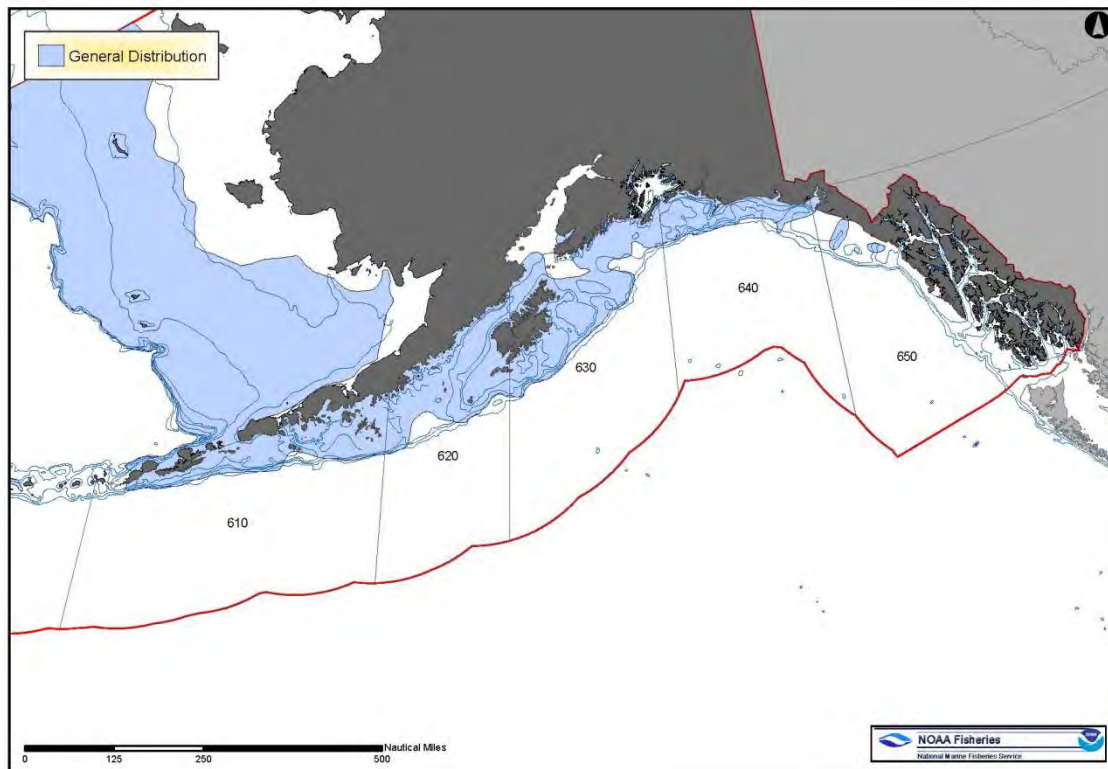
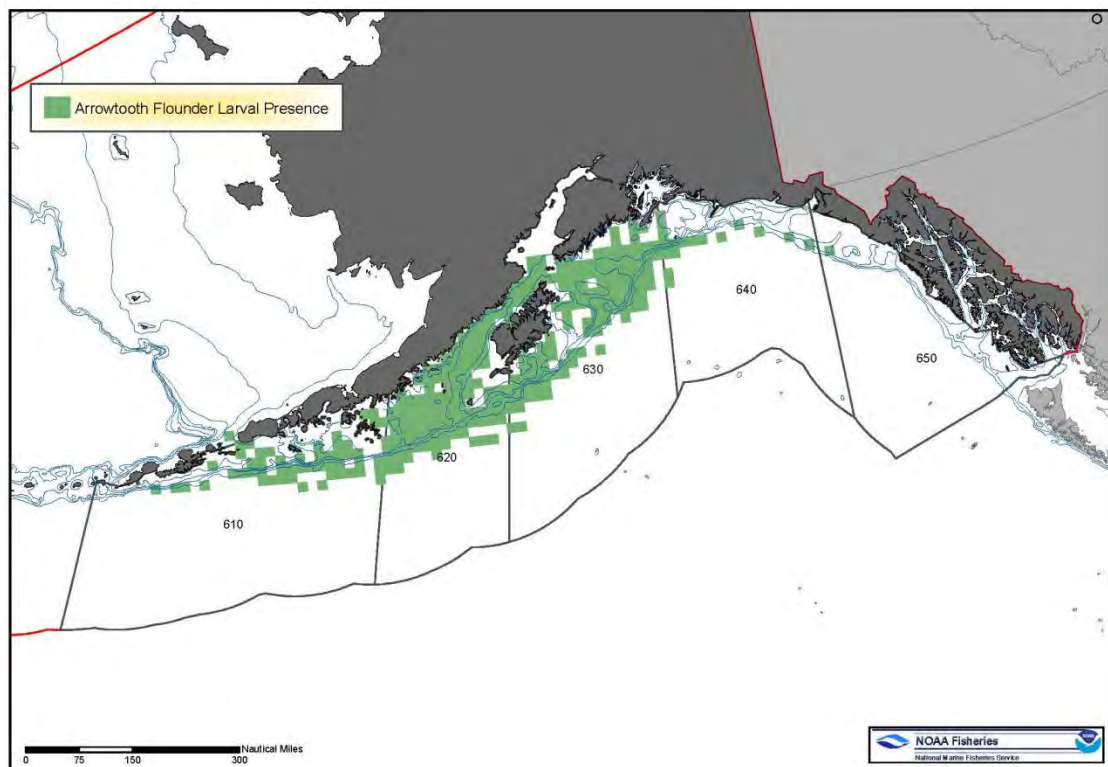
Figure E- 27 EFH Distribution – GOA Flathead Sole (Late Juveniles/Adults)**Figure E- 28 EFH Distribution – GOA Arrowtooth Flounder (Larvae)**

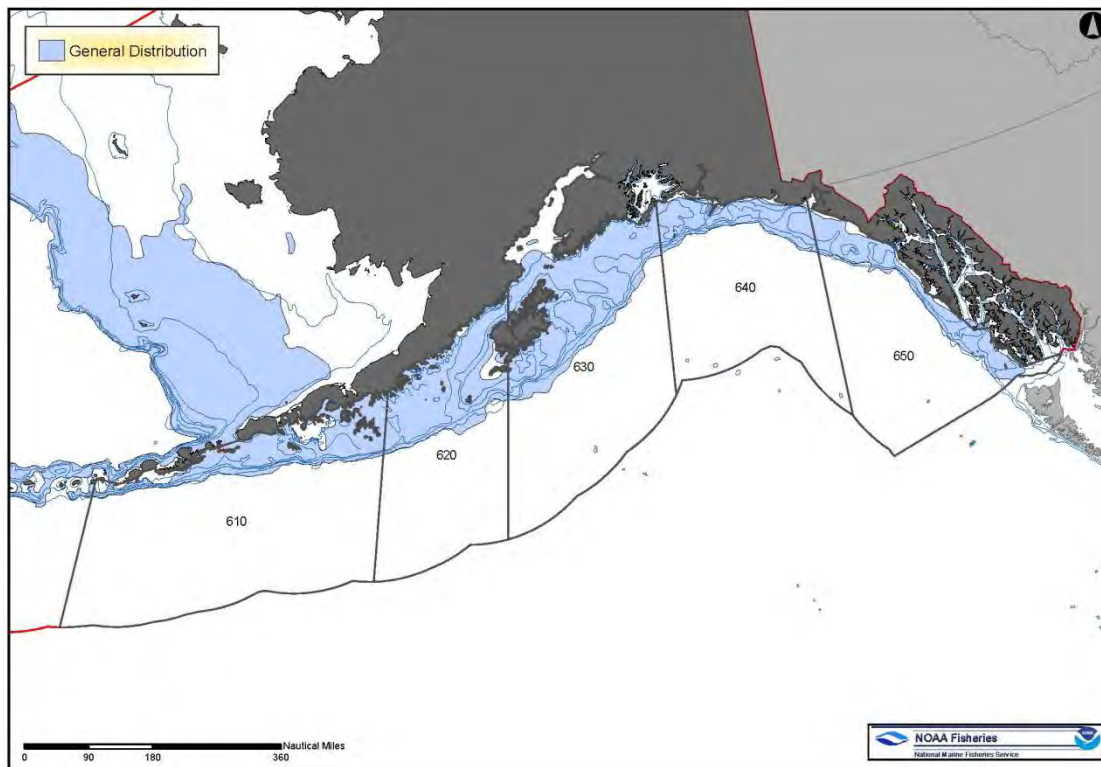
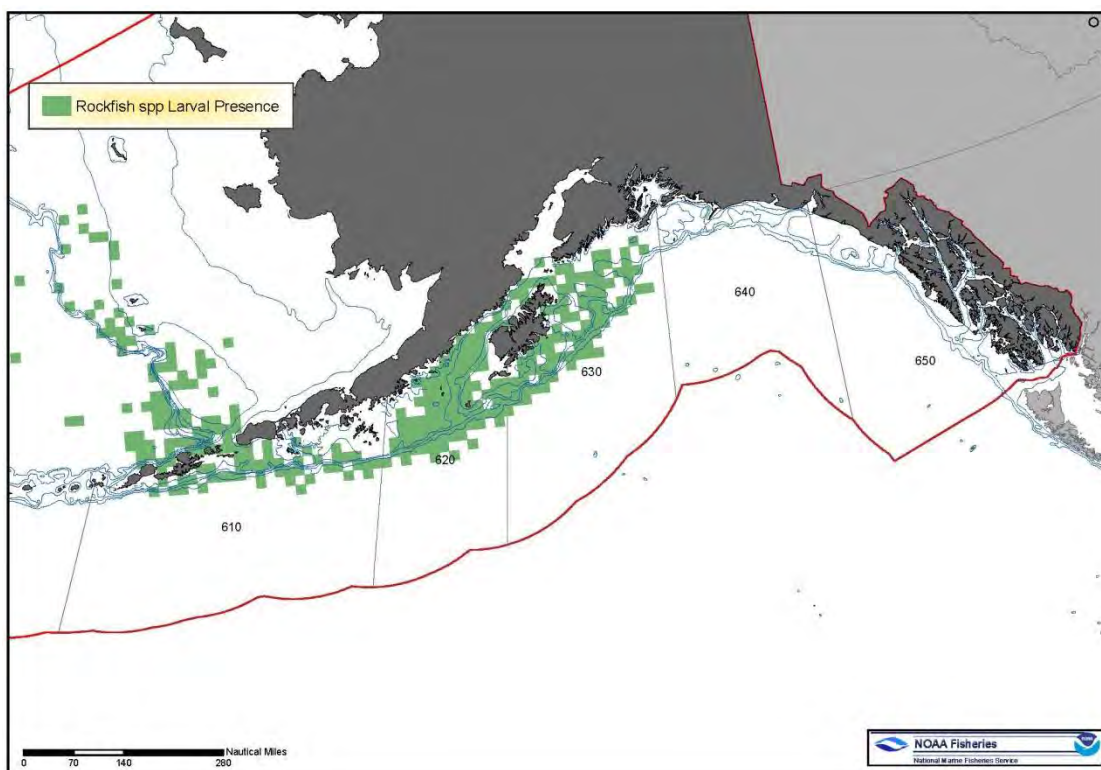
Figure E- 29 EFH Distribution – GOA Arrowtooth Flounder (Late Juveniles/Adults)**Figure E- 30 EFH Distribution – GOA Rockfish (Larvae)**

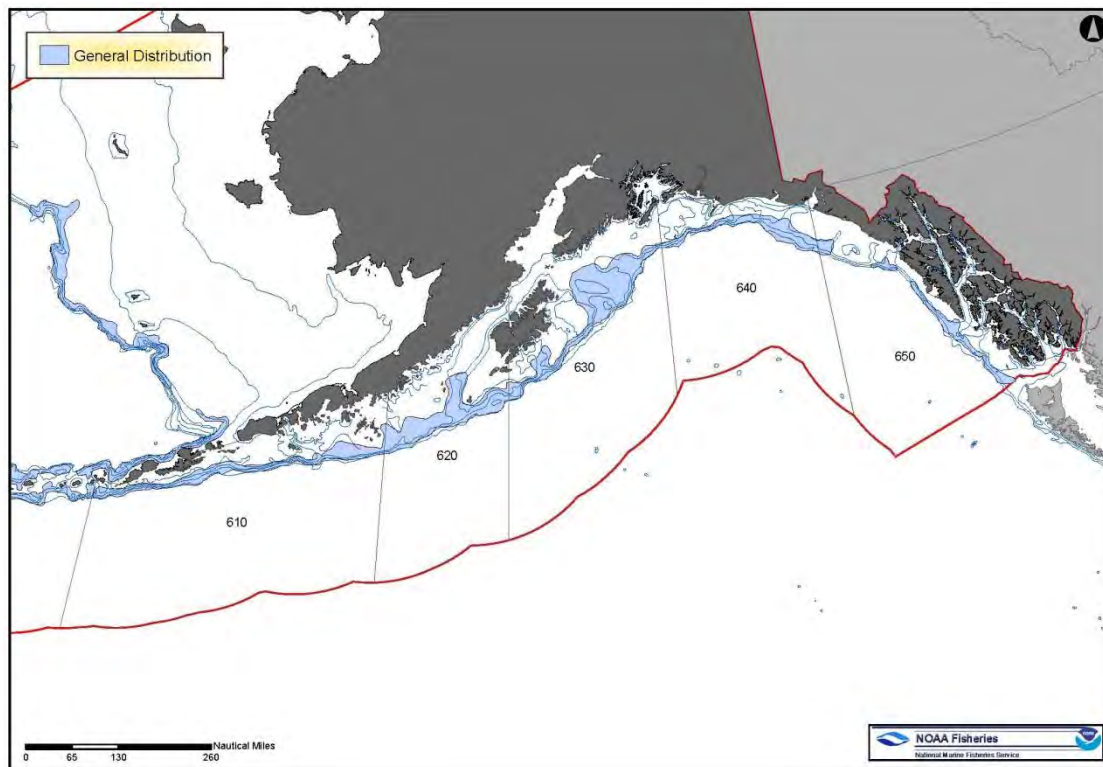
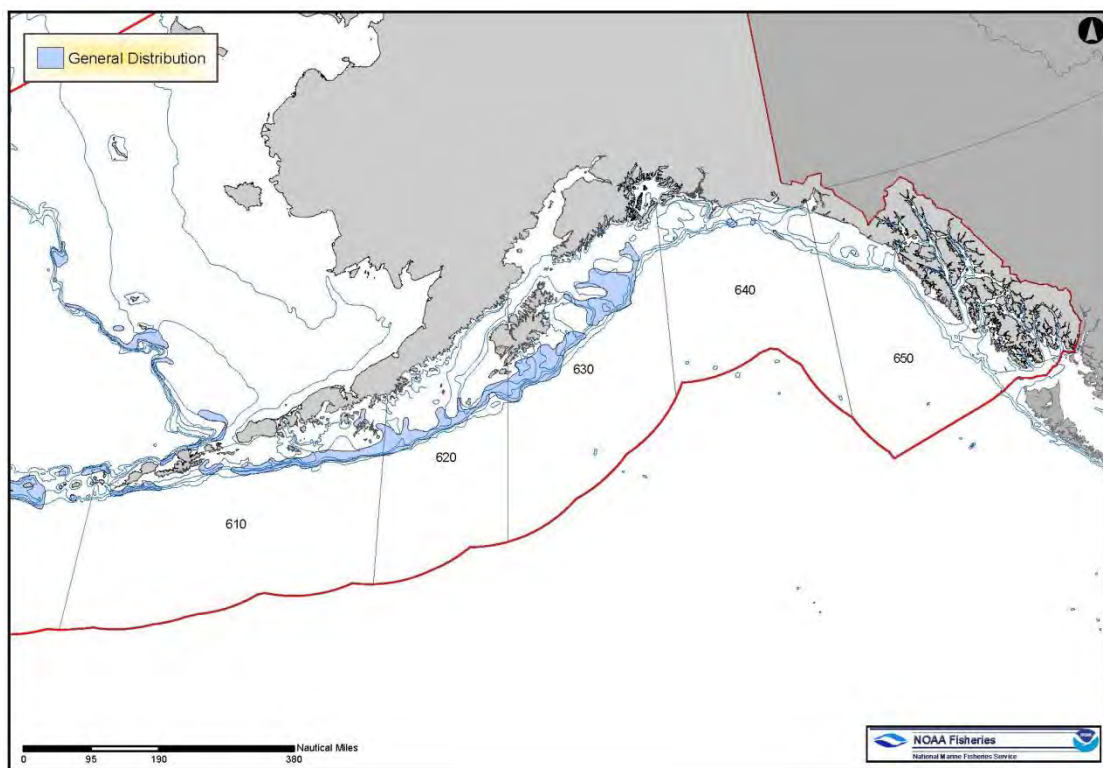
Figure E- 31 EFH Distribution – GOA Pacific Ocean Perch (Late Juveniles/Adults)**Figure E- 32 EFH Distribution – GOA Northern Rockfish (Late Juveniles/Adults)**

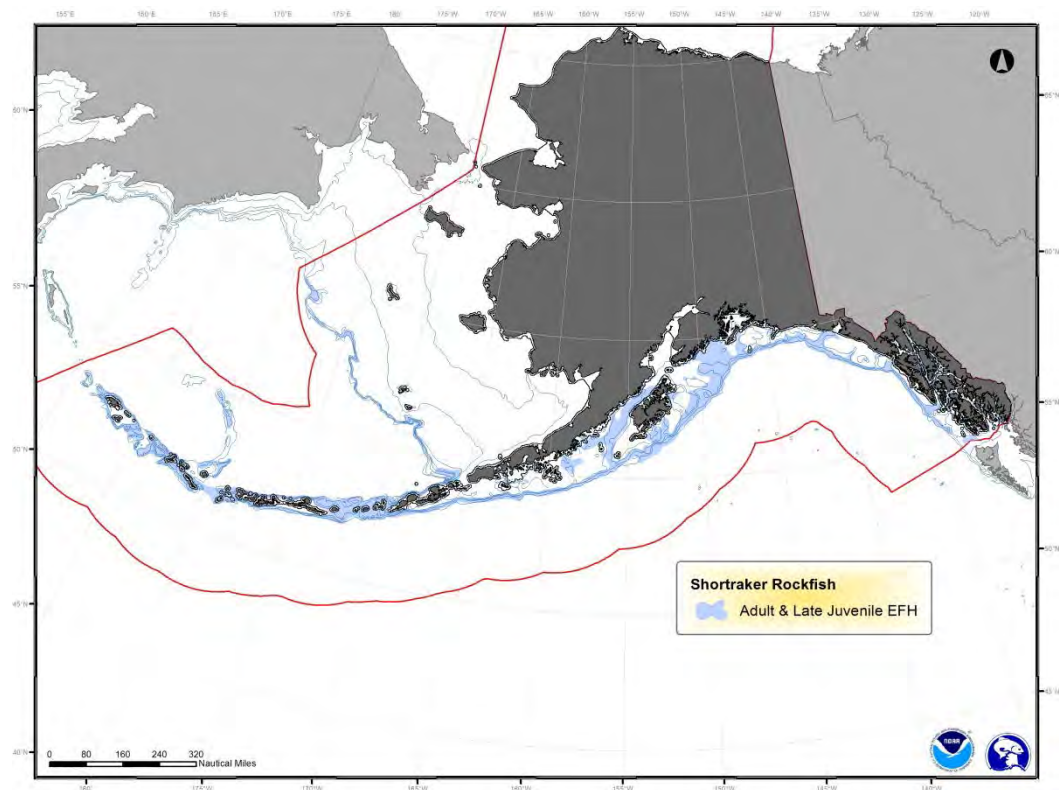
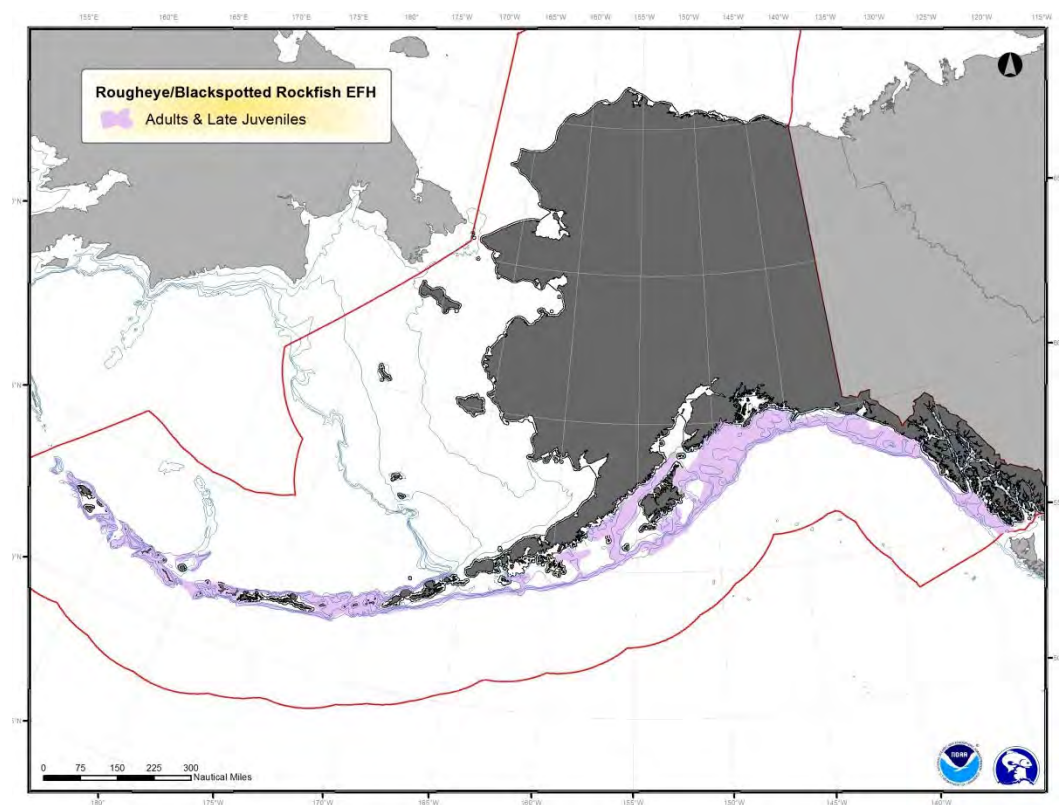
Figure E- 33 EFH Distribution – GOA Shortraker Rockfish (Late Juveniles/Adults)**Figure E- 34 EFH Distribution – GOA Blackspotted/Rougheye Rockfish (Late Juveniles/Adults)**

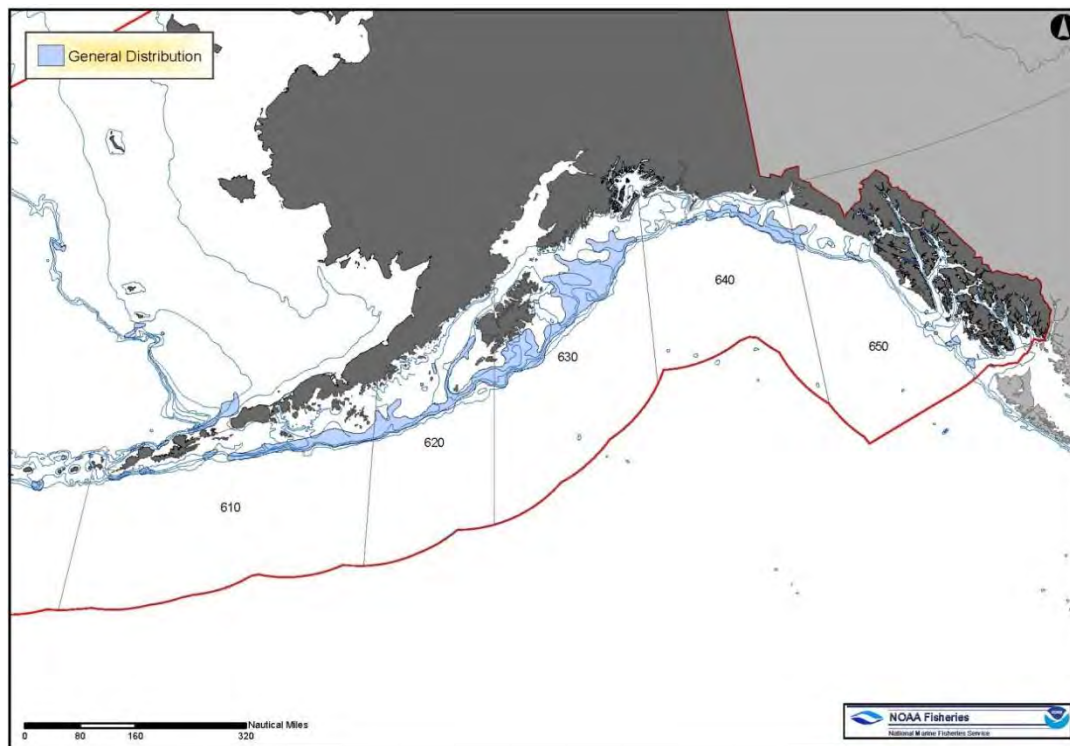
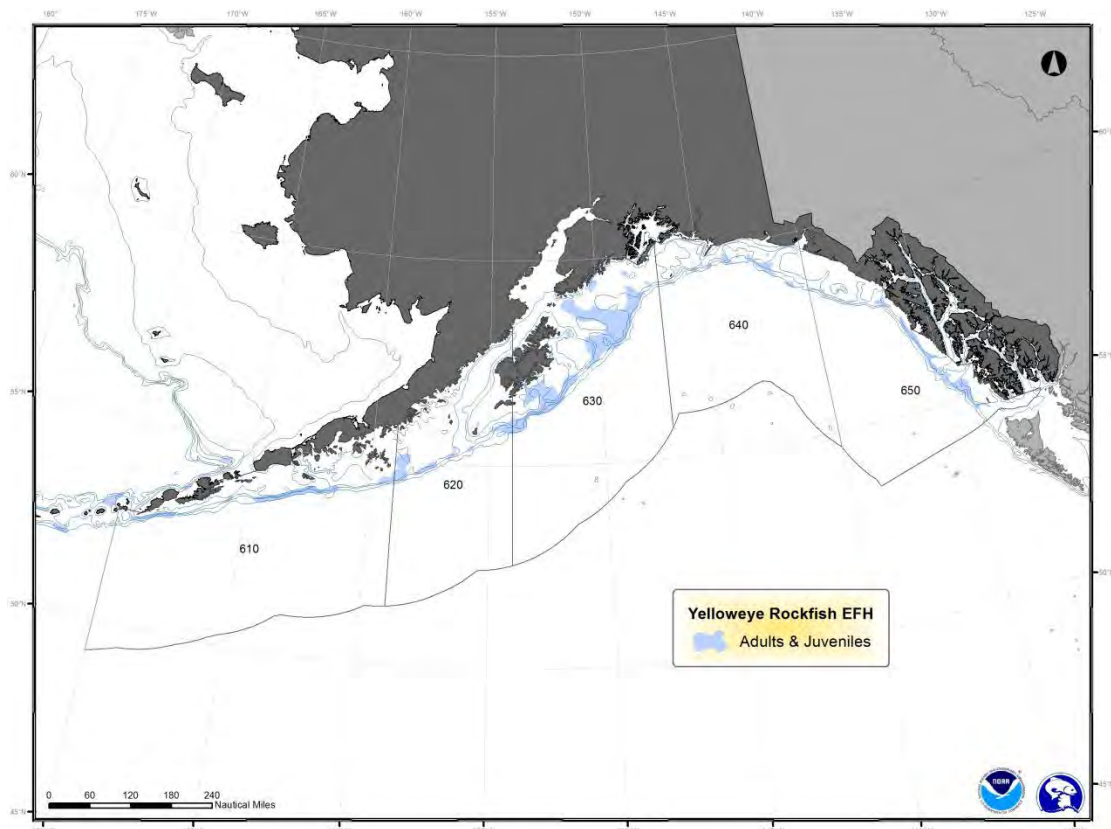
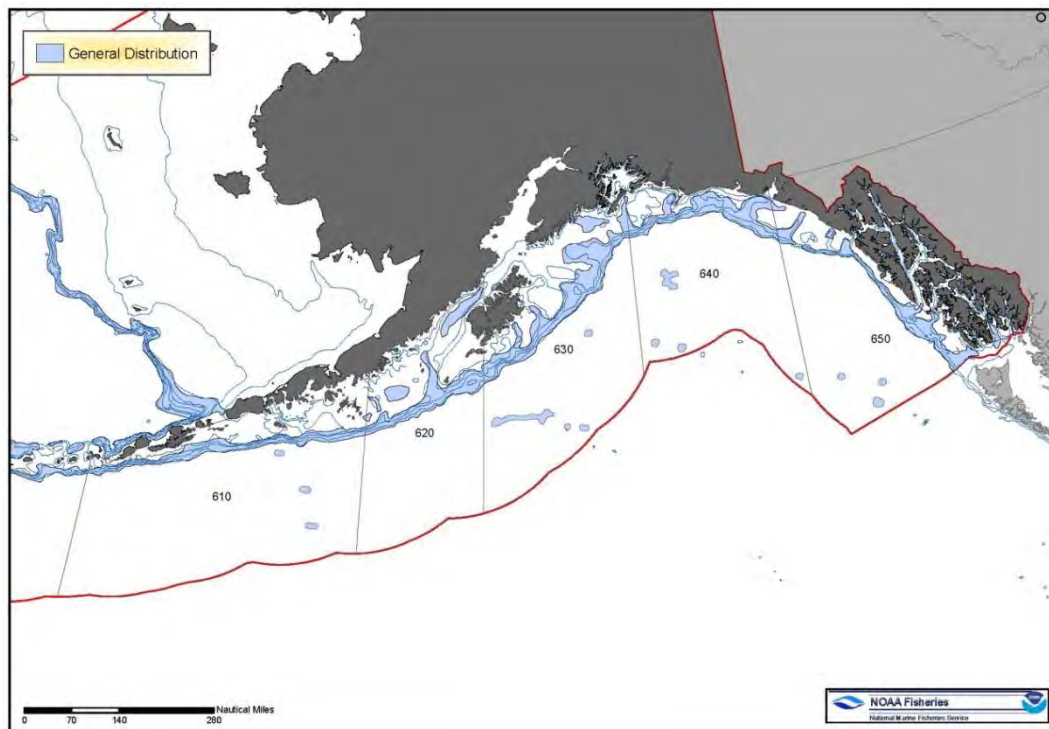
Figure E- 35 EFH Distribution – GOA Dusky Rockfish (Adults)**Figure E- 36 EFH Distribution – GOA Yelloweye Rockfish (Juveniles/Adults)**

Figure E- 37 EFH Distribution – GOA Thornyhead Rockfish (Late Juveniles/Adults)**Figure E- 38 EFH Distribution – GOA Atka Mackerel (Eggs)**

Note, map indicates known locations of Atka mackerel eggs, but is likely not all-inclusive.

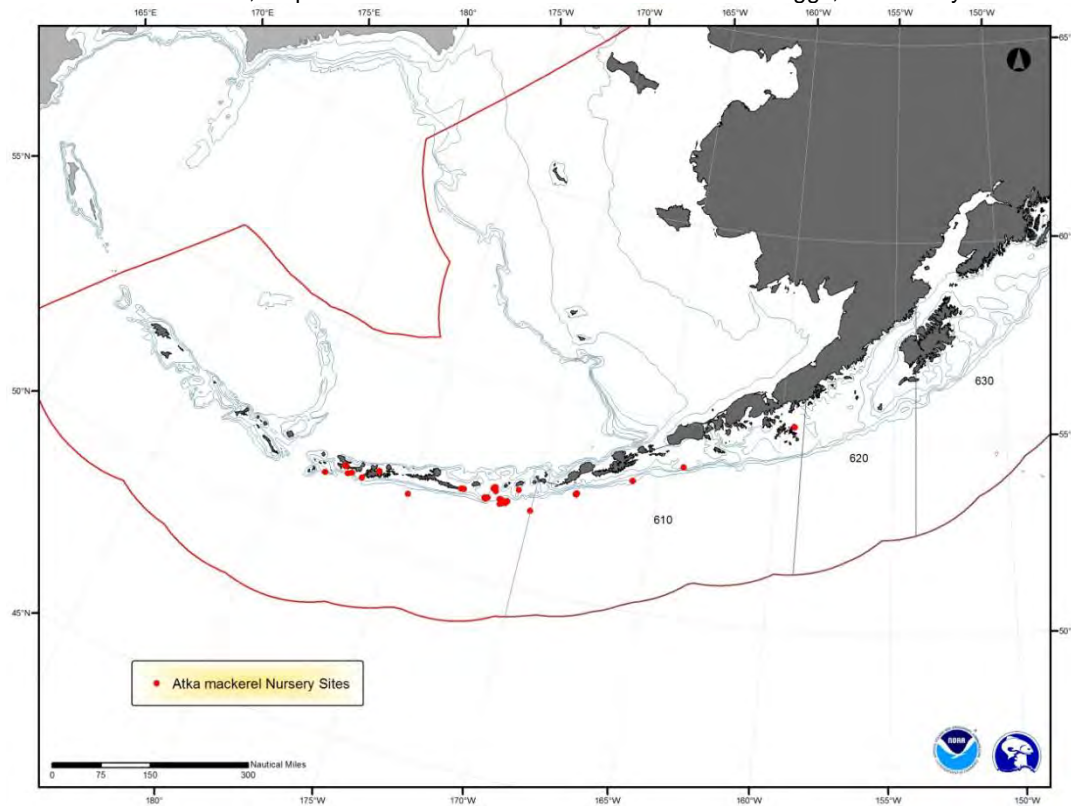


Figure E- 39 EFH Distribution – GOA Atka Mackerel (Larvae)

Note, EFH distribution includes both green boxes and black crosses.

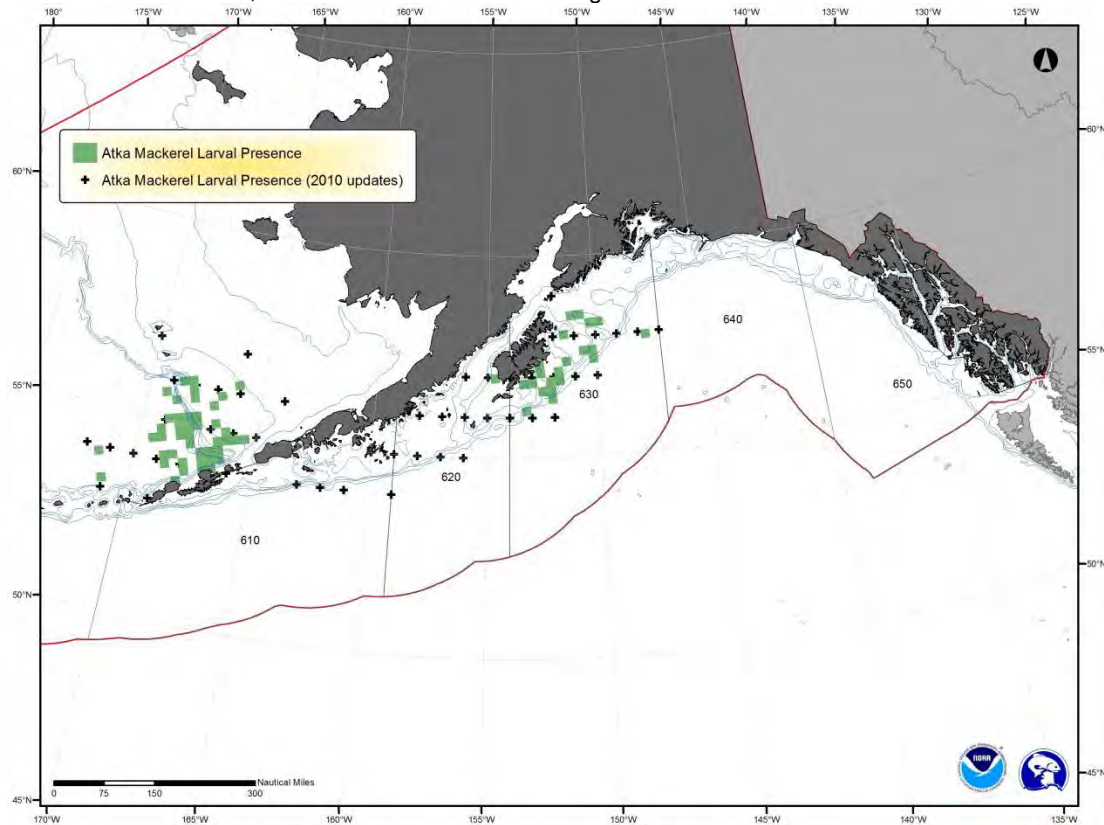
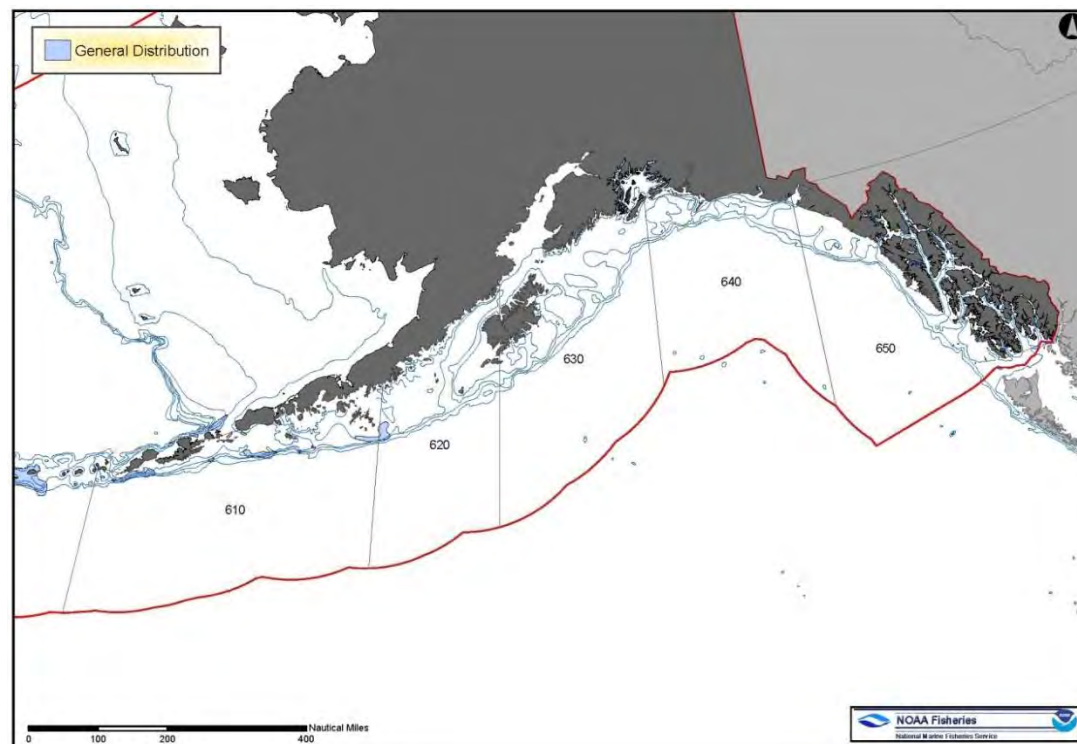
**Figure E- 40 EFH Distribution – GOA Atka Mackerel (Late Juveniles/Adults)**

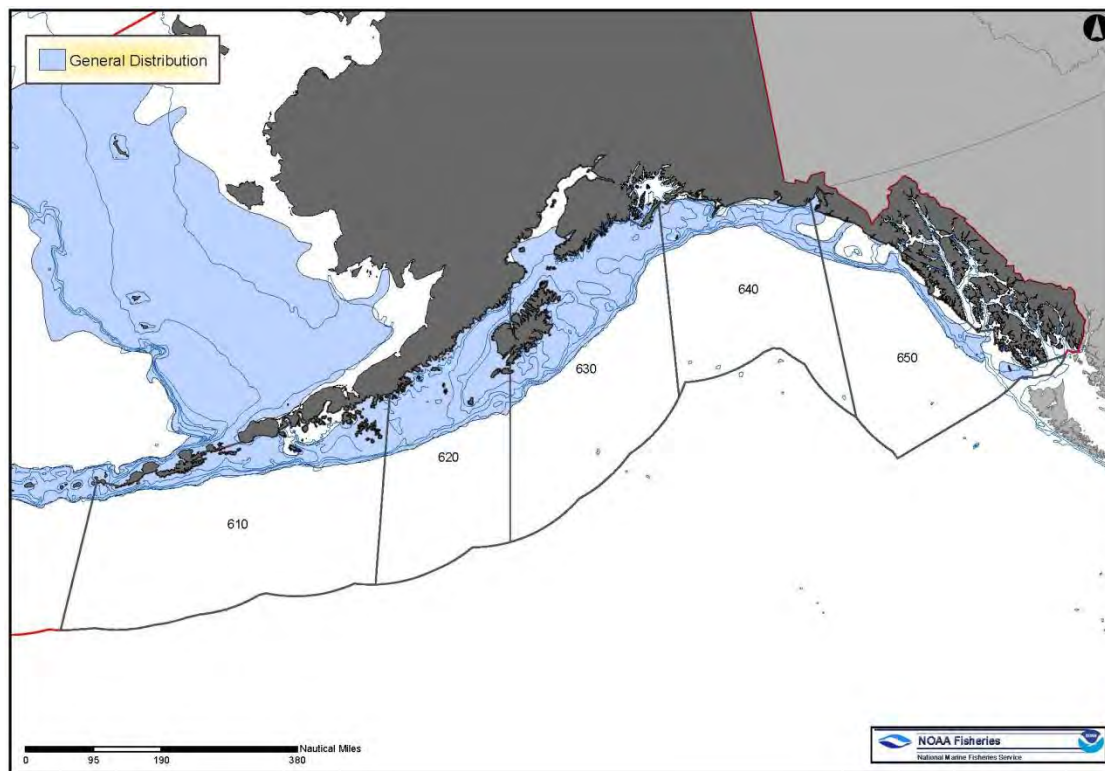
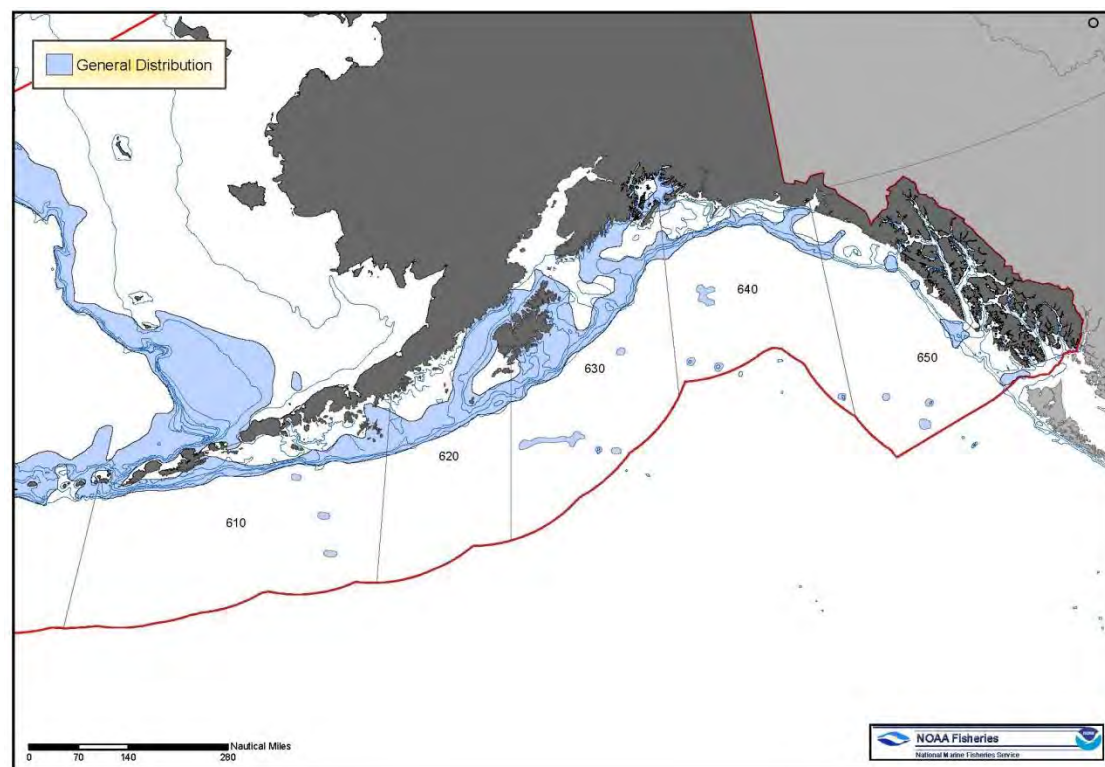
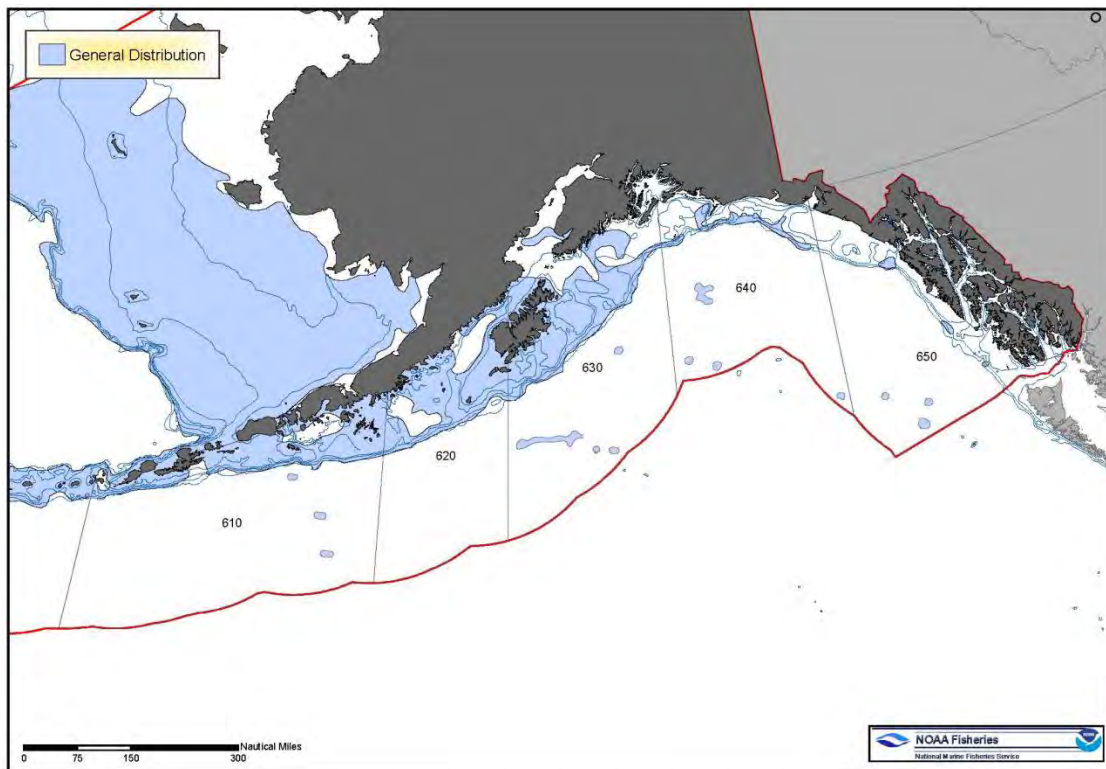
Figure E- 41 EFH Distribution – GOA Skate (Adults)**Figure E- 42 EFH Distribution – GOA Squid (Late Juveniles/Adults)**

Figure E- 43 EFH Distribution – GOA Sculpin (Juveniles/Adults)

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Adverse Effects on Essential Fish Habitat

F.2 Non-fishing Activities that may Adversely Affect Essential Fish Habitat

The waters and substrates that comprise EFH are susceptible to a wide array of human activities unrelated to fishing. Broad categories of such activities include, but are not limited to, mining, dredging, fill, impoundment, discharges, water diversions, thermal additions, actions that contribute to nonpoint source pollution and sedimentation, introduction of potentially hazardous materials, introduction of exotic species, and the conversion of aquatic habitat that may eliminate, diminish, or disrupt the functions of EFH. Non-fishing activities discussed in this document are subject to a variety of regulations and restrictions designed to limit environmental impacts under federal, state, and local laws. Listing all applicable environmental laws and management practices is beyond the scope of the document. Moreover, the coordination and consultation required by section 305(b) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) does not supersede the regulations, rights, interests, or jurisdictions of other federal or state agencies. NMFS may use the information in this document as a source when developing conservation recommendations for specific actions under section 305(b)(4)(A) of the MSA. NMFS will not recommend that state or federal agencies take actions beyond their statutory authority, and NMFS' EFH conservation recommendations are not binding.

Ideally, actions that are not water-dependent should not be located in EFH if such actions may have adverse impacts on EFH. Activities that may result in significant adverse effects on EFH should be avoided where less environmentally harmful alternatives are available. If there are no alternatives, the impacts of these actions should be minimized. Environmentally sound engineering and management practices should be employed for all actions that may adversely affect EFH. If avoidance or minimization is not practicable, or will not adequately protect EFH, compensatory mitigation; as defined for section 404 of the Clean Water Act (CWA) should be considered to conserve and enhance EFH.

The potential for effects from larger, less readily managed processes associated with human activity also exists, such as climate change and ocean acidification. Climate change may lead to habitat changes that prompt shifts in the distribution of managed species. Likewise, should ocean conditions warm to allow for new shipping routes, new vectors may emerge for introducing invasive species in cargo and ballast waters. Ocean acidification could also alter species distributions and complicated food web dynamics. These larger ecosystem-level effects are discussed in this document where applicable, within each activity type.

This section of the fishery management plan (FMP) synthesizes a comprehensive review of the "Impacts to Essential Fish Habitat from Non-fishing Activities in Alaska" (NMFS 2011), which is incorporated in the FMP by reference. The general purpose of that document is to identify non-fishing activities that may adversely impact EFH and provide conservation recommendations that can be implemented for specific types of activities to avoid or minimize adverse impacts to EFH. This information must be included in FMPs under section 303(a)(7) of the MSA. It is also useful to NMFS biologists reviewing proposed actions that may adversely

affect EFH, and the comprehensive document (NMFS 2011) will be utilized by federal action agencies undertaking EFH consultations with NMFS, especially in preparing EFH assessments.

The conservation recommendations for each activity category are suggestions the action agency or others can undertake to avoid, offset, or mitigate impacts to EFH. NMFS develops EFH conservation recommendations for specific activities case-by-case based on the circumstances; therefore, the recommendations in this document may or may not apply to any particular project. Because many non-fishing activities have similar adverse effects on living marine resources, some redundancy in the descriptions of impacts and the accompanying conservation recommendations between sections in this report is unavoidable.

The comprehensive non-fishing activities document (NMFS 2011) updates and builds upon a collaborative evaluation of non-fishing effects to EFH completed in 2004 by the NMFS Alaska Region, Northwest Region, and Southwest Region and the respective Fisheries Science Centers. In April 2005, NMFS completed the Final Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska (EFH EIS; NMFS 2005), and the North Pacific Fishery Management Council (Council) amended its FMPs to address the EFH requirements of the MSA. The EFH EIS contained an Appendix (Appendix G) that addressed non-fishing impacts to EFH. A 5-year review of the Council's EFH provisions, including those addressing non-fishing impacts to EFH, was completed by the Council in April 2010 (NPFMC and NMFS 2010), on the basis of which this section has been updated.

The remainder of this section addresses non-fishing activities that may adversely affect EFH. These activities are grouped into the four different systems in which they usually occur: upland, river or riverine, estuary or estuarine, and coastal or marine.

F.2.1 Upland Activities

Upland activities can impact EFH through both point source and nonpoint source pollution. Nonpoint source impacts are discussed here. Technically, the term "nonpoint source" means anything that does not meet the legal definition of point source in section 502(14) of the CWA, which refers to discernible, confined, and discrete conveyance from which pollutants are or may be discharged. Land runoff, precipitation, atmospheric deposition, seepage, and hydrologic modification, generally driven by anthropogenic development, are the major contributors to nonpoint source pollution.

Nonpoint source pollution is usually lower in intensity than an acute point source event, but may be more damaging to fish habitat in the long term. It may affect sensitive life stages and processes, is often difficult to detect, and its impacts may go unnoticed for a long time. When population impacts are detected, they may not be tied to any one event or source, and may be difficult to correct, clean up, or mitigate.

The impacts of nonpoint source pollution on EFH may not necessarily represent a serious, widespread threat to all species and life history stages. The severity of the threat of any specific pollutant to aquatic organisms depends upon the type and concentration of the pollutant and the length of exposure for a particular species and its life history stage. For example, species that spawn in areas that are relatively deep with strong currents and well-mixed water may not be as susceptible to pollution as species that inhabit shallow, inshore areas near or within enclosed

bays and estuaries. Similarly, species whose egg, larval, and juvenile life history stages utilize shallow, inshore waters and rivers may be more prone to coastal pollution than are species whose early life history stages develop in offshore, pelagic waters.

F.2.1.1 Silviculture/Timber Harvest

Recent revisions to federal and state timber harvest regulations in Alaska and best management practices (BMPs) have resulted in increased protection of EFH on federal, state, and private timber lands (United States Department of Agriculture 2008; <http://www.fs.fed.us/r10/tongass/projects/tlmp/>).

These revised regulations include forest management practices, which when fully implemented and effective, could avoid or minimize adverse effects to EFH. However, if these management practices are ineffective or not fully implemented, timber harvest could have both short and long term impacts on EFH throughout many coastal watersheds and estuaries. Historically, timber harvest in Alaska was not conducted under the current protective standards, and these past practices may have degraded EFH in some watersheds.

Potential Adverse Impacts

In both small and large watersheds there are many complex and important interactions between fish and forests (Northcote and Hartman 2004). Five major categories of silvicultural activities can adversely affect EFH if appropriate forestry practices are not followed: (1) construction of logging roads, (2) creation of fish migration barriers, (3) removal of streamside vegetation, (4) hydrologic changes and sedimentation, and (5) disturbance associated with log transfer facilities (LTFs). Possible effects to EFH include the following (Northcote and Hartman 2004):

- Removal of the dominant vegetation and conversion of mature and old-growth upland and riparian forests to tree stands or forests of early seral stage;
- Reduction of soil permeability and increase in the area of impervious surfaces;
- Increase in erosion and sedimentation due to surface runoff and mass wasting processes, also potentially affecting riparian areas;
- Impaired fish passage because of inadequate design, construction, and/or maintenance of stream crossings;
- Altered hydrologic regimes resulting in inadequate or excessive surface and stream flows, increased streambank and streambed erosion, loss of complex instream habitats;
- Changes in benthic macroinvertebrate populations,
- Loss of instream and riparian cover;
- Increased surface runoff with associated contaminants (e.g., herbicides, fertilizers, and fine sediments) and higher temperatures;
- Alterations in the supply of large woody debris (LWD) and sediment, which can have negative effects on the formation and persistence of instream habitat features; and
- Excess debris in the form of small pieces of wood and silt, which can cover benthic habitat and reduce dissolved oxygen levels.

Recommended Conservation Measures

The following recommended conservation measures for silviculture/timber harvest should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH. Additionally, management standards, guidelines, and best management practices are available from the Forest Service Region 10, the State of Alaska Division of Forestry, and forest plans for the Tongass and Chugach National Forests.

- **Stream Buffers:** For timber operations in watersheds with EFH, adhere to modern forest management practices and BMPs, including the maintenance of vegetated buffers along all streams to the extent practicable in order to reduce sedimentation and supply large wood.
- **Estuary and Beach Fringe:** For timber operations adjacent to estuaries or beaches, maintain vegetated buffers as needed to protect EFH.
- **Watershed Analysis:** A watershed analysis should be incorporated into timber and silviculture projects whenever practicable.
- **Forest Roads:** Forest roads can be a major cause of sediment into streams and road culverts can block or inhibit upstream fish passage. Roads need to be designed to minimize sediment transport problems and to avoid fish passage problems.

F.2.1.2 Pesticides

Pesticides are substances intended to prevent, destroy, control, repel, kill, or regulate the growth of undesirable biological organisms. Pesticides include the following: insecticides, herbicides, fungicides, rodenticides, repellents, bactericides, sanitizers, disinfectants, and growth regulators. More than 900 different active pesticide ingredients are currently registered for use in the United States and are formulated with a variety of other inert ingredients that may also be toxic to aquatic life. Legal mandates covering pesticides are the CWA and the Federal Insecticide, Fungicide, and Rodenticide Act. Water quality criteria for the protection of aquatic life have only been developed for a few of the currently used ingredients (EPA, Office of Pesticide Programs). While agricultural run-off is a major source of pesticide pollution in the lower 48 states, in Alaska, other human activities, such as fire suppression on forested lands, forest site preparation, noxious weed control, right-of-way maintenance (e.g., roads, railroads, power lines), algae control in lakes and irrigation canals, riparian habitat restoration, and urban and residential pest control are the most common sources of these substances.

Pesticides are frequently detected in freshwater and estuarine systems that provide EFH. Pesticides can enter the aquatic environment as single chemicals or as complex mixtures. Direct applications, surface runoff, spray drift, agricultural return flows, and groundwater intrusions are all examples of transport processes that deliver pesticides to aquatic ecosystems. Habitat alteration from pesticides is different from more conventional water quality parameters because, unlike temperature or dissolved oxygen, the presence of pesticides can be difficult to detect due to limitations in proven methodologies. This monitoring may also be expensive. As analytical methodologies have improved in recent years, the number of pesticides documented in fish and their habitats has increased. In addition, pesticides may bioaccumulate in the ecosystem by retention in sediments and detritus, which are then ingested by macroinvertebrates, and which, in

turn, are eaten by larger invertebrates and fish (Atlantic States Marine Fisheries Commission 1992).

Potential Adverse Impacts

There are three basic ways that pesticides can adversely affect EFH. These are (1) a direct, lethal or sublethal, toxicological impact on the health or performance of exposed fish; (2) an indirect impairment of aquatic ecosystem structure and function; and (3) a loss of aquatic macroinvertebrates that are prey for fish and aquatic vegetation that provides physical shelter for fish.

Recommended Conservation Measures

The following recommended conservation measures regarding pesticides (including insecticides, herbicides, fungicides, rodenticides, repellents, bactericides, sanitizers, disinfectants, and growth regulators) should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Incorporate integrated pest management and BMPs as part of the authorization or permitting process (Scott et al. 1999). If pesticides must be applied, consider area, terrain, weather, droplet size, pesticide characteristics, and other conditions to avoid or reduce effects to EFH.
- Carefully review labels and ensure that application is consistent with the product's directions.
- Avoid the use of pesticides within 500 linear feet and/or 1,000 aerial feet of anadromous fish bearing streams.
- For forestry vegetation management projects, establish a 35-foot pesticide-free buffer area from any surface or marine water body and require that pesticides not be applied within 200 feet of a public water source (Alaska Department of Environmental Conservation guidelines).
- Consider current and recent meteorological conditions. Rain events may increase pesticide runoff into adjacent water bodies. Saturated soils may inhibit pesticide penetration.
- Do not apply pesticides when wind speeds exceed 10 mph.
- Begin application of pesticide products nearest to the aquatic habitat boundary and proceed away from the aquatic habitat; do not apply towards a water body.

F.2.1.3 Urban and Suburban Development

Urban and suburban development is most likely the greatest non-fishing threat to EFH (NMFS 1998 a, 1998b). Urban and suburban development and the corresponding infrastructure result in four broad categories of impacts to aquatic ecosystems: hydrological, physical, water quality and biological (CWP 2003).

Potential Adverse Impacts

Potential impacts to EFH most directly related to general urban and suburban development discussed below are the watershed effects of land development, including stormwater runoff.

Other development-related impacts are discussed in later sections of this document, including dredging, wetland fill, and shoreline construction.

Development activities within watersheds and in coastal marine areas can impact EFH on both long and short timeframes. The Center for Watershed Protection (CWP) made a comprehensive review of the impacts associated with impervious cover and urban development and found a negative relationship between watershed development and 26 stream quality indicators (CWP 2003). The primary impacts include (1) the loss of hyporheic zones (the region beneath and next to streams where surface and groundwater mix), and riparian and shoreline habitat and vegetation; and, (2) runoff. Removal of riparian and upland vegetation has been shown to increase stream water temperatures, reduce supplies of LWD, and reduce sources of prey and nutrients to the water system. An increase in impervious surfaces in a watershed, such as the addition of new roads, buildings, bridges, and parking facilities, results in a decreased infiltration to groundwater and increased runoff volumes. This also has the potential to adversely affect water quality and the shape of the hydrograph in downstream water bodies (i.e., estuaries and coastal waters).

Recommended Conservation Measures

The following recommended conservation measures should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH where threats of impacts from urban and suburban development exist.

- Implement BMPs for sediment control during construction and maintenance operations (USEPA 1993).
- Avoid using hard engineering structures for shoreline stabilization and channelization when possible.
- Encourage comprehensive planning for watershed protection, and avoid or minimize filling and building in coastal and riparian areas affecting EFH.
- Where feasible, remove obsolete impervious surfaces from riparian and shoreline areas, and reestablish water regime, wetlands, and native vegetation.
- Protect and restore vegetated buffer zones of appropriate width along streams, lakes, and wetlands that include or influence EFH.
- Manage stormwater to replicate the natural hydrologic cycle, maintaining natural infiltration and runoff rates to the maximum extent practicable.
- Where instream flows are insufficient to maintain water quality and quantity needed for EFH, establish conservation guidelines for water use permits, and encourage the purchase or lease of water rights and the use of water to conserve or augment instream flows.
- Use the best available technologies in upgrading wastewater systems to avoid combined sewer overflow problems and chlorinated sewage discharges into rivers, estuaries, and the ocean.
- Design and install proper wastewater treatment systems.
- Where vegetated swales are not feasible, install and maintain oil/water separators to treat runoff from impervious surfaces in areas adjacent to marine or anadromous waters.

F.2.1.4 Road Building and Maintenance

Roads and trails have always been part of man's impact on his environment (Luce and Crowe 2001). Federal, state, and local transportation departments devote huge budgets to construction and upgrading of roads. As in other places, roads play an important part in access and thus are vital to the economy of Alaska (Connor 2007).

Potential Adverse Impacts

Today's road design construction and management practices have improved from the past. Roads however, still have a negative effect on the biotic integrity of both terrestrial and aquatic ecosystems (Trombulak and Frissell 2000), and the effects of roads on aquatic habitat can be profound. Potential adverse impacts to aquatic habitats resulting from existence of roads in watersheds include (1) increased surface erosion, including mass wasting events, and deposition of fine sediments; (2) changes in water temperature; (3) elimination or introduction of migration barriers such as culverts; (4) changes in streamflow; (5) introduction of invasive species; and (6) changes in channel configuration; and (7) the concentration and introduction of polycyclic aromatic hydrocarbons, heavy metals and other pollutants.

Recommended Conservation Measures

The following conservation measures should be viewed as options to avoid and minimize adverse impacts from road building and maintenance and promote the conservation, enhancement, and proper functioning of EFH.

- Roads should be sited to avoid sensitive areas such as streams, wetlands, and steep slopes to the extent practicable.
- Build bridges rather than culverts for stream crossings when possible. If culverts are to be used, they should be sized, constructed, and maintained to match the gradient and width of the stream, so as to accommodate design flood flows; they should be large enough to provide for migratory passage of adult and juvenile fishes.
- Design bridge abutments to minimize disturbances to stream banks and place abutments outside of the floodplain whenever possible.
- Specify erosion control measures in road construction plans.
- Avoid side casting of road materials on native surfaces and into streams.
- Use only native vegetation in stabilization plantings.
- Use seasonal restrictions to avoid impacts to habitat during species critical life history stages (e.g., spawning and egg development periods).
- Properly maintain roadway and associated stormwater collection systems.
- Limit roadway sanding and the use of deicing chemicals during the winter to minimize sedimentation and introduction of contaminants into nearby aquatic habitats.

F.2.2 Riverine Activities

F.2.2.1 Mining

Mining within riverine habitats may result in direct and indirect chemical, biological, and physical impacts to habitats within the mining site and surrounding areas during all stages of

operations. On site mining activities include exploration, site preparation, mining and milling, waste management, decommissioning or reclamation, and abandonment (NMFS 2004, American Fisheries Society 2000). Mining and its associated activities have the potential to cause adverse effects to EFH from exploration through post-closure. The operation of metal, coal, rock quarries, and gravel pit mines in upland and riverine areas has caused varying degrees of environmental damage in urban, suburban, and rural areas. Some of the most severe damage, however, occurs in remote areas, where some of the most productive fish habitat is often located (Sengupta 1993). In Alaska, existing regulations, promulgated and enforced by other federal and state agencies, are designed to control and manage these changes to the landscape to avoid and minimize impacts. However, while environmental regulations may avoid, limit, control, or offset many potential impacts, mining will, to some degree, always alter landscapes and environmental resources (National Research Council 1999). (Additional information on mining impacts in the marine environment is covered later in this synthesis.)

F.2.2.1.1 Mineral Mining

Mining and mineral extraction activities take many forms, such as commercial and recreational suction dredging, placer, open pit and surface mining, and contour operations. The process for mineral extraction involves exploration, mine development, mining (extraction), processing and reclamation.

Potential Adverse Impacts

The potential adverse effects of mineral mining on fish populations and EFH are well documented (Frag et al. 2003, Hansen et al. 2002, Brix et al. 2001, Goldstein et al. 1999) and depend on the type, extent, and location of the activities. Impacts associated with the extraction of material from within or near a stream or river bed may include (1) alteration in channel morphology, hydraulics, lateral migration and natural channel meander; (2) increases in channel incision and bed degradation; (3) disruption in pre-existing balance of suspended sediment transport and turbidity; (4) direct impacts to fish spawning and nesting habitats (redds), juveniles, and prey items; (5) simplification of in-channel fluvial processes and LWD deposition; (6) altered surface and ground water regimes and hydro-geomorphic and hyporheic processes; and (7) destruction of the riparian zone during extraction operations. Additional impacts may include mining-related pollution, acid mine drainage, habitat fragmentation and conversion, altered temperature regimes, reduction in oxygen concentration, the release of toxic materials (NMFS 2008), and additional impacts to wetland and riverine habitats. Many of these types of impacts have been previously introduced in the document. The additional discussion that follows is intended to round out the discussion of impacts that have not been previously introduced.

Recommended Conservation Measures

The following measures are adapted from recommendations in Spence et al. (1996), NMFS (2004), and Washington Department of Fish and Wildlife (2009). These conservation recommendations for mineral mining should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- To the extent practicable, avoid mineral mining in waters, water sources and watersheds, riparian areas, hyporheic zones, and floodplains providing habitat for federally managed species.
- Schedule necessary in-water activities when the fewest species/least vulnerable life stages of federally managed species will be present.
- Minimize spillage of dirt, fuel, oil, toxic materials, and other contaminants into EFH. Prepare a spill prevention plan if appropriate.
- Treat and test wastewater (acid neutralization, sulfide precipitation, reverse osmosis, electrochemical, or biological treatments) and recycle on site to minimize discharge to streams.
- Minimize the effects of sedimentation on fish habitat, using methods such as contouring, mulching, construction of settling ponds, and sediment curtains. Monitor turbidity during operations, and cease operations if turbidity exceeds predetermined threshold levels.
- If possible, reclaim, rather than bury, mine waste that contains heavy metals, acid materials, or other toxic compounds to limit the possibility of leachate entering groundwater.
- Restore natural contours and use native vegetation to stabilize and restore habitat function to the extent practicable. Monitor the site to evaluate performance.
- Minimize the aerial extent of ground disturbance and stabilize disturbed lands to reduce erosion.
- For large scale mining operations, stochastic models should be employed to make predictions of ground and surface hydrologic impacts and acid generating potential in mine pits and tailing impoundments.

F.2.2.1.2 Sand and Gravel Mining

In Alaska, riverine sand and gravel mining is extensive and can involve several methods: wet-pit mining (i.e., removal of material from below the water table); dry-pit mining on beaches, exposed bars, and ephemeral streambeds; and subtidal mining.

Potential Adverse Impacts

Primary impacts associated with riverine sand and gravel mining activities include (1) turbidity plumes and re-suspension of sediment and nutrients, (2) removal of spawning habitat, and (3) alteration of channel morphology. These often lead to secondary impacts including: (1) alteration of migration patterns; (2) physical and thermal barriers to upstream and downstream migration; (3) increased fluctuation in water temperature; (4) decrease in dissolved oxygen; (5) high mortality of early life stages; (6) increased susceptibility to predation; (7) loss of suitable habitat (Packer et al. 2005); (8) decreased nutrients (from loss of floodplain connection and riparian vegetation); and (9) decreased food production (loss of invertebrates) (Spence et al. 1996).

Recommended Conservation Measures

The following recommended conservation measures for sand and gravel mining are adapted from NMFS (2004) and OWRRI (1995). They should be viewed as options to avoid and minimize

adverse impacts to EFH due to sand and gravel mining and promote the conservation, enhancement, and proper functioning of EFH.

- To the extent practicable, avoid sand/gravel mining in waters, water sources and watersheds, riparian areas, hyporheic zones and floodplains providing habitat for federally managed species.
- Identify upland or off-channel (where the channel will not be captured) gravel extraction sites as alternatives to gravel mining in or adjacent to EFH, if possible.
- If operations in EFH cannot be avoided, design, manage, and monitor sand and gravel mining operations to minimize potential direct and indirect impacts to living marine resources and habitat. For example, minimize the areal extent and depth of extraction.
- Include restoration, mitigation, and monitoring plans, as appropriate, in sand/gravel extraction plans.
- Implement seasonal restrictions to avoid impacts to habitat during species critical life history stages.

F.2.2.2 Organic and Inorganic Debris

Organic and inorganic debris, and its impacts to EFH, extend beyond riverine systems into estuarine coastal and marine systems. To reduce duplication, impacts to other systems are also addressed here.

Natural occurring flotsam, such as LWD and macrophyte wrack (i.e., kelp), plays an important role in aquatic ecosystems, including EFH. LWD and wrack promote habitat complexity and provide structure to various aquatic and shoreline habitats.

The natural deposition of LWD creates habitat complexity by altering local hydrologic conditions, nutrient availability, sediment deposition, turbidity, and other structural habitat conditions. In riverine systems, the physical structure of LWD provides cover for managed species, creates habitats and microhabitats (e.g., pools, riffles, undercut banks, and side channels), retains gravels, and helps maintain underlying channel structure (Abbe and Montgomery 1996, Montgomery et al. 1995, Ralph et al. 1994, Spence et al. 1996). LWD also plays similar role in salt marsh habitats (Maser and Sedell 1994). In benthic ocean habitats, LWD enriches local nutrient availability as deep-sea wood borers convert the wood to fecal matter, providing terrestrially-based carbon to the ocean food chain (Maser and Sedell 1994). When deposited on coastal shorelines, macrophyte wrack creates microhabitats and provides a food source for aquatic and terrestrial organisms such as isopods and amphipods, which play an important role in marine food webs.

Conversely, inorganic flotsam and jetsam debris can negatively impact EFH. Inorganic marine debris is a problem along much of the coastal United States, where it litters shorelines, fouls estuaries, entangles fish and wildlife, and creates hazards in the open ocean. Marine debris consists of a wide variety of man-made materials, including general litter, plastics, hazardous wastes, and discarded or lost fishing gear. The debris enters waterbodies indirectly through rivers and storm water outfalls, as well as directly via ocean dumping and accidental release. Although laws and regulatory programs exist to prevent or control the problem, marine debris continues to affect aquatic resources.

F.2.2.2.1 Organic Debris Removal

Natural occurring flotsam, such as LWD and macrophyte wrack (i.e., kelp), is sometimes intentionally removed from streams, estuaries, and coastal shores. This debris is removed for a variety of reasons, including dam operations, aesthetic concerns, and commercial and recreational purposes (e.g., active beach log harvests, garden mulch, and fertilizer). However, the presence of organic debris is important for maintaining aquatic habitat structure and function.

Potential Adverse Impacts

The removal of organic debris from natural systems can reduce habitat function, adversely impacting habitat quality. Reductions in LWD inputs to estuaries may also affect the ecological balance of estuarine systems by altering rates and patterns of nutrient transport, sediment deposition, and availability of in-water cover for larval and juvenile fish. In rivers and streams of the Pacific Northwest, the historic practice of removing LWD to improve navigability and facilitate log transport has altered channel morphology and reduced habitat complexity, thereby negatively affecting habitat quality for spawning and rearing salmonids (Koski 1992, Sedell and Luchessa 1982).

Beach grooming and wrack removal can substantially alter the macrofaunal community structure of exposed sand beaches (Dugan et al. 2000). Species richness, abundance, and biomass of macrofauna associated with beach wrack (e.g., sand crabs, isopods, amphipods, and polychaetes) are higher on ungroomed beaches than on those that are groomed (Dugan et al. 2000). The input and maintenance of wrack can strongly influence the structure of macrofauna communities, including the abundance of sand crabs (*Emerita analoga*) (Dugan et al. 2000), an important prey species for some managed species of fish.

Recommended Conservation Measures

The recommended conservation measures for organic debris removal are listed below. They should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Encourage the preservation of LWD whenever possible, removing it only when it presents a threat to life or property.
- Encourage appropriate federal, state, and local agencies to aid in the downstream movement of LWD around dams, culverts, and bridges wherever possible, rather than removing it from the system.
- Educate landowners and recreationalists about the benefits of maintaining LWD.
- Localize beach grooming practices, and minimize them whenever possible.
- Advise gardeners to only harvest dislodged, dead kelp and leave live, growing kelp (whether dislodged or not).

F.2.2.2.2 Inorganic Debris

Inorganic debris in the marine environment is a chronic problem along much of the U.S. coast, resulting in littered shorelines and estuaries with varying degrees of negative effects to coastal ecosystems. Nationally, land-based sources of marine debris account for about 80 percent of the marine debris on beaches and in U.S. waters. Debris can originate from combined sewer

overflows and storm drains, stormwater runoff, landfills, solid waste disposal, poorly maintained garbage bins, floating structures, and general littering of beaches, rivers, and open waters. It generally enters waterways indirectly through rivers and storm drains or by direct ocean dumping. Ocean-based sources of debris also create problems for managed species. These include discarded or lost fishing gear (NMFS 2008), and galley waste and trash from commercial merchant, fishing, military, and other vessels.

Potential Adverse Impacts

Land and ocean sourced inorganic marine debris is a very diverse problem, and adverse effects to EFH are likewise varied. Floating or suspended trash can directly affect managed species that consume or are entangled in it. Toxic substances in plastics can kill or impair fish and invertebrates that use habitat polluted by these materials. The chemicals that leach from plastics can persist in the environment and can bioaccumulate through the food web.

Once floatable debris settles to the bottom of estuaries, coastal, and open ocean areas, it can continue to cause environmental problems. Plastics and other materials with a large surface area can cover and suffocate immobile animals and plants, creating large spaces devoid of life. Currents can carry suspended debris to underwater reef habitats where the debris can become snagged, damaging these sensitive habitats. The typical floatable debris from combined sewer overflows includes street litter, sewage containing viral and bacterial pathogens, pharmaceutical by-products from human excretion, and pet wastes. Pathogens can also contaminate shellfish beds and reefs.

Recommended Conservation Measures

Pollution prevention and improved waste management can occur through regulatory controls and best management practices. The recommended conservation measures for minimizing inorganic debris listed in the section below should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Encourage proper trash disposal, particularly in coastal and ocean settings, and participate in coastal cleanup activities.
- Advocate for local, state, and national legislation that rewards proper disposal of debris.
- Encourage enforcement of regulations addressing marine debris pollution and proper disposal.
- Provide resources and technical guidance for development of studies and solutions addressing the problem of marine debris.
- Educate the public on the impact of marine debris and provide guidance on how to reduce or eliminate the problem.
- Implement structural controls that collect and remove trash before it enters nearby waterways.
- Consider the use of centrifugal separation to physically separate solids and floatables from water in combined sewer outflows.
- Encourage the development of incentives and funding mechanisms to recover lost fishing gear.

- Require all existing and new commercial construction projects near the coast to develop and implement refuse disposal plans.

F.2.2.3 Dam Operation

Dams provide sources of hydropower, water storage, and flood control. Construction and operation of dams can affect basic hydrologic and geomorphic function including the alteration of physical, biological, and chemical processes that, in turn, can have effects on water quality, timing, quantity, and alter sediment transport.

Potential Adverse Impacts (adapted from NMFS 2008)

The effects of dam construction and operation on fish and aquatic habitat include (1) complete or partial upstream and downstream migratory impediment; (2) water quality and flow pattern alteration; (3) alteration to distribution and function of ice, sediment, and nutrient budgets; (4) alterations to the floodplain, including riparian and coastal wetland systems and associated functions and values; and (5) thermal impacts. Dam construction and operations can impede or block anadromous fish passage and other aquatic species migration in streams and rivers. Unless proper fish passage structures or devices are operational, dams can either prevent access to productive upstream spawning and rearing habitat or can alter downstream juvenile migration. Turbines, spillways, bypass systems, and fish ladders also affect the quality and quantity of EFH available for salmon passage in streams and rivers (Pacific Fishery Management Council [PFMC] 1999). The construction of a dam can fragment habitat, resulting in alterations to both upstream and downstream biogeochemical processes.

Recommended Conservation Measures (adapted from NMFS 2008)

The following conservation recommendations regarding dams should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Avoid construction of new dam facilities, where possible.
- Construct and design facilities with efficient and functional upstream and downstream adult and juvenile fish passage which ensures safe, effective, and timely passage.
- Operate dams within the natural flow fluctuations rates and timing and, when possible, mimic the natural hydrograph, allow for sediment and wood transport, and consider and allow for natural ice function. Monitor water flow and reservoir flow fluctuation.
- Understand longer term climatic and hydrologic patterns and how they affect habitat; plan project design and operation to minimize or mitigate for these changes.
- Use seasonal restrictions for construction, maintenance, and operation of dams to avoid impacts to habitat during species' critical life history stages.
- Develop and implement monitoring protocols for fish passage.
- Retrofit existing dams with efficient and functional upstream and downstream fish passage structures.
- Construct dam facilities with the lowest hydraulic head practicable for the project purpose. Site the project at a location where dam height can be reduced.
- Downstream passage should prevent adults and juveniles from passing through the

turbines and provide sufficient water downstream for safe passage.

- Coordinate maintenance and operations that require drawdown of the impoundment with state and federal resource agencies to minimize impacts to aquatic resources.
- Develop water and energy conservation guidelines for integration into dam operation plans and into regional and watershed-based water resource plans.
- Encourage the preservation of LWD, whenever possible.
- Develop a sediment transport and geomorphic maintenance plan to allow for peak flow mimicking that will result in sediment pulses through the reservoir/dam system and allow high flow geomorphic processes.

F.2.2.4 Commercial and Domestic Water Use

An increasing demand for potable water, combined with inefficient use of freshwater resources and natural events (e.g., droughts) have led to serious ecological damage worldwide (Deegan and Buchsbaum 2005). Because human populations are expected to continue increasing in Alaska, it is reasonable to assume that water uses, including water impoundments and diversion, will similarly increase (Gregory and Bisson 1997). Groundwater supplies 87 percent of Alaska's 3,500 public drinking water systems. Ninety percent of the private drinking water supplies are groundwater. Each day, roughly 275 million gallons of water derived from aquifers, which directly support riverine systems, are used for domestic, commercial, industrial, and agricultural purposes in Alaska (Groundwater Protection Council 2010). Surface water sources serve a large number of people from a small number of public water systems (e.g., Anchorage and several southeastern communities).

Potential Adverse Impacts

The diversion of freshwater for domestic and commercial uses can affect EFH by (1) altering natural flows and the process associated with flow rates, (2) altering riparian habitats by removing water or by submersion of riparian areas, (3) removing the amount and altering the distribution of prey bases, (4) affecting water quality, and (5) entrapping fishes. Water diversions can involve either withdrawals (reduced flow) or discharges (increased flow).

Recommended Conservation Measures

These conservation measures for commercial and domestic water use should be viewed as options to avoid and minimize adverse impacts from commercial and domestic water use and promote the conservation, enhancement, and proper functioning of EFH.

- Design water diversion and impoundment projects to create flow conditions that provide for adequate fish passage, particularly during critical life history stages. Avoid low water levels that strand juveniles and dewater redds. Incorporate juvenile and adult fish passage facilities on all water diversion projects (e.g., fish bypass systems). Install screens at water diversions on fish-bearing streams, as needed.
- Maintain water quality necessary to support fish populations by monitoring and adjusting water temperature, sediment loads, and pollution levels.
- Maintain appropriate flow velocity and water levels to support continued stream functions. Maintain and restore channel, floodplain, riparian, and estuarine conditions.

- Where practicable, ensure that mitigation is provided for unavoidable impacts to fish and their habitat.

F.2.3 Estuarine Activities

A large portion of Alaska's population resides near the state's 33,904-mile coastline (NOAA 2010). The dredging and filling of coastal wetlands for commercial and residential development, port, and harbor development directly removes important wetland habitat and alters the habitat surrounding the developed area. Physical changes from shoreline construction can result in secondary impacts such as increased suspended sediment loading, shading from piers and wharves, as well as introduction of chemical contamination from land-based human activities (Robinson and Pederson 2005). Even development projects that appear to have minimal individual impacts can have significant cumulative effects on the aquatic ecosystem (NMFS 2008).

F.2.3.1 Dredging

The construction of ports, marinas, and harbors typically involves dredging sediments from intertidal and subtidal habitats to create navigational channels, turning basins, anchorages, and berthing docks. Additionally, periodic dredging is used to maintain the required depths after sediment is deposited into these facilities. Dredging is also used to create deepwater navigable channels or to maintain existing channels that periodically fill with sediments. (Impacts from dredging from marine mining are also addressed later.)

Potential Adverse Impacts

Dredging activities can adversely affect benthic and water-column habitat. The environmental effects of dredging on managed species and their habitat can include (1) direct removal/burial of organisms; (2) turbidity and siltation, including light attenuation from turbidity; (3) contaminant release and uptake, including nutrients, metals, and organics; (4) release of oxygen consuming substances (e.g., chemicals and bacteria); (5) entrainment; (6) noise disturbances; and (7) alteration to hydrodynamic regimes and physical habitat.

Recommended Conservation Measures

The recommended conservation measures for dredging are listed in the following section. They should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Avoid new dredging in sensitive habitat areas to the maximum extent practicable.
- Reduce the area and volume of material to be dredged to the maximum extent practicable.
- Avoid dredging and placement of equipment used in conjunction with dredging operations in special aquatic sites and other high value habitat areas.
- Implement seasonal restrictions to avoid impacts to habitat during species critical life history stages (e.g., spawning season, egg, and larval development period).
- Utilize BMPs to limit and control the amount and extent of turbidity and sedimentation.

- For new dredging projects, undertake multi-season, pre-, and post-dredging biological surveys to assess the cumulative impacts to EFH and allow for implementation of adaptive management techniques.
- Prior to dredging, test sediments for contaminants as per U.S. Environmental Protection Agency (EPA) and U.S. Army Corps of Engineers (USACE) requirements.
- Provide appropriate compensation for significant impacts (short-term, long-term, and cumulative) to benthic environments resulting from dredging.
- Identify excess sedimentation in the watershed that prompts excessive maintenance dredging activities, and implement appropriate management actions, if possible.

F.2.3.2 Material Disposal and Filling Activities

Material disposal and filling activities can directly remove important habitat and alter the habitat surrounding the developed area. The discharge of dredged materials or the use of fill material in aquatic habitats can result in covering or smothering existing submerged substrates, loss of habitat function, and adverse effects on benthic communities.

F.2.3.2.1 Disposal of Dredged Material

Potential Adverse Impacts (adapted from NMFS 2008)

The disposal of dredged material can reduce the suitability of water bodies for managed species and their prey by (1) reducing floodwater retention in wetlands; (2) reducing nutrients uptake and release; (3) decreasing the amount of detrital input, an important food source for aquatic invertebrates (Mitsch and Gosselink 1993); (4) habitat conversion through alteration of water depth or substrate type; (5) removing aquatic vegetation and preventing natural revegetation; (6) impeding physiological processes to aquatic organisms (e.g., photosynthesis, respiration) caused by increased turbidity and sedimentation (Arruda et al. 1983, Cloern 1987, Dennison 1987, Barr 1993, Benfield and Minello 1996, Nightingale and Simenstad 2001a); (7) directly eliminating sessile or semi-mobile aquatic organisms via entrainment or smothering (Larson and Moehl 1990, McGraw and Armstrong 1990, Barr 1993, Newell et al. 1998); (8) altering water quality parameters (i.e., temperature, oxygen concentration, and turbidity); and (9) releasing contaminants such as petroleum products, metals, and nutrients (USEPA 2000a).

Recommended Conservation Measures

The following recommended conservation measures for dredged material disposal should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Avoid disposing dredged material in wetlands, submerged aquatic vegetation and other special aquatic sites whenever possible.
- Test sediment compatibility for open-water disposal per EPA and USACE requirements.
- Ensure that disposal sites are properly managed and monitored to minimize impacts associated with dredge material.
- Where long-term maintenance dredging is anticipated, acquire and maintain disposal sites for the entire project life.

- Encourage beneficial uses of dredged materials.

F.2.3.2.2 Fill Material

Like the discharge of dredged material, the discharge of fill material to create upland areas can remove productive habitat and eliminate important habitat functions.

Potential Adverse Impacts

Adverse impacts to EFH from the introduction of fill material include (1) loss of habitat function and (2) changes in hydrologic patterns.

Recommended Conservation Measures

The following recommended conservation measures for the discharge of fill material should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Federal, state, and local resource management and permitting agencies should address the cumulative impacts of fill operations on EFH.
- Minimize the areal extent of any fill in EFH, or avoid it entirely.
- Consider alternatives to the placement of fill into areas that support managed species.
- Fill should be sloped to maintain shallow water, photic zone productivity; allow for unrestricted fish migration; and provide refugia for juvenile fish.
- In marine areas of kelp and other aquatic vegetation, fill (including artificial structure fill reefs) should be designed to maximize kelp colonization and provide areas for juvenile fish to find shelter from higher currents and exposure to predators.
- Fill materials should be tested and be within the neutral range of 7.5 to 8.4 pH.

F.2.3.3 Vessel Operations, Transportation, and Navigation

In Alaska, the growth in coastal communities is putting demands on port districts to increase infrastructure to accommodate additional vessel operations for cargo handling and marine transportation. Port expansion has become an almost continuous process due to economic growth, competition between ports, and significant increases in vessel size. In addition, increasing boat sales have put more pressure on improving and building new harbors, an important factor in Alaska because of the limited number of roads.

Potential Adverse Impacts

Activities associated with the expansion of port facilities, vessel/ferry operations, and recreational marinas can directly and indirectly impact EFH. Impacts include (1) loss and conversion of habitat; (2) altered light regimes and loss of submerged aquatic vegetation; (3) altered temperature regimes; (4) siltation, sedimentation, and turbidity; (5) contaminant releases; and, (6) altered tidal, current, and hydrologic regimes.

Recommended Conservation Measures

The following recommended conservation measures for vessel operations, transportation infrastructure, and navigation, should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Locate marinas in areas of low biological abundance and diversity.
- Leave riparian buffers in place to help maintain water quality and nutrient input.
- Include low-wake vessel technology, appropriate routes, and BMPs for wave attenuation structures as part of the design and permit process.
- Incorporate BMPs to prevent or minimize contamination from ship bilge waters, antifouling paints, shipboard accidents, shipyard work, maintenance dredging and disposal, and nonpoint source contaminants from upland facilities related to vessel operations and navigation.
- Locate mooring buoys in water deep enough to avoid grounding and to minimize the effects of prop wash.
- Use catchment basins for collecting and storing surface runoff to remove contaminants prior to delivery to any receiving waters.
- Locate facilities in areas with enough water velocity to maintain water quality levels within acceptable ranges.
- Locate marinas where they do not interfere with natural processes so as to affect adjacent habitats.
- To facilitate movement of fish around breakwaters, breach gaps and construct shallow shelves to serve as “fish benches,” as appropriate.
- Harbor facilities should be designed to include practical measures for reducing, containing, and cleaning up petroleum spills.

F.2.3.4 Invasive Species

Introductions of invasive species into estuarine, riverine, and marine habitats have been well documented (Rosecchi et al. 1993, Kohler and Courtenay 1986, Spence et al. 1996) and can be intentional (e.g., for the purpose of stock or pest control) or unintentional (e.g., fouling organisms). Exotic fish, shellfish, pathogens, and plants can be spread via shipping, recreational boating, aquaculture, biotechnology, and aquariums. The introduction of nonindigenous organisms to new environments can have many severe impacts on habitat (Omori et al. 1994).

Invasive aquatic species that are considered high priority threats to Alaska’s marine waters include: Atlantic salmon (*Salmo salar*), green crab (*Carcinus maenas*), Chinese mitten crab (*Eriocheir sinensis*), signal crayfish (*Pacifastacus leniunculus*), zebra mussels (*Dreissena polymorpha*), New Zealand mudsnail (*Potamopyrgus antipodarum*), saltmarsh cordgrass

(*Spartina alterniflora*), purple loosestrife (*Lythrum salicaria*), and tunicates (*Botrylloides violaceus* and *Didemnum vexillum*).¹

Potential Adverse Impacts

Invasive species can create five types of negative effects on EFH: (1) habitat alteration, (2) trophic alteration, (3) gene pool alteration, (4) spatial alteration, and (5) introduction of diseases.

Recommended Conservation Measures

The following recommended conservation measures for invasive species should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Uphold fish and game regulations of the Alaska Board of Fisheries (AS 16.05.251) and Board of Game (AS 16.05.255), which prohibit and regulate the live capture, possession, transport, or release of native or exotic fish or their eggs.
- Adhere to regulations and use best management practices outlined in the State of Alaska Aquatic Nuisance Species Management Plan (Fay 2002).
- Encourage vessels to perform a ballast water exchange in marine waters to minimize the possibility of introducing invasive estuarine species into similar habitats.
- Discourage vessels that have not performed a ballast water exchange from discharging their ballast water into estuarine receiving waters.
- Require vessels brought from other areas over land via trailer to clean any surfaces that may harbor non-native plant or animal species (e.g., propellers, hulls, anchors, fenders).
- Treat effluent from public aquaria displays and laboratories and educational institutes using non-native species before discharge.
- Encourage proper disposal of seaweeds and other plant materials used for packing purposes when shipping fish or other animals.
- Undertake a thorough scientific review and risk assessment before any non-native species are introduced.

F.2.3.5 Pile Installation and Removal (From NMFS 2005)

Pilings are an integral component of many overwater and in-water structures. They provide support for the decking of piers and docks, function as fenders and dolphins to protect structures, support navigation markers, and help in the construction of breakwaters and bulkheads. Materials used in pilings include steel, concrete, wood (both treated and untreated), plastic, or a combination thereof. Piles are usually driven into the substrate by using either impact or vibratory hammers.

¹ <http://www.adfg.state.ak.us/special/invasive/invasive.ph>

F.2.3.5.1 Pile Driving

Potential Adverse Impacts

Pile driving can generate intense underwater sound pressure waves that may adversely affect EFH. These pressure waves have been shown to injure and kill fish (CalTrans 2001, Longmuir and Lively 2001, Stotz and Colby 2001, Stadler, pers. obs. 2002). Fish injuries associated directly with pile driving are poorly studied, but include rupture of the swim bladder and internal hemorrhaging (CalTrans 2001, Abbott and Bing-Sawyer 2002, Stadler pers. obs. 2002). Sound pressure levels (SPLs) 100 decibels (dB) above the threshold for hearing are thought to be sufficient to damage the auditory system in many fishes (Hastings 2002).

The type and intensity of the sounds produced during pile driving depend on a variety of factors, including the type and size of the pile, the firmness of the substrate into which the pile is being driven, the depth of water, and the type and size of the pile-driving hammer. Driving large hollow steel piles with impact hammers produces intense, sharp spikes of sound that can easily reach levels injurious to fish. Vibratory hammers, on the other hand, produce sounds of lower intensity, with a rapid repetition rate. A key difference between the sounds produced by impact hammers and those produced by vibratory hammers is the responses they evoke in fish. The differential responses to these sounds are due to the differences in the duration and frequency of the sounds.

Systems using air bubbles have been successfully designed to reduce the adverse effects of underwater SPLs on fish. Both confined (i.e., metal or fabric sleeve) and unconfined air bubble systems have been shown to attenuate underwater sound pressures (Longmuir and Lively 2001, Christopherson and Wilson 2002, Reyff and Donovan 2003).

Recommended Conservation Measures

The following recommended conservation measures for pile driving should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Install hollow steel piles with an impact hammer at a time of year when larval and juvenile stages of fish species with designated EFH are not present.

If the first measure is not possible, then the following measures regarding pile driving should be incorporated when practicable to minimize adverse effects:

- Drive piles during low tide when they are located in intertidal and shallow subtidal areas.
- Use a vibratory hammer when driving hollow steel piles.
- Implement measures to attenuate the sound should SPLs exceed the 180 dB (re: 1 μ Pa) threshold.
- Surround the pile with an air bubble curtain system or air-filled coffer dam.
- Use a smaller hammer to reduce sound pressures.
- Use a hydraulic hammer if impact driving cannot be avoided.

- Drive piles when the current is reduced in areas of strong current, to minimize the number of fish exposed to adverse levels of underwater sound.

F.2.3.5.2 Pile Removal

Potential Adverse Impacts

The primary adverse effect of removing piles is the suspension of sediments, which may result in harmful levels of turbidity and release of contaminants contained in those sediments (see earlier). Vibratory pile removal tends to cause the sediments to slough off at the mudline, resulting in relatively low levels of suspended sediments and contaminants. Breaking or cutting the pile below the mudline may suspend only small amounts of sediment, providing that the stub is left in place, and little digging is required to access the pile. Direct pull or use of a clamshell to remove broken piles may, however, suspend large amounts of sediment and contaminants. When the piling is pulled from the substrate using these two methods, sediments clinging to the piling will slough off as it is raised through the water column, producing a potentially harmful plume of turbidity and/or contaminants. The use of a clamshell may suspend additional sediment if it penetrates the substrate while grabbing the piling.

While there is a potential to adversely affect EFH during the removal of piles, many of the piles removed in Alaska are old creosote-treated timber piles. In some cases, the long-term benefits to EFH obtained by removing a chronic source of contamination may outweigh the temporary adverse effects of turbidity.

Recommended Conservation Measures

The following recommended conservation measures for pile removal should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Remove piles completely rather than cutting or breaking them off, if they are structurally sound.
- Minimize the suspension of sediments and disturbance of the substrate when removing piles. Measures to help accomplish this include, but are not limited to, the following:
 - When practicable, remove piles with a vibratory hammer.
 - Remove the pile slowly to allow sediment to slough off at, or near, the mudline.
 - The operator should first hit or vibrate the pile to break the bond between the sediment and the pile.
 - Encircle the pile, or piles, with a silt curtain that extends from the surface of the water to the substrate.
- Complete each pass of the clamshell to minimize suspension of sediment if pile stubs are removed with a clamshell.
- Place piles on a barge equipped with a basin to contain attached sediment and runoff water after removal.

- Using a pile driver, drive broken/cut stubs far enough below the mudline to prevent release of contaminants into the water column as an alternative to their removal.

F.2.3.6 Overwater Structures (from NMFS 2005)

Overwater structures include commercial and residential piers and docks, floating breakwaters, barges, rafts, booms, and mooring buoys. These structures typically are located in intertidal areas out to about 49 feet (15 meters) below the area exposed by the mean lower low tide (i.e., the shallow subtidal zone).

Potential Adverse Impacts

Overwater structures and associated developments may adversely affect EFH in a variety of ways, primarily by (1) changes in ambient light conditions, (2) alteration of the wave and current energy regime, (3) introduction of contaminants into the marine environment, and (4) activities associated with the use and operation of the facilities (Nightingale and Simenstad 2001b).

Recommended Conservation Measures

The following recommended conservation measures for overwater structures should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Use upland boat storage whenever possible to minimize need for overwater structures.
- Locate overwater structures in deep enough waters to avoid intertidal and shade impacts, minimize or preclude dredging, minimize groundings, and avoid displacement of submerged aquatic vegetation, as determined by a preconstruction survey.
- Design piers, docks, and floats to be multiuse facilities to reduce the overall number of such structures and to limit impacted nearshore habitat.
- Incorporate measures that increase the ambient light transmission under piers and docks.
 - Maximize the height and minimize the width to decrease the shade footprint.
 - Use reflective materials on the underside of the dock to reflect ambient light.
 - Use the fewest number of pilings necessary to support the structures.
 - Align piers, docks, and floats in a north-south orientation to allow the arc of the sun to cross perpendicular to the structure and to reduce the duration of light limitation.
- Use floating rather than fixed breakwaters whenever possible, and remove them during periods of low dock use. Encourage seasonal use of docks and off-season haul-out.
- Locate floats in deep water to avoid light limitation and grounding impacts to the intertidal or shallow subtidal zone.
- Maintain at least 1 foot (0.30 meter) of water between the substrate and the bottom of the float at extreme low tide.
- Conduct in-water work when managed species and prey species are least likely to be impacted.
- To the extent practicable, avoid the use of treated wood timbers or pilings.

- Mitigate for unavoidable impacts to benthic habitats.

F.2.3.7 Flood Control/Shoreline Protection (from NMFS 2005)

Structures designed to protect humans from flooding events can result in varying degrees of change in the physical, chemical, and biological characteristics of shoreline and riparian habitat. These structures also can have long-term adverse effects on tidal marsh and estuarine habitats. Tidal marshes are highly variable, but typically have freshwater vegetation at the landward side, saltwater vegetation at the seaward side, and gradients of species in between that are in equilibrium with the prevailing climatic, hydrographic, geological, and biological features of the coast. These systems normally drain through tidal creeks that empty into the bay or estuary. Freshwater entering along the upper edges of the marsh drains across the surface and enters the tidal creeks. Structures placed for coastal shoreline protection may include concrete or wood seawalls, rip-rap revetments (sloping piles of rock placed against the toe of the dune or bluff in danger of erosion from wave action), dynamic cobble revetments (natural cobble placed on an eroding beach to dissipate wave energy and prevent sand loss), vegetative plantings, and sandbags.

Potential Adverse Impacts

Dikes, levees, ditches, or other water controls at the upper end of a tidal marsh can cut off all tributaries feeding the marsh, preventing the flow of freshwater, annual renewal of sediments and nutrients, and the formation of new marshes. Water controls within the marsh can intercept and carry away freshwater drainage, thus blocking freshwater from flowing across seaward portions of the marsh, or conversely increase the speed of runoff of freshwater to the bay or estuary. This can result in lowering the water table, which may permit saltwater intrusion into the marsh, and create migration barriers for aquatic species. In deeper channels where anoxic conditions prevail, large quantities of hydrogen sulfide may be produced that are toxic to marsh grasses and other aquatic life (NMFS 2008). Acid conditions of these channels can also result in release of heavy metals from the sediments.

Long-term effects of shoreline protection structures on tidal marshes include land subsidence (sometimes even submergence), soil compaction, conversion to terrestrial vegetation, greatly reduced invertebrate populations, and general loss of productive wetland characteristics (NMFS 2005). Alteration of the hydrology of coastal salt marshes can reduce estuarine productivity, restrict suitable habitat for aquatic species, and result in salinity extremes during droughts and floods (NMFS 2008). Armoring shorelines to prevent erosion and to maintain or create shoreline real estate can reduce the amount of intertidal habitat, and affects nearshore processes and the ecology of numerous species (Williams and Thom 2001). Hydraulic effects on the shoreline include increased energy seaward of the armoring, reflected wave energy, dry beach narrowing, substrate coarsening, beach steepening, changes in sediment storage capacity, loss of organic debris, and downdrift sediment starvation (Williams and Thom 2001). Installation of breakwaters and jetties can result in community changes from burial or removal of resident biota, changes in cover and preferred prey species, and predator attraction (Williams and Thom 2001). As with armoring, breakwaters and jetties modify hydrology and nearshore sediment transport, as well as movement of larval forms of many species (Williams and Thom 2001).

Recommended Conservation Measures

The following recommended conservation measures for flood and shoreline protection should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Avoid or minimize the loss of coastal wetlands as much as possible.
- Do not dike or drain tidal marshlands or estuaries.
- Wherever possible, use soft in lieu of “hard” shoreline stabilization and modifications.
- Ensure that the hydrodynamics and sedimentation patterns are properly modeled and that the design avoids erosion to adjacent properties when “hard” shoreline stabilization is deemed necessary.
- Include efforts to preserve and enhance fishery habitat to offset impacts.
- Avoid installing new water control structures in tidal marshes and freshwater streams.
- Ensure water control structures are monitored for potential alteration of water temperature, dissolved oxygen concentration, and other parameters.
- Use seasonal restrictions to avoid impacts to habitat during critical life history stages.
- Address the cumulative impacts of development activities in the review process for flood control and shoreline protection projects.
- Use an adaptive management plan with ecological indicators to oversee monitoring and to ensure that mitigation objectives are met. Take corrective action as needed.

F.2.3.8 Log Transfer Facilities/In-Water Log Storage (from NMFS 2005)

Rivers, estuaries, and bays were historically the primary ways to transport and store logs in the Pacific Northwest, and log storage continues in some tidal areas today. Using estuaries and bays and nearby uplands for storage of logs is common in Alaska, with most log transfer facilities (LTFs) found in Southeast Alaska and a few located in Prince William Sound. LTFs are facilities that are constructed wholly or in part in waterways and used to transfer commercially harvested logs to or from a vessel or log raft, or for consolidating logs for incorporation into log rafts (USEPA 2000b). LTFs may use a crane, A-frame structure, conveyor, slide or ramp to move logs from land into the water. Logs can also be placed in the water at the site by helicopters.

Potential Adverse Impacts

Log handling and storage in the estuaries and intertidal zones can result in modification of benthic habitat and water quality degradation within the area of bark deposition (Levings and Northcote 2004). EFH may be physically impacted by activities associated with LTFs. LTFs may cause shading and other indirect effects similar in many ways to those of floating docks and other over-water structures (see earlier).

Recommended Conservation Measures

The following recommended conservation measures for log transfer and storage facilities should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

The physical, chemical, and biological impacts of LTF operations can be substantially reduced by adherence to appropriate siting and operational constraints. Adherence to the Alaska Timber Task Force (ATTF) operational and siting guidelines and BMPs in the National Pollutant Discharge Elimination System (NPDES) General Permit will reduce (1) the amount of bark and wood debris that enters the marine and coastal environment, (2) the potential for displacement or harm to aquatic species, and (3) the accumulation of bark and wood debris on the ocean floor. The following conservation measures reflect those guidelines.²

- Restrict or eliminate storage and handling of logs from waters where state and federal water quality standards cannot be met at all times outside of the authorized zone of deposition.
- Minimize potential impacts of log storage by employing effective bark and wood debris control, collection, and disposal methods at log dumps, raft building areas, and mill-side handling zones; avoiding free-fall dumping of logs; using easy let-down devices for placing logs in the water; and bundling logs before water storage (bundles should not be broken except on land and at millside).
- Do not store logs in the water if they will ground at any time or shade sensitive aquatic vegetation such as eelgrass.
- Avoid siting log-storage areas and LTFs in sensitive habitat and areas important for specified species, as required by the ATTF guidelines.
- Site log storage areas and LTFs in areas with good currents and tidal exchanges.
- Use land-based storage sites where possible.

F.2.3.9 Utility Line, Cables, and Pipeline Installation

With the continued development of coastal regions comes greater demand for the installation of cables, utility lines for power and other services, and pipelines for water, sewage, and other utilities. The installation of pipelines, utility lines, and cables can have direct and indirect impacts on the offshore, nearshore, estuarine, wetland, beach, and rocky shore coastal zone habitats. Many of the direct impacts occur during construction, such as ground disturbance in the clearing of the right-of-way, access roads, and equipment staging areas. Indirect impacts can include increased turbidity, saltwater intrusion, accelerated erosion, and introduction of urban and industrial pollutants due to ground clearing and construction.

Potential Adverse Impacts

Adverse effects on EFH from the installation of pipelines, utility lines, and cables can occur through (1) destruction of organisms and habitat; (2) turbidity impacts; (3) resuspension and

² See also http://www.fs.fed.us/r10/TLMP/F_PLAN/APPEND_G.PDF.

release of contaminants; (4) changes in hydrology; and; (5) destruction of vertically complex hard bottom habitat (e.g., hard corals and vegetated rocky reef).

Recommended Conservation Measures

The following recommended conservation measures for cable and utility line installation should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Align crossings along the least environmentally damaging route.
- Use horizontal directional drilling where cables or pipelines would cross anadromous fish streams, salt marsh, vegetated inter-tidal zones, or steep erodible bluff areas adjacent to the intertidal zone.
- Store and contain excavated material on uplands.
- Backfill excavated wetlands with either the same or comparable material capable of supporting similar wetland vegetation, and at original marsh elevations.
- Use existing rights-of-way whenever possible.
- Bury pipelines and submerged cables where possible.
- Remove inactive pipelines and submerged cables unless they are located in sensitive areas (e.g., marsh, reefs, sea grass).
- Use silt curtains or other barriers to reduce turbidity and sedimentation whenever possible.
- Limit access for equipment to the immediate project area. Tracked vehicles are preferred over wheeled vehicles.
- Limit construction equipment to the minimum size necessary to complete the work.
- Conduct construction during the time of year when it will have the least impact on sensitive habitats and species.
- Suspend transmission lines beneath existing bridges or conduct directional boring under streams to reduce the environmental impact.
- For activities on the Continental Shelf, implement the following to the extent practicable:
 - Shunt drill cuttings through a conduit and either discharge the cuttings near the sea floor, or transport them ashore.
 - Locate drilling and production structures, including pipelines, at least 1 mile (1.6 kilometers) from the base of a hard-bottom habitat.
 - Bury pipelines at least 3 feet (0.9 meter) beneath the sea floor whenever possible.
 - Locate alignments along routes that will minimize damage to marine and estuarine habitat.

F.2.3.10 Mariculture

Productive embayments are often used for commercial culturing and harvesting operations. These locations provide protected waters for geoduck, oyster, and mussel culturing. In 1988, Alaska passed the Alaska Aquatic Farming Act (AAF Act) which is designed to encourage establishment and growth of an aquatic farming industry in the state. The AAF Act establishes four criteria for issuance of an aquatic farm permit, including the requirement that the farm may not significantly affect fisheries, wildlife, or other habitats in an adverse manner. Aquatic farm permits are issued by the Alaska Department of Natural Resources (ADNR).

Potential Adverse Impacts

Shellfish aquaculture tends to have less impact on EFH than finfish aquaculture because the shellfish generally are not fed or treated with chemicals (OSPAR Commission 2009). Adverse impacts to EFH by mariculture operations include (1) risk of introducing undesirable species and disease; (2) physical disturbance of intertidal and subtidal areas; (3) impacts on estuarine food webs, including disruption of eelgrass habitat (e.g., dumping of shell on eelgrass beds, repeated mechanical raking or trampling, and impacts from predator exclusion netting, though few studies have documented impacts). Hydraulic dredges used to harvest oysters in coastal bays can cause long-term adverse impacts to eelgrass beds by reducing or eliminating the beds (Phillips 1984).

Recommended Conservation Measures

The following recommended conservation measures for mariculture facilities should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Site mariculture operations away from kelp or eelgrass beds.
- Do not enclose or impound tidally influenced wetlands for mariculture.
- Undertake a thorough scientific review and risk assessment before any non-native species are introduced.
- Encourage development of harvesting methods to minimize impacts on plant communities and the loss of food and/or habitat to fish populations during harvesting operations.
- Provide appropriate mitigation for the unavoidable, extensive, or permanent loss of plant communities.
- Ensure that mariculture facilities, spat, and related items transported from other areas are free of nonindigenous species.

F.2.4 Coastal/Marine Activities

F.2.4.1 Point-Source Discharges

Point source pollutants are generally introduced via some type of pipe, culvert, or similar outfall structure. These discharge facilities typically are associated with domestic or industrial activities, or in conjunction with collected runoff from roadways and other developed portions of the coastal landscape. Waste streams from sewage treatment facilities and watershed runoff may be combined in a single discharge. Point source discharges introduce inorganic and organic

contaminants into aquatic habitats, where they may become bioavailable to living marine resources.

Potential Adverse Impacts (adopted from NMFS 2008)

The Clean Water Act (CWA) includes important provisions to address acute or chronic water pollution emanating from point source discharges. Under the NPDES program, most point-source discharges are regulated by the state or EPA. While the NPDES program has led to ecological improvements in U.S. waters, point sources continue to introduce pollutants into the aquatic environment, albeit at reduced levels.

Determining the fate and effect of natural and synthetic contaminants in the environment requires an interdisciplinary approach to identify and evaluate all processes sensitive to pollutants. This is critical as adverse effects may be manifested at the biochemical level in organisms (Luoma 1996) in a manner particular to the species or life stage exposed. Exposure to pollutants can inhibit (1) basic detoxification mechanisms, e.g., production of metallothioneins or antioxidant enzymes; (2) disease resistance; (3) the ability of individuals or populations to counteract pollutant-induced metabolic stress; (4) reproductive processes including gamete development and embryonic viability; (5) growth and successful development through early life stages; (6) normal processes including feeding rate, respiration, osmoregulation; and (7) overall Darwinian fitness (Capuzzo and Sassner 1977; Widdows et al. 1990; Nelson et al. 1991; Stiles et al. 1991; Luoma 1996; Thurberg and Gould 2005).

Recommended Conservation Measures

The following recommended conservation measures for point source discharges should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Locate discharge points in coastal waters well away from shellfish beds, sea grass beds, corals, and other similar fragile and productive habitats.
- Reduce potentially high velocities by diffusing effluent to acceptable velocities.
- Determine baseline benthic productivity by sampling before any construction activity.
- Provide for mitigation when degradation or loss of habitat occurs.
- Institute source-control programs that effectively reduce noxious materials.
- Ensure compliance with pollutant discharge permits, which set effluent limitations and/or specify operation procedures, performance standards, or BMPs.
- Treat discharges to the maximum extent practicable.
- Use land-treatment and upland disposal/storage techniques where possible.
- Avoid siting pipelines and treatment facilities in wetlands and streams.

F.2.4.2 Seafood Processing Waste—Shoreside and Vessel Operation

Seafood processing is conducted throughout much of coastal Alaska. Processing facilities may be vessel-based or located onshore (ADEC 2010a). Seafood processing facilities generally consist of mechanisms to offload the harvest from fishing boats; tanks to hold the seafood until

the processing lines are ready to accept them; processing lines, process water, and waste collection systems; treatment and discharge facilities; processed seafood storage areas; and necessary support facilities such as electrical generators, boilers, retorts, water desalinators, offices, and living quarters. In addition, recreational fish cleaning at marinas and small harbors can produce a large quantity of fish waste.

Pollutants of concern from seafood processing wastewater are primarily components of the biological wastes generated by processing raw seafood into a marketable form, chemicals used to maintain sanitary conditions for processing equipment and fish containment structures, and refrigerants (ammonia and freon) that may leak from refrigeration systems used to preserve seafood (ADEC 2010b). Biological wastes include fish parts (e.g., heads, fins, bones, entrails); and chemicals, which are primarily disinfectants that must be used in accordance with EPA specifications.

Potential Adverse Impacts

Seafood processing operations have the potential to adversely affect EFH through the discharge of nutrients, chemicals, fish byproducts, and “stickwater” (water and entrained organics originating from the draining or pressing of steam-cooked fish products). Seafood processing discharges influence nutrient loading, eutrophication, and anoxic and hypoxic conditions significantly influencing marine species diversity and water quality (Theriault et al. 2006, Roy Consultants 2003, Lotze et al. 2003). Although fish waste is biodegradable, fish parts that are ground to fine particles may remain suspended for some time, thereby overburdening habitats from particle suspension (NMFS 2005). Scum and foam from seafood waste deposits can also occur on the water surface and/or increase turbidity. Turbidity decreases light penetration into the water column, reducing primary production. In addition, stickwater takes the form of a fine gel or slime that can concentrate on surface waters and move onshore to cover intertidal areas.

Recommended Conservation Measures

The following recommended conservation measures for fish processing waste should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- To the maximum extent practicable, base effluent limitations on site-specific water quality concerns.
- Encourage the use of secondary or wastewater treatment systems where possible.
- Do not allow designation of new zones of deposit for fish processing waste and instead seek disposal options that avoid an accumulation of waste.
- Promote sound recreational fish waste management through a combination of fish-cleaning restrictions, public education, and proper disposal of fish waste.
- Encourage alternative uses of fish processing wastes.
- Explore options for additional research.
- Monitor biological and chemical changes to the site of processing waste discharges.

F.2.4.3 Water Intake Structures/Discharge Plumes

Withdrawals of riverine, estuarine, and marine waters are common for a variety of uses such as to cool power-generating stations and create temporary ice roads and ice ponds. In the case of power plants, the subsequent discharge of heated and/or chemically treated discharge water can also occur.

Potential Adverse Impacts

Water intake structures and effluent discharges can interfere with or disrupt EFH functions in the source or receiving waters by (1) entrainment, (2) impingement, (3) degrading water quality, (4) operation and maintenance, and (5) construction-related impacts.

Recommended Conservation Measures

The following recommended conservation measures for water intakes and discharges should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Locate facilities that rely on surface waters for cooling in areas other than estuaries, inlets, heads of submarine canyons, rock reefs, or small coastal embayments where managed species or their prey concentrate.
- Design intake structures to minimize entrainment or impingement.
- Design power plant cooling structures to meet the best technology available requirements as developed pursuant to section 316(b) of the CWA.
- Regulate discharge temperatures so they do not appreciably alter the ambient temperature to an extent that could cause a change in species assemblages and ecosystem function in the receiving waters.
- Avoid the use of biocides (e.g., chlorine) to prevent fouling where possible.
- Treat all discharge water from outfall structures to meet state water quality standards at the terminus of the pipe.

F.2.4.4 Oil and Gas Exploration, Development, and Production

Two agencies, the Bureau of Ocean Energy Management and the Bureau of Safety and Environmental Enforcement are responsible for regulating oil and gas operations on the Outer Continental Shelf (OCS). The ADNRR Division of Oil and Gas exercises similar authority over State waters (ADNRR 1999). Offshore petroleum exploration, development, and production activities have been conducted in Alaska waters or on the Alaska OCS since the 1960s (Kenai Peninsula Borough 2004). As demand for energy resources grows, the debate over trying to balance the development of oil and gas resources and the protection of the environment will also continue.

Potential Adverse Impacts

Offshore oil and gas operations can be classified into exploration, development, and production activities (which includes transportation). These activities occur at different depths in a variety of habitats, and can cause an assortment of physical, chemical, and biological disturbances

(NMFS 2005, Helvey 2002). (Some of these disturbances are listed below; however, not all of the potential disturbances in this list apply to every type of activity.)

- Noise from seismic surveys, vessel traffic, and construction of drilling platforms or islands
- Physical alterations to habitat from the construction, presence, and eventual decommissioning and removal of facilities such as islands or platforms, storage and production facilities, and pipelines to onshore common carrier pipelines, storage facilities, or refineries
- Waste discharges, including well drilling fluids, produced waters, surface runoff and deck drainage, domestic waste waters generated from the offshore facility, solid waste from wells (drilling muds and cuttings), and other trash and debris from human activities associated with the facility
- Oil spills
- Platform storage and pipeline decommissioning

The potential disturbances and associated adverse impacts on the marine environment have been reduced through operating procedures required by regulatory agencies and, in many cases, self-imposed by facilities operators. Most of the activities associated with oil and gas operations are conducted under permits and regulations that require companies to minimize impacts or avoid construction in sensitive marine habitats. New technological advances in operating procedures also reduce the potential for impacts.

Recommended Conservation Measures

The following recommended conservation measures for oil and gas exploration and development should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH:

- Avoid the discharge of produced waters into marine waters and estuaries.
- Avoid discharge of muds and cuttings into the marine and estuarine environment.
- To the extent practicable, avoid the placement of fill to support construction of causeways or structures in the nearshore marine environment.
- As required by federal and state regulatory agencies, encourage the use of geographic response strategies that identify EFH and environmentally sensitive areas.
- Evaluate potential impacts to EFH that may result from activities carried out during the decommissioning phase of oil and gas facilities.
- Vessel operations and shipping activities should be familiar with Alaska Geographic Response Strategies which detail environmentally sensitive areas of Alaska's coastline.

F.2.4.5 Habitat Restoration and Enhancement

Habitat loss and degradation are major, long-term threats to the sustainability of fishery resources (NMFS 2002). Viable coastal and estuarine habitats are important to maintaining healthy fish stocks. Good water quality and quantity, appropriate substrate, ample food sources,

and adequate shelter from predators are needed to sustain fisheries. Restoration and/or enhancement of coastal and riverine habitat that supports managed fisheries and their prey will assist in sustaining and rebuilding fish stocks by increasing or improving ecological structure and functions. Habitat restoration and enhancement may include, but is not limited to, improvement of coastal wetland tidal exchange or reestablishment of natural hydrology; dam or berm removal; fish passage barrier removal or modification; road-related sediment source reduction; natural or artificial reef, substrate, or habitat creation; establishment or repair of riparian buffer zones; improvement of freshwater habitats that support anadromous fishes; planting of native coastal wetland and submerged aquatic vegetation; and improvements to feeding, shade or refuge, spawning, and rearing areas that are essential to fisheries.

Potential Adverse Impacts

The implementation of restoration and enhancement activities may have localized and temporary adverse impacts on EFH. Possible impacts can include (1) localized nonpoint source pollution such as influx of sediment or nutrients, (2) interference with spawning and migration periods, (3) temporary removal feeding opportunities, (4) indirect effects from construction phase of the activity (5) direct disturbance or removal of native species, and (6) temporary or permanent habitat disturbance.

Recommended Conservation Measures

The following recommended conservation measures for habitat restoration and enhancement should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Use BMPs to minimize and avoid potential impacts to EFH during restoration activities.
 - Use turbidity curtains, hay bales, and erosion mats.
 - Plan staging areas in advance, and keep them to a minimum size.
 - Establish buffer areas around sensitive resources.
 - Remove invasive plant and animal species from the proposed action area before starting work. Plant only native plant species.
 - Establish temporary access pathways before restoration activities.
- Avoid restoration work during critical life stages for fish such as spawning, nursery, and migration.
- Provide adequate training and education for volunteers and project contractors to ensure minimal impact to the restoration site.
- Conduct monitoring before, during, and after project implementation.
- To the extent practicable, mitigate any unavoidable damage to EFH.
- Remove and, if necessary, restore any temporary access pathways and staging areas used.
- Determine benthic productivity by sampling before any construction activity in the case of subtidal enhancement (e.g., artificial reefs). Avoid areas of high productivity to the maximum extent possible.

F.2.4.6 Marine Mining

Mining activities, which are also described in Sections 3.1.1 and 3.1.2 of the EFH EIS (NMFS 2005), can lead to the direct loss or degradation of EFH for certain species. Offshore mining, such as the extraction of gravel and gold in the Bering Sea, can increase turbidity, and resuspension of organic materials could impact eggs and recently hatched larvae in the area. Mining large quantities of beach gravel can also impact turbidity, and may significantly affect the transport and deposition of sand and gravel along the shore, both at the mining site and down-current (NMFS 2005).

Potential Adverse Impacts

Impacts from mining on EFH include both physical impacts (i.e., intertidal dredging) and chemical impacts (i.e., additives such as flocculants) (NMFS 2005). Physical impacts may include the removal of substrates that serve as habitat for fish and invertebrates; habitat creation or conversion in less productive or uninhabitable sites, such as anoxic holes or silt bottom; burial of productive habitats, such as in near-shore disposal sites (as in beach nourishment); release of harmful or toxic materials either in association with actual mining, or in connection with machinery and materials used for mining; creation of harmful turbidity levels; and adverse modification of hydrologic conditions so as to cause erosion of desirable habitats. Submarine disposal of mine tailings can also alter the behavior of marine organisms.

Recommended Conservation Measures

The following recommended conservation measures for marine mining should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- To the extent practicable, avoid mining in waters containing sensitive marine benthic habitat, including EFH (e.g., spawning, migrating, and feeding sites).
- Minimize the areal extent and depth of extraction to reduce recolonization times.
- Monitor turbidity during operations, and cease operations if turbidity exceeds predetermined threshold levels.
- Monitor individual mining operations to avoid and minimize cumulative impacts.
- Use seasonal restrictions as appropriate to avoid and minimize impacts to EFH during critical life history stages of managed species (e.g., migration and spawning).
- Deposit tailings within as small an area as possible.

F.2.5 References

- Abbe, T.B. and D.R. Montgomery. 1996. "Large woody debris jams, channel hydraulics, and habitat formation in large rivers." *Regulated Rivers: Research and Management*. 12:201-221.
<http://www.cems.uvm.edu/ce361/papers/abbe1996.pdf>
- Abbott, R. and E. Bing-Sawyer. 2002. Assessment of pile driving impacts on the Sacramento blackfish (*Othodon microlepidotus*). Draft report prepared for Caltrans District 4. October 10, 2002.

- Alaska Department of Environmental Conservation (ADEC). 2010a. Ocean Discharge Criteria Evaluation Alaska Offshore Seafood Processors APDES General Permit AKG523000. Prepared by Tetra Tech, 10306 Eaton Place Suite 340, Fairfax, VA 22030. 152 pp.
- ADEC. 2010b. Wastewater Discharge Authorization Program, 555 Cordova Street, Anchorage, AK 99501. Fact Sheet Alaska Offshore Seafood Processors General Permit AKG523000. 43 pp.
- Alaska Department of Natural Resources (ADNR). 1999. Cook Inlet Areawide 1999 Oil and Gas Lease Sale, Final Finding of the Director. Volume II. Appendix B: "Laws and Regulations Pertaining to Oil and Gas Exploration, Development, Production, and Transportation."
- American Fisheries Society (AFS). 2000. AFS Policy Statement #13: Effects of Surface Mining on Aquatic Resources in North America (Revised). (Abbreviated) http://www.fisheries.org/afs/docs/policy_13f.pdf
- Arruda, J.A., G.R. Marzolf, R.T. Faulk. 1983. The role of suspended sediments in the nutrition of zooplankton in turbid reservoirs. *Ecology* 64(5):1225-35.
- Atlantic States Marine Fisheries Commission. 1992. Fishery management plan for inshore stocks of winter flounder. Washington (DC): ASMFC. FMR No. 21. 138 p.
- Barr B.W. 1993. Environmental impacts of small boat navigation: vessel/sediment interactions and management implications. In: Magoon OT, editor. Coastal Zone '93: proceedings of the eighth Symposium on Coastal and Ocean Management; 1993 Jul 19-23; New Orleans, LA. American Shore and Beach Preservation Association. p 1756-70.
- Benfield, M.C. and T. J. Minello. 1996. "Relative effects of turbidity and light intensity on reactive distance and feeding of an estuarine fish." *Environmental Biology of Fishes*. 46:211-216.
- Brix, K.V., D.K. DeForest, and W.J. Adams 2001. Assessing acute and chronic copper risks to freshwater aquatic life using species sensitivity distributions for different taxonomic groups. *Environmental Toxicology and Chemistry*. 20(8): 1846-1856.
- CalTrans. 2001. Fisheries Impact Assessment, Pile Installation Demonstration Project for the San Francisco - Oakland Bay Bridge, East Span Seismic Safety Project, August 2001. 59 pp.
- Capuzzo J.M., and J.J. Sassner Jr. 1977. The effect of chromium on filtration rates and metabolic activity of *Mytilus edulis* L. and *Mya arenaria* L. In: Vernberg FJ, and others, editors. Physiological responses of marine biota to pollutants. San Diego (CA): Academic Press. p 225-37.
- Center for Watershed Protection (CWP). 2003. Impacts of Impervious Cover on Aquatic Systems. Elliott City, MD, www.cwp.org. 141 pp.
- Christopherson, A. and J. Wilson. 2002. Technical Letter Report Regarding the San Francisco-Oakland Bay Bridge East Span Project Noise Energy Attenuation Mitigation. Peratrovich, Nottingham & Drage, Inc. Anchorage, Alaska. 27 pp.
- Cloern, J.E. 1987. "Turbidity as a control on phytoplankton biomass and productivity in estuaries." *Continental Shelf Research*. 7:1367-1381.
- Conner, Billy, Director Alaska University Transportation Center. University of Alaska, Fairbanks PO Box 755900. 2007 Interview in Building Alaska. http://www.buildingalaskamovie.com/interviews_billy.html
- Deegan, L.A. and R.N. Buchsbaum. 2005. The effect of habitat loss and degradation on fisheries. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline on fisheries resources in New England: evaluating the

- impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 67-96.
- Dennison, W.C. 1987. "Effect of light on seagrass photosynthesis, growth and depth distribution." *Aquatic Botany*. 27:15-26.
- Dugan, J.E., D.M. Hubbard, D.L. Martin, J.M. Engle, D.M. Richards, G.E. Davis, K.D. Lafferty, and R.F. Ambrose. 2000. Macrofauna communities of exposed sandy beaches on the Southern California mainland and Channel Islands. pp 339-346. In Brown, D.R., K.L. Mitchell, and H.W. Chang, eds. Proceedings of the Fifth California Islands Symposium. Minerals Management Service Publication # 99-0038.
- Farag, A.M., D.A. Skaar, E. Nimick, C. MacConnell, and C. Hogstrand. 2003. Characterizing aquatic health using salmonids mortality, physiology, and biomass estimates in streams with elevated concentrations of arsenic, cadmium, copper, lead, and zinc in the Boulder River Watershed, Montana. *Transaction of the American Fisheries Society* 132(3): 450-457.
- Fay, V. 2002. Alaska Aquatic Nuisance Species Management Plan. Alaska Department of Fish and Game Publication. Juneau, AK. http://www.adfg.state.ak.us/special/invasive/ak_ansmp.pdf.
- Goldstein, J.N., D.F. Woodward, and A.M. Farag. 1999. Movement of adult Chinook salmon during spawning migration in a metals-contaminated system, Coeur d'Alene River, Idaho. *Transactions of the American Fisheries Society* 128:121-129.
- Gregory, S.V. and P.A. Bisson. 1997. Degradation and loss of anadromous salmonid habitat in the Pacific Northwest. In Stouder, J.D., P.A. Bisson, and R.J. Naiman, eds. *Pacific Salmon and Their Ecosystems: Status and Future Options*, pp. 277-314. Chapman and Hall, New York.
- Groundwater Protection Council. 2010. State Groundwater Fact Sheets. http://www.gwpc.org/e-library/documents/state_fact_sheets/alaska.pdf. Ground Water Protection Council, 13308 N. MacArthur Blvd., Oklahoma City, OK 73142.
- Hansen, J.A., Lipton J., and Welsh P.G. 2002. *Environmental toxicology and chemistry*. 21 (3): 633-639
- Hastings, M.C. 2002. Clarification of the meaning of sound pressure levels and the known effects of sound on fish. Document in support of Biological Assessment for San Francisco-Oakland Bay Bridge East Span Seismic Safety Project. August 26, 2002. Revised August 27, 2002. 8 pp.
- Helvey, M. 2002. "Are southern California oil and gas platforms essential fish habitat?" *ICES Journal of Marine Science*. 59:S266-S271.
- Kenai Peninsula Borough. 2004. Cook Inlet Oil and Gas, Kenai Peninsula Borough Oil and Gas History. <http://www.cookinletoilandgas.org/kpb/history.htm>
- Kohler, C.C. and W.R. Courtenay, Jr. 1986. "Introduction of aquatic species." *Fisheries*. 11(2):39-42. Proceedings of the Seventh International Zebra Mussel and Aquatic Nuisance Species Conference. 1997.
- Koski, K.V. 1992. Restoring stream habitats affected by logging activities. Pages 343-404 in G. W. Thayer (editor) *Restoring the nation's marine environment*. Publication UM-SG-TS-92-06. Maryland Sea Grant College, College Park, MD.
- Larson, K. and C. Moehl. 1990. Entrainment of anadromous fish by hopper dredge at the mouth of the Columbia River. In C.A. Simenstad, ed. *Effects of dredging on anadromous Pacific coast fishes*. University of Washington Sea Grant. pp. 102-112.

- Levings, C.D. and T. G. Northcote. 2004. Effects of forestry on estuarine ecosystems supporting fishes. *In* T.G. Northcote and G.F.Hartman, editors, *Fishes and Forestry Worldwide Watershed Interactions and Management*, Blackwell Publishing, pp 320 -335.
- Longmuir, C. and T. Lively. 2001. Bubble curtain systems for use during marine pile driving. Report by Fraser River Pile & Dredge Ltd., New Westminster, British Columbia. 9 pp.
- Lotze, H., I. Milewski, B. Worm, and Z. Koller. 2003 Nutrient Pollution: A Eutrophication Survey of Eelgrass Beds in Estuaries and Coastal Bays in Northern and Eastern New Brunswick. Conservation Council of New Brunswick Inc.
- Luce, A. and M.Crowe. 2001. "Invertebrate terrestrial diversity along a gravel road on Barrie Island, Ontario, Canada." *Great Lakes Entomologist*. 34(1):55-60 SPR-SUM.
- Luoma, S.N. 1996. The developing framework of marine ecotoxicology: pollutants as a variable in marine ecosystems. *Journal of Experimental Marine Biology and Ecology* 200:29-55.
- Maser, C. and J.R. Sedell. 1994. *From the Forest to the Sea: the Ecology of Wood in Streams, Estuaries and Oceans*. St. Lucie Press, Delray Beach, FL. 200 pp.
- McGraw, K. and D. Armstrong. 1990. Fish entrainment by dredges in Grays Harbor, Washington. *In* C.A. Simenstad, ed. *Effects of dredging on anadromous Pacific coast fishes*. University of Washington Sea Grant. pp. 113-131.
- Mitsch W.J., Gosselink JG. 1993. *Wetlands*. 2nd ed. New York (NY): Van Nostrand Reinhold. 722 pp.
- Montgomery, D.R., R.D. Smith, K.M. Schmidt, and G.R. Pess. 1995. "Pool Spacing in Forest Channels." *Water Resources Research*. 31:1097-1105.
- National Marine Fisheries Service (NMFS). 2011. Impacts to Essential Fish Habitat from Non-fishing Activities in Alaska. National Marine Fisheries Service, Alaska Region. Juneau, Alaska. November, 2011.
- NMFS. 2008. Impacts to Marine Fisheries Habitat from Nonfishing Activities in the Northeastern United States. Northeast Regional Office Gloucester, Massachusetts NOAA Technical Memorandum NMFS-NE-209.
- NMFS. 2005. Final Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska, Appendix G Non-fishing Impacts to Essential Fish Habitat and Recommended Conservation Measures.
- NMFS. 2004. Draft National Gravel Extraction Policy. 1335 East-West Highway, Silver Spring, MD 20910. <http://www.nmfs.noaa.gov/habitat/habitatprotection/pdf/gravelguidance.pdf>
- NMFS. 2002. Environmental Assessment, NMFS' Restoration Plan for the Community-Based Restoration Program. Prepared by the NOAA Restoration Center, Office of Habitat Conservation. Silver Spring, MD.
- NMFS. 1998a. Draft document - Non-fishing threats and water quality: A reference for EFH consultation
- NMFS. 1998b. Final recommendations: Essential Fish Habitat for Pacific Coast Groundfish. Prepared by: The Core Team for EFH for Pacific Coast Groundfish June 3, 1998. 2725 Montlake Blvd. E. Seattle, WA 98112. http://www.psmfc.org/efh/groundfish_desc.pdf.
- National Oceanic and Atmospheric Agency (NOAA). 2010. Office of Ocean and Coastal Resource Management. Ocean and Coastal Management in Alaska. <http://coastalmanagement.noaa.gov/mystate/ak.html>.

- National Research Council. 1999. Committee on Hardrock Mining. Hardrock Mining on Federal Lands. Appendix B. Potential Environmental Impacts of Hardrock Mining. (http://www.nap.edu/html/hardrock_fed_land/appB.html).
- Nelson D, Miller J, Rusanowsky D, Greig R, Sennefelder G, Mercaldo-Allen R, Kuropat C, Gould E, Thurberg F, Calabrese A. 1991. Comparative reproductive success of winter flounder in Long Island Sound: a three-year study (biology, biochemistry, and chemistry). *Estuaries* 14(3):318-31.
- Newell, R.C., L.J. Seiderer, and D.R. Hitchcock. 1998. "The impact of dredging on biological resources of the sea bed." *Oceanography and Marine Biology Annual Review*. 36:127-178.
- Nightingale, B. and C.A. Simenstad. 2001a. Dredging activities: Marine issues. Washington State Transportation Center, University of Washington, Seattle, WA 98105. (Document available through the National Technical Information Service, Springfield, VA 22616).
- Nightingale, B. and C.A. Simenstad. 2001b. Overwater Structures: Marine Issues. White paper submitted to Washington Department of Fish and Wildlife, Washington Department of Ecology and Washington Department of Transportation. www.wa.gov/wdfw/hab. 133 pp.
- North Pacific Fishery Management Council and NMFS. 2010. Essential Fish Habitat (EFH) 5-year Review for 2010 Summary Report: Final. April 2010. <http://www.alaskafisheries.noaa.gov/habitat/efh/review.htm>.
- Northcote, T.G. and G.F. Hartman. 2004. Fishes and Forestry - Worldwide Watershed Interactions and Management, Blackwell Publishing, Oxford, UK, 789 pp.
- Omori, M., S. Van der Spoel, C.P. Norman. 1994. Impact of human activities on pelagic biogeography. *Progress in Oceanography* 34 (2-3):211-219.
- Oregon Water Resource Research Institute (OWRRI). 1995. Gravel disturbance impacts on salmon habitat and stream health, volume 1. Summary report. Oregon State University, Corvallis, Oregon. (Also available Vol. II: Technical background report). Available from Oregon Division of State Lands, Salem, Oregon, 503-378-3805.
- OSPAR Commission. 2009. Assessment of Impacts of Mariculture . Publication Number: 442/2009. London, UK
- Pacific Fishery Management Council (PFMC). 1999. Appendix A: Identification and description of essential fish habitat, adverse impacts, and recommended conservation measures for salmon. Amendment 14 to the Pacific Coast Salmon Plan. Portland, OR. 146 pp.
- Packer, D.B., Griffin K., McGlynn K.E. 2005. National Marine Fisheries Service national gravel extraction guidance. Washington (DC): US Department of Commerce. NOAA Technical Memorandum NMFS-F/SPO-70. [cited 2008 Jul 15]. 27 p. Available from: <http://www.nmfs.noaa.gov/habitat/habitatprotection/anadfish/gravel.htm>.
- Phillips, R.C. 1984. The ecology of eelgrass meadows in the Pacific Northwest: a community profile. U.S. Fish and Wildlife Service. FWS/OBS-84/24. 85 pp.
- Ralph, S., G. Poole, L. Conquest, and R. Naiman. 1994. "Stream channel morphology and woody debris in logged and unlogged basins in western Washington." *Can. J. Fish. Aquatic Sciences*. 51:37-51.
- Reyff, J.A and P. Donovan. 2003. Benicia-Martinez Bridge Bubble Curtain Test - Underwater Sound Measurement Data. Memo to Caltrans dated January 31, 2003. 3 pp.
- Robinson W.E., and Pederson J. 2005. Contamination, habitat degradation, overfishing - An "either-or" debate? In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England:

- evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 1-10.
- Rosecchi, E., A.J. Crivelli, G. Catsadorakis. 1993. The establishment and impact of *Pseudorabiosa parva*, an exotic fish species introduced into lake Mikri Prespa (northwestern Greece). *Aquatic Conservation: Marine and Freshwater Ecosystems* 3:223-231.
- Roy Consultants Ltd., NATECH Environmental Services Inc. and OCL Group. Environmental Management Consultants. 2003. Lamèque Bay environmental management study. Report No. 133-01.
- Scott G.I., M.H. Fulton, D.W. Moore, E.F. Wirth, G.T. Chandler, P.B. Key, J.W. Daugomah, E.D. Strozier, J. Devane, J.R. Clark, M.A. Lewis, D.B. Finley, W. Ellenberg, and K.J. Karnaky. 1999. "Assessment of risk reduction strategies for the management of agricultural nonpoint source pesticide runoff in estuarine ecosystems." *Toxicology and Industrial Health*. 15:200-213.
- Sedell, J.R., and K.J. Luchessa. 1982. Using the historical record as an aid to salmonid habitat enhancement. In Armantrout, N.B. (ed.), *Acquisition and utilization of aquatic habitat inventory information*, p. 210-222. American Fisheries Society, Western Division, Bethesda, MD.
- Sengupta, M. 1993. *Environmental Impacts of Mining: Monitoring, Restoration, and Control*. CRC Press, Inc. 2000 Corporate Blvd., N.W. Boca Raton, FL. 33431. p.1.
- Spence, B.C., G.A. Lomnický, R.M. Hughes, and R.P. Novitzki. 1996. An ecosystem approach to salmonid conservation. TR-4501-96-6057. ManTech Environmental Research Services Corp., Corvallis, OR. 356 pp. (Available from the NMFS Habitat Branch, Portland, OR).
- Stadler, J.H. 2002. Personal observation of fish-kill occurring during pile driving activity at the Winslow Ferry Terminal, Winslow, WA. October 7, 2002. Fish Biologist, DOC/NOAA/National Marine Fisheries Service/HCD, Lacey, WA.
- Stiles, S., J. Choromanski, D. Nelson, J. Miller, R. Grieg, and G. Sennefelder. 1991. Early reproductive success of the hard clam (*Mercenaria mercenaria*) from five sites in Long Island Sound. *Estuaries* 14(3):332-42.
- Stotz, T. and J. Colby. 2001. January 2001 dive report for Mukilteo wingwall replacement project. Washington State Ferries Memorandum. 5 pp. + appendices.
- Theriault, M.H., S.C. Courtenay, C. Godin and W.B. Ritchie. 2006. Evaluation of the Community Aquatic Monitoring Program (CAMP) to assess the health of four coastal areas within the southern Gulf of St. Lawrence with special reference to the impacts of effluent from seafood processing plants. *Can. Tech. Rep. Fish. Aquat. Sci.* 2649: vii + 60 p.
- Thurberg, F.P., and E. Gould. 2005. Pollutant effects upon cod, haddock, pollock, and flounder of the inshore fisheries of Massachusetts and Cape Cod Bays. In: Buchsbaum R, Pederson J, Robinson WE, editors. *The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation*. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 43-66.
- Trombulak, S.C. and C.A. Frissell. 2000. "Review of ecological effects of roads on terrestrial and aquatic communities." *Conservation Biology*. 14(10):18-30. February.
- United States Department of Agriculture Forest Service. 2008. Tongass Monitoring and Evaluation Report – Appendix B http://www.fs.fed.us/r10/tongass/projects/tlmp/2008_monitoring_report/index2008.shtml
- United States Environmental Protection Agency (USEPA). 2000a. Environmental Screening Checklist and Workbook for the Water Transportation Industry. August 2000.

-
- USEPA, Region 10. 2000b. Authorization to discharge under the National Pollutant Discharge Elimination System (NPDES) for Section 402 modifications of Section 404 permits for log Transfer Facilities which received a Section 404 permit prior to October 22, 1985. NPDES Permit Number AK-G70-0000. March 2000. 1200 Sixth Avenue, OW-130 Seattle, Washington 98101.
- USEPA. 1993. Guidance for specifying management measures for sources of nonpoint pollution in coastal waters. EPA Office of Water. 840-B-92-002. 500+ pp.
- Washington Department of Fish and Wildlife. 2009. Gold and fish. Rules for mineral prospecting and placer mining. 2nd edition. April 2009. Olympia, WA.
- Widdows J, Burns K.A., Menon N.R., Page D., Soria S. 1990. Measurement of physiological energetics (scope for growth) and chemical contaminants in mussel (*Arca zebra*) 220 transplanted along a contamination gradient in Bermuda. Journal of Experimental Marine Biology and Ecology 138:99-117.
- Williams, G.D. and R.M. Thom. 2001. Marine and estuarine shoreline modification issues. White paper submitted to Washington Department of Fish and Wildlife, Washington Department of Ecology and Washington Department of Transportation. www.wa.gov/wdfw/hab/ahg. 99 pp.

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Appendix 3 Crab FMP Amendment 40 - amendment text for updating EFH description and non-fishing impacts to EFH, changing HAPC timeline, and updating EFH research objectives (EFH Omnibus Amendment)

1. In the Executive Summary, in the text box titled “Amendments to the BSAI King and Tanner Crab FMP”, delete “(proposed)” after Amendments 12 and 16, and insert the following description of Amendment 40 in sequential order:

40. Revisions to essential fish habitat information (revised Amendment 16).

2. In Section 8.1.6.2, Description of Habitat Areas of Particular Concern, insert the following two new paragraphs before the paragraph beginning “In 2005...”:

Proposed HAPCs, identified on a map, must meet at least two of the four considerations established in 50 CFR 600.815(a)(8), and rarity of the habitat is a mandatory criterion. HAPCs may be developed to address identified problems for FMP species, and they must meet clear, specific, adaptive management objectives.

The Council will initiate the HAPC process by setting priorities and issuing a request for HAPC proposals. Any member of the public may submit a HAPC proposal. HAPC proposals may be solicited every 5 years, to coincide with the EFH 5-year review, or may be initiated at any time by the Council. The Council will establish a process to review the proposals. The Council may periodically review existing HAPCs for efficacy and considerations based on new scientific research.

3. In Section 8.1.6.3, Conservation and Enhancement Recommendations for EFH and HAPC, revise the section content as follows (note, delete text indicated with ~~strikeout~~, insert text that is underlined):

Appendix F identifies fishing and non-fishing threats to EFH. Conservation and enhancement recommendations for non-fishing threats to EFH and HAPCs are described therein.

In order to protect EFH from fishing threats, the Council established the following areas (maps of these areas, as well as their coordinates, are contained in Appendix F):

- Aleutian Islands Habitat Conservation Area
- Aleutian Islands Coral Habitat Protection Areas

~~Maps of these areas, as well as their coordinates, are contained in Appendix F. In addition, the Council established restrictions for these areas as described below. In order to minimize adverse effects of fishing, the Council established restrictions for the EFH conservation areas and HAPCs. These restrictions are described below.~~

Aleutian Islands Habitat Conservation Area

The use of nonpelagic trawl gear is prohibited year-round in the Aleutian Islands Habitat Conservation Area, except in designated areas; however, the use of trawl gear is prohibited in the king and Tanner crab fisheries (see Section 8.1.1).

Aleutian Islands Coral Habitat Protection Areas

The use of bottom contact gear, as described in 50 CFR part 679, and anchoring by federally permitted fishing vessels is prohibited in the Aleutian Islands Coral Habitat Protection Areas.

~~In order to minimize adverse effects of fishing, the Council also established restrictions for HAPCs. These restrictions are described below.~~

Alaska Seamount Habitat Protection Areas

The use of bottom contact gear and anchoring by a federally permitted fishing vessel, as described in 50 CFR part 679, is prohibited in the Alaska Seamount Habitat Protection Area. Anchoring by a federally permitted fishing vessel, as described in 50 CFR part 679, is also prohibited.

Bowers Ridge Habitat Conservation Zone

The use of mobile bottom contact gear, as described in 50 CFR part 679, is prohibited in the Bowers Ridge Habitat Conservation Zone.

4. In Section 8.1.6.4, Review of EFH and HAPC, revise the second paragraph as follows (note, delete text indicated with ~~strikeout~~, insert text that is underlined):

~~Additionally, the Council may use the FMP amendment cycle every three years to solicit proposals for HAPCs and/or conservation and enhancement measures to minimize the potential adverse effects of fishing. Any proposal endorsed by the Council would be implemented by FMP amendment. HAPC proposals may be solicited every 5 years, coinciding with the EFH 5-year review, or may be initiated at any time by the Council.~~

5. Delete Section 8.1.7, Habitat Areas of Particular Concern, in its entirety, and renumber Section 8.1.8, AFA Sideboard Restrictions, as Section 8.1.7.

6. In Appendix D, excise the existing heading and content of Appendix D.3, Essential Fish Habitat and Habitat Areas of Particular Concern. Insert the complete Section D.3 after Appendix E, and rename it as Appendix F. Rename existing Appendices F, G, and H sequentially as Appendices G, H, and I.

7. In the new Appendix F, Section 1.0, insert the following new paragraph at the end of the section:

In 2009 and 2010, the Council undertook a 5-year review of EFH for the Council's managed species, which was documented in the Final EFH 5-year Review for 2010 Summary Report published in April 2010 (NPFMC and NMFS 2010). The review evaluated new information on EFH, including EFH descriptions and identification, and fishing and non-fishing activities that may adversely affect EFH. The review also assessed information gaps and research needs, and identified whether any revisions to EFH are needed or suggested. The Council identified various elements of the EFH descriptions meriting revision, and approved omnibus amendments 98/90/40/15/11 to the BSAI Groundfish FMP, the GOA Groundfish FMP, the BSAI King and Tanner Crab FMP, the Scallop FMP, and the Salmon FMP, respectively, in 2011. Amendment 40 to the BSAI King and Tanner Crab FMP revised the EFH descriptions for crab species; updated the description of EFH impacts from non-fishing activities, and EFH conservation recommendations for non-fishing activities; revised the timeline associated with the HAPC process to a 5-year timeline coinciding with the EFH 5-year review; and updated EFH research objectives in the FMP.

8. *In the new Appendix F, Section 2.0, revise the table references in the first paragraph as follows (note, delete text indicated with strikeout, insert text that is underlined), and insert new Tables 1-3 directly afterward.*

This section describes habitat requirements and life histories of the crab species managed by this FMP. Information contained in this appendix details life history information for federally managed crab species. Each species or species group is described individually; however, summary tables that denote habitat associations (Table 12), biological associations ~~reproductive traits~~ (Table 23), and predator and prey associations (Table 34) are also provided. In each section, a species-specific table summarizes habitat requirements.

BSAI Crab Species	Life Stage	Nearshore			Shelf		Slope			Stratum Reference				Location			Physical Oceanography	Substrate	Structure	Community Associations	Oceano-graphic Properties																																																						
		Freshwater	Estuarine	Intertidal	Subtidal	Inner 1-50m	Middle 51-100m	Outer 101-200m	Upper 201-300m	Inter-mediate 301-500m	Lower 501-700m	Basin 701-1000m	1001-3000m	Shallows	Island Pass	Bay/Flord					Bank	Flat	Edge	Gully	Surface	Near surface	Semi-demersal	Demersal	1-200m (epi)	201-1000m (meso)	>1000m (bathy)	Upwelling areas	Gyres	Thermo/pycnocline	Fronts	Edges (ice, bath)	Organic Debris	Mud	Sand	Gravel	Mud & sand	Mud & gravel	Sand & mud	Gravel & mud	Gravel & sand	Gravel & sand & mud	Gravel & mud & sand	Cobble	Rock	Bars	Sinks	Slumps/Rock falls/Debris	Channels	Ledges	Pinnacles	Seamounts	Reefs	Vertical Walls	Man-made	Algal Cover	Arenones	Enchinoderms	Soft Coral	Hard Coral	Mollusca	Drift Algae/Kelp	Kelp	Polychaetes	Sea Grasses	Sea Onions	Tunicates	Temperature (Celsius)	Salinity (ppt)	Oxygen Conc (ppm)	Life Stage

Table 2. Summary of biological associations for BSAI crab species.

BSAI Crab Species	Life Stage	Reproductive Traits																											
		Age at Maturity				Fertilization/Egg Development					Spawning Behavior							Spawning Season											
		Female		Male		External	Internal	Oviparous	Ovoviviparous	Viviparous	Batch Spawner	Broadcast Spawner	Egg Case Deposition	Nest Builder	Egg/Young Guarder	Egg/Young Bearer	January	February	March	April	May	June	July	August	September	October	November	December	
		50%	100%	50%	100%																								
Blue King Crab	M	6+		6+		x		x								x	x	x	x	x	x	x							
	LJ																												
	EJ																												
	L																												
	E																												
Golden King Crab	M	6+		6+		x		x								x	x	x	x	x	x	x	x	x	x	x	x	x	
	LJ																												
	EJ																												
	L																												
	E																												
Red King Crab	M	7 to 8		7 to 10		x		x								x	x	x	x	x	x	x							
	LJ																												
	EJ																												
	L																												
	E																												
Snow Crab	M	5 to 6		6 to 8		x	x	x								x	x	x	x	x	x	x							
	LJ																												
	EJ																												
	L																												
	E																												
Tanner Crab	M	6 to 8		6 to 8		x	x	x								x	x	x	x	x	x	x							
	LJ																												
	EJ																												
	L																												
	E																												

Table 3. Summary of predator and prey associations for BSAI crab species.

[illegible]

9. In the new Appendix F, Section 2.2, delete the sentence that immediately precedes Table 1, “The following abbreviations are used in the habitat tables to specify location, position in the water column, bottom type, and other oceanographic features.”

10. In the new Appendix F, Section 2.1, delete existing Tables 1, 2, 3, and 4, including captions.

11. In the new Appendix F, delete existing Sections 2.3 through 2.10, and replace with revised Sections 2.3 through 2.7 in the attached file.

12. In the new Appendix F, Section 3.0, make the following edits to the existing second and third paragraphs (note, delete text indicated with ~~strikeout~~, insert text that is underlined), and insert a new fourth paragraph:

EFH is determined to be the general distribution of a species described by life stage. General distribution is a subset of a species’ total population distribution, and is identified as the distribution of 95 percent of the species population, for a particular life stage, if life history data are available for the species. Where information is insufficient and a suitable proxy cannot be inferred, EFH is not described. General distribution is used to describe EFH for all stock conditions whether or not higher levels of information exist, because the available higher level data are not sufficiently comprehensive to account for changes in stock distribution (and thus habitat use) over time.

EFH is described for FMP-managed species by life stage as general distribution using ~~new~~ guidance from the EFH Final Rule (67 FR 2343), ~~such as including the updated~~ EFH Level of Information definitions. Analytical tools are used and recent scientific information is incorporated for each life history stage from updated scientific habitat assessment reports. EFH descriptions include both text (see section 3.1) and maps (see section 3.2), if information is available for a species’ particular life stage. ~~These descriptions are risk averse, supported by scientific rationale, and accounts for changing oceanographic conditions, regime shifts, and the seasonality of migrating crabs. The methodology and data sources for the EFH descriptions are described in Appendix D to the EFH EIS (NMFS 2005).~~

EFH descriptions are interpretations of the best scientific information. In support of this information, a thorough review of FMP species is contained in the Environmental Impact Statement for Essential Fish Habitat Identification and Conservation (NMFS 2005) (EFH EIS) is contained in Section 3.2.1, Biology, Habitat Usage, and Status of Magnuson-Stevens Act Managed Species and detailed by life history stage in Appendix F: EFH Habitat Assessment Reports. This EIS was supplemented in 2010 by a 5-year review, which re-evaluated EFH descriptions and fishing and non-fishing impacts on EFH in light of new information (NPFMC and NMFS 2010). The EFH descriptions are risk averse, supported by scientific rationale, and account for changing oceanographic conditions and regime shifts.

13. In the new Appendix F, Section 3.3.5 HAPC Process, revise the existing final two paragraphs, as follows (note, deletions are indicated with ~~strikeout~~, insertions are indicated with underline):

The Council will initiate the HAPC process by setting priorities and issuing a request for HAPC proposals. Any member of the public may submit a HAPC proposal. HAPC proposals may be solicited every ~~3 years or on a schedule established by the Council 5 years, to coincide with the EFH 5-year review, or may be initiated at any time by the Council.~~ The Council will establish a process to review the proposals. The Council may periodically review existing HAPCs for efficacy and considerations based on new scientific research.

~~Criteria to evaluate the HAPC proposals will be reviewed by the Council and the Scientific and Statistical Committee prior to the request for proposals. The Council will establish a process to review the proposals and may establish HAPCs and conservation measures (NPFMC 2005).~~

14. In the new Appendix F, Section 4.0, Effects of Fishing on Essential Fish Habitat, insert the following new paragraph at the end of the section:

The evaluation of fishing effects on EFH for BSAI crab species was reconsidered as part of the Council's EFH 5-year Review for 2010, and is documented in the Final Summary Report for that review (NPFMC and NMFS 2010). The review evaluated new information since the development of the EFH EIS, for individual species and their habitat needs, as well as the distribution of fishing intensity, spatial habitat classifications, classification of habitat features, habitat- and feature-specific recovery rates, and gear- and habitat-specific sensitivity of habitat features. Based on the review, the Council concluded that recent research results are consistent with the habitat sensitivity and recovery parameters and distributions of habitat types used in the analysis of fishing effects documented in the EFH EIS. The review noted that fishing intensity has decreased overall, gear regulations have been designated to reduce habitat damage, and area closures have limited the expansion of effort into areas of concern.

15. In the new Appendix F, Section 4.4.2 Blue King Crab, revise the existing paragraph as follows (note, delete text indicated with ~~strikeout~~, insert text that is underlined) .

Summary of Effects—Fishing activity effects are unknown or ~~ies~~ are considered to have overall minimal and temporary effects on the EFH for blue king crab, although ~~both~~ the Pribilof Islands stock is below MSST and the St. Matthew stock of blue king crabs has just recovered to B_{MSY} ~~are considered to be below MSST~~. ~~It is unknown if~~ Habitat loss or degradation by fishing activities ~~had probably did not play~~ any role in the decline of these stocks. For the Pribilof Islands blue king crab, any fishing activities thought to have adverse consequences on habitat have previously been mitigated by establishment of the Pribilof Islands trawl closure area. For St. Matthew blue king crab, there has never been a groundfish bottom trawl fishery in the area. Given the current very small overlap and fishing intensity in areas with blue king crab of all life stages, professional judgement indicates that fisheries do not currently adversely affect the EFH of blue king crab.

16. In the new Appendix F, Section 4.4.5 Tanner Crab, revise the existing paragraph as follows (note, delete text indicated with ~~strikeout~~, insert text that is underlined) .

Summary of Effects—Fishing activities are considered to have ~~overall~~ minimal and temporary effects on the EFH for Tanner crabs. Tanner crab settle and grow on mud habitat, which was the least affected habitat in the EBS. This analysis of the spatial distribution of Tanner crabs relative to expected habitat impacts indicates that Tanner crabs have not demonstrated shifts away from regions heavily impacted by fishing. ~~The closure of the Bristol Bay region and its associated reduction in habitat impacts did not attract crabs to the region.~~ The effects of fishing activities on Tanner crab feeding activities is minimal.

17. In the new Appendix F, delete Section 4.4.4 Scarlet King Crab and Section 4.4.7 Deepwater Tanner Crabs, and renumber all subsections in Section 4.4 accordingly.

18. In the new Appendix F, delete existing text in Section 5.0 Non-fishing Impacts, and replace with the revised Section 5.0 in the attached file.

19. In the new Appendix F, Section 7.0 Research Approach for EFH, revise the first paragraph as follows (note, delete text indicated with ~~strikeout~~, insert text that is underlined):

The EFH EIS (NMFS 2005) identified ~~a the following~~ research approach for EFH regarding minimizing fishing impacts. The research approach was revised in 2010 following the Council's EFH 5-year Review for 2010, documented in a Final Summary Report (NPFMC and NMFS 2010).

20. In the new Appendix F, Section 7.0 Research Approach for EFH, delete existing text under the heading “Objectives” and replace with the following:

Establish a scientific research and monitoring program to understand the degree to which impacts have been reduced within habitat closure areas, and to understand how benthic habitat recovery of key species is occurring.

21. In the new Appendix F, Section 7.0 Research Approach for EFH, delete existing text under the heading “Research Activities” and replace with the following:

- Fishing effort data from observers and remote sensing would be used to study changes in bottom trawl and other fishing gear activity in the closed (and open) areas. Effects of displaced fishing effort would have to be considered. The basis of comparison would be changes in the structure and function of benthic communities and populations, as well as important physical features of the seabed, after comparable harvests of target species are taken with each gear type.
- Monitor the structure and function of benthic communities and populations in the newly closed areas, as well as important physical features of the seabed, for changes that may indicate recovery of benthic habitat. Whether these changes constitute recovery from fishing or just natural variability/shifts requires comparison with an area that is undisturbed by fishing and otherwise comparable.
- Validate the LEI model and improve estimates of recovery rates, particularly for the more sensitive habitats, including coral and sponge habitats in the Aleutian Islands region, possibly addressed through comparisons of benthic communities in trawled and untrawled areas.
- Obtain high resolution mapping of benthic habitats, particularly in the on-shelf regions of the Aleutian Islands.
- Time series of maturity at age should be collected to facilitate the assessment of whether habitat conditions are suitable for growth to maturity.
- In the case of red king crab spawning habitat in southern Bristol Bay, research the current impacts of trawling on habitat in spawning areas and the relationship of female crab distribution with respect to bottom temperature.

22. In the new Appendix F, Section 8.0, insert the following reference alphabetically.

NPFMC and NMFS. 2010. Essential Fish Habitat (EFH) 5-year Review for 2010 Summary Report: Final. April 2010. <http://www.alaskafisheries.noaa.gov/habitat/efh/review.htm>

23. Update the Table of Contents at the beginning of the new Appendix F.

24. In the new Appendix H, Literature Cited, insert the following reference alphabetically.

NPFMC and NMFS. 2010. Essential Fish Habitat (EFH) 5-year Review for 2010 Summary Report: Final. April 2010. <http://www.alaskafisheries.noaa.gov/habitat/efh/review.htm>

25. Update the Table of Contents for the FMP.

2.3 Red king crab (*Paralithodes camtschaticus*)

2.3.1 Life History and General Distribution

Red king crab (*Paralithodes camtschaticus*) is widely distributed throughout the Bering Sea and Aleutian Islands, Gulf of Alaska, Sea of Okhotsk, and along the Kamchatka shelf. Red king crab are typically at depths less than 100 fathoms. King crab molt multiple times per year through age 3 after which molting is annual. At larger sizes, king crab may skip molt as growth slows. Females grow slower and do not get as large as males. In Bristol Bay, 50 percent maturity is attained by males at 12 cm carapace length (CL) and 9 cm CL by females (about 7 years). Female red king crab in the Norton Sound area reach 50 percent maturity at 6.8 cm and do not attain maximum sizes found in other areas. Size at 50 percent maturity for females in the western Aleutians is 8.9 cm CL. Natural mortality of adult red king crab is assumed to be about 16.5 percent per year ($M=0.18$), due to old age, disease, and predation.

The size at 50 percent maturity is 7 and 9 cm CL for female and male red king crabs, respectively, from Norton Sound and St. Matthew and St. Lawrence Islands; it is 9 and 12 cm, respectively, for Bristol Bay and the Pribilof and Aleutian Islands.

2.3.2 Fishery

The red king crab fisheries are prosecuted using mesh covered pots (generally 7 or 8 feet square) set on single lines. Mean age at recruitment is about 8 to 9 years. Two discrete populations of red king crab are actively fished in the Bering Sea and Aleutian Islands region: Bristol Bay and Norton Sound. A third population surrounding the Aleutian Islands was managed separately as Adak and Dutch Harbor stocks until 1996 when the management areas were combined. The fishery on the Adak stock was closed in 1996, and the fishery on the Dutch Harbor stock has closed since the 1983/1984 season. These fisheries historically occurred in the winter and spring. Red king crab are allowed as bycatch during golden king crab fisheries in those areas. Other populations of red king crab are fished in the Pribilof Islands area, St. Matthew Island area, and St. Lawrence Island area, but are managed in conjunction with the predominant blue king crab fisheries. Red king crab stocks are managed separately to accommodate different life histories and fishery characteristics. Only male red king crab greater than 16.5 cm CL are allowed to be taken from Bristol Bay and the Pribilof and Aleutian Islands. The minimum size limit for harvest of male crab from the Norton Sound and the St. Matthew and St. Lawrence Islands population is 12 cm. Since the individual fishing quota fishery in 2005, the season in Bristol Bay begins on November 1 and can last for 3 months. Bycatch in red king crab fisheries consists primarily of Tanner crab and nonlegal red king crab. The commercial fishery for red king crab in Norton Sound occurs in the summer, opening in late June, and a winter through-the-ice fishery opens November 15 and closes May 15.

Bottom trawls and dredges could disrupt nursery and adult feeding areas.

2.3.3 Relevant Trophic Information

Pacific cod is the main predator on red king crabs. Walleye pollock, yellowfin sole, and Pacific halibut are minor consumers of pelagic larvae, settling larvae, and larger crabs, respectively. Juvenile crab may be cannibalistic during molting.

2.3.4 Habitat and Biological Associations

Egg: Egg hatch of larvae is synchronized with the spring phytoplankton bloom in southeast Alaska suggesting temporal sensitivity in the transition from benthic to planktonic habitat. Also see mature phase description; eggs are carried by adult female crab.

Larvae: Red king crab larvae spend 2 to 3 months in pelagic larval stages before settling to the benthic life stage. Reverse diel migration and feeding patterns of larvae coincide with the distribution of food sources.

Early Juvenile: Early juvenile stage red king crabs are solitary and need high relief habitat or coarse substrate such as boulders, cobble, shell hash, and living substrates such as bryozoans and stalked ascidians. Young-of-the-year crabs occur at depths of 50 m or less.

Late Juvenile: Late juvenile stage red king crabs ages 2 to 4 years exhibit decreasing reliance on habitat and a tendency for the crab to form pods consisting of thousands of crabs. Late juvenile crab associate with deeper waters and migrate to shallower water for molting and mating in the spring. Aggregation behavior continues into adulthood.

Mature: Mature red king crabs exhibit seasonal migration to shallow waters for reproduction. The remainder of the year, red king crabs are found in deeper waters. In Bristol Bay, red king crabs mate when they enter shallower waters (less than 50 m), generally beginning in January and continuing through June. Males grasp females just prior to female molting, after which the eggs (43,000 to 500,000 eggs) are fertilized and extruded on the female's abdomen. The female red king crab carries the eggs for 11 months before they hatch, generally in April.

Habitat and Biological Associations: Red king crab

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	11 mo.	N/A	May–April	N/A	N/A	N/A	fronts	
Larvae	3–5 mo.	diatoms, phytoplankton, copepod nauplii	April–August	inner and middle continental shelf (1–100 m)	pelagic	N/A	fronts	
Juveniles	1 to 5–6 yrs	diatoms, hydroids	all year	inner and middle continental shelf (1–100 m), nearshore bays, beach (intertidal)	demersal	subaquatic vegetation (epifauna), rock, cobble, gravel	fronts	found among biogenic assemblages (sea onions, tube worms, bryozoans, ascidians, sea stars)
Adults	5–6+ yrs	mollusks, echinoderms, polychaetes, decapod, crustaceans, algae, urchins, hydroids, sea stars	spawning Jan–June	inner and middle continental shelf (1–100 m), nearshore bays, beach (intertidal)	demersal	sand, mud, cobble, gravel	fronts	

N/A = not applicable

2.3.5 Literature

Foy, R.J. 2011. Stock Assessment and Fishery Evaluation Report for the Pribilof Islands Red King Crab Fisheries of the Bering Sea and Aleutian Islands Region. *In* 2011 Stock Assessment and Fishery Evaluation Report for the King and Tanner Crab Fisheries in the Bering Sea and Aleutian Islands. NPFMC, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

Zheng, J. and M.S.M. Siddeek. 2011. Bristol Bay Red King Crab Stock Assessment in Spring 2011. *In* 2011 Stock Assessment and Fishery Evaluation Report for the King and Tanner Crab Fisheries in the Bering Sea and Aleutian Islands. NPFMC, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

2.4 Blue king crab (*Paralithodes platypus*)

2.4.1 Life History and General Distribution

Blue king crab (*Paralithodes platypus*) has a discontinuous distribution throughout its range (Hokkaido, Japan, to Southeast Alaska). In the Bering Sea, discrete populations exist in the cooler waters around the Pribilof Islands, St. Matthew Island, and St. Lawrence Island. Smaller populations have been found in Herendeen Bay and around Nunivak and King Island, as well as isolated populations in the Gulf of Alaska. Blue king crab molt multiple times as juveniles. In the Pribilof Islands area, 50 percent maturity of females is attained at 9.6 cm CL, which occurs at about 5 years of age. Blue king crab in the St. Matthew Island area mature at smaller sizes (50 percent maturity at 8.1 cm CL for females) and do not get as large overall. Skip molting occurs with increasing probability for those males larger than 10 cm CL and is more prevalent for St. Matthew Island crab. Larger female blue king crab have a biennial ovarian cycle and a 14-month embryonic period. Unlike red king crab, juvenile blue king crab do not form pods, instead they rely on cryptic coloration for protection from predators. Adult male blue king crab occur at an average depth of 70 m and an average temperature of 0.6 °C.

The size at 50 percent maturity is 9 cm and 12 cm CL for female and male crabs from the Pribilof Islands, and 8 cm and 10.5 cm CL for St. Matthew Island.

2.4.2 Fishery

The blue king crab fisheries are prosecuted using mesh covered pots (generally 7 or 8 feet square) set on single lines. Two discrete stocks of blue king crab are fished: the Pribilof Islands and the St. Matthew Island stocks. These blue king crab fisheries occurred in September in past years. Bycatch in the blue king crab fisheries consists almost entirely of non-legal blue king crabs. Only male crabs greater than 16.5 cm carapace width (CW) are harvested in the Pribilof Islands, while the St. Matthew Island fishery is managed with a minimum size limit of 140 mm.

Bottom trawls and dredges could disrupt nursery and adult feeding areas.

2.4.3 Relevant Trophic Information

Pacific cod is a predator on blue king crabs.

2.4.4 Habitat and Biological Associations

Egg: See mature phase description; eggs are carried by adult female crab.

Larvae: Blue king crab larvae spend 3.5 to 4 months in pelagic larval stages before settling to the benthic life stage. Larvae are found in waters between 40 and 60 m deep.

Early Juvenile: Early juvenile blue king crabs require substrate characterized by gravel and cobble overlaid with shell hash and sponge, hydroid, and barnacle assemblages. These habitat areas have been found at 40 to 60 m around the Pribilof Islands.

Late Juvenile: Late juvenile blue king crabs are found in nearshore rocky habitat with shell hash.

Mature: Mature blue king crabs occur most often between 45 and 75 m deep on mud-sand substrate adjacent to gravel rocky bottom. Female crabs are found in a habitat with a high percentage of shell hash. Mating occurs in mid-spring. Larger older females reproduce biennially, while small females tend to reproduce annually. Fecundity of females ranges from 50,000 to 200,000 eggs per female. It has been suggested that spawning may depend on the availability of nearshore rocky-cobble substrate for protection of females. Larger older crabs disperse farther offshore and are thought to migrate inshore for molting and mating.

Habitat and Biological Associations: Blue king crab

Stage - EFH Level	Duration or Age	Diet/ Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	14 mo.	N/A	starting April–May	N/A	N/A	N/A	fronts	
Larvae	3.5 to 4 mo.	U	April–July	middle and inner continental shelf (1–100 m)	pelagic	N/A	fronts	
Juveniles	to about 5 years	U	all year	middle and inner continental shelf (1–100 m)	demersal	cobble, gravel, rock	fronts	
Adults	5+ years	U	spawning Feb–Jun	middle and inner continental shelf (1–100 m)	demersal	sand, mud, cobble, gravel, rock	fronts	

N/A = not applicable

2.4.5 Literature

- R.J. 2011. Stock Assessment and Fishery Evaluation Report for the Pribilof Islands Blue King Crab Fisheries of the Bering Sea and Aleutian Islands Region. *In* 2011 Stock Assessment and Fishery Evaluation Report for the King and Tanner Crab Fisheries in the Bering Sea and Aleutian Islands. NPFMC, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.
- Gaeuman, W. 2011. 2011 Saint Matthew Island Blue King Crab Stock Assessment. *In* 2011 Stock Assessment and Fishery Evaluation Report for the King and Tanner Crab Fisheries in the Bering Sea and Aleutian Islands. NPFMC, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

2.5 Golden king crab (*Lithodes aequispina*)

2.5.1 Life History and General Distribution

Golden king crab (*Lithodes aequispina*), also called brown king crab, range from Japan to British Columbia (NMFS 2004). In the Bering Sea and Aleutian Islands, golden king crab are found primarily at depths from 200 to 1,000 m (Somerton and Otto 1986), generally in high relief habitat such as inter-island passes, and they are usually slope-dwelling (NMFS 2004). Size at sexual maturity of males has been estimated to be 13.0 cm CL in the eastern Bering Sea south of 54°14' N. latitude, 10.9 cm CL in the Bowers Ridge area, and 12.1 cm CL in the Segum Pass area (Otto and Cummiskey 1985). Size at sexual maturity of females has been estimated to be 11.1 cm CL in the eastern Bering Sea south of 54°14' N. latitude, 10.6 cm CL in the Bowers Ridge area, and 11.3 cm CL in the Segum Pass area (Otto and Cummiskey 1985). Females carry an average of approximately 10,000 eggs (Shirley 2006), although they may carry up to 27,000 eggs (Jewett et al. 1985), depending on their size. Females carry and incubate eggs approximately 12 months prior to hatching, but time between production of successive clutches is approximately 590 days due to a prolonged period between hatching of the clutch and molting by the female (Shirley 2006). Reproduction is asynchronous and aseasonal (Adams and Paul 1999, Somerton

and Otto 1985) as is the molting cycle (McBride et al. 1982, Otto and Cummiskey 1985, Sloan 1985, Blau and Pengilly 1994, Paul and Paul 2000).

2.5.2 Fishery

The golden king crab fisheries are prosecuted using mesh covered pots set on longlines to minimize gear loss. The primary fishery is in the Aleutian Islands, with minor catches coming from localized areas in the Bering Sea and Gulf of Alaska. The golden king crabs in the Aleutian Islands in the areas east and west of 174° W. longitude are managed as two separate stocks. The commercial fishing season for golden king crabs in the Aleutian Islands Area is August 15 through May 15, and male crabs greater than 15.2 cm CW are harvested. Bycatch in the commercial golden king crab fishery consists almost exclusively of non-legal golden king crab. Escape mechanisms were adopted into regulation by the Alaska Board of Fisheries in 1996 to reduce capture and handling mortality of non-target crab; a minimum of four 5.5-inch rings or at least one-third of one vertical pot surface composed of not less than 9-inch stretched webbing are required on pots used in golden king crab fisheries. Commercial fishing for golden king crabs in the Aleutian Islands Area typically occurs at depths of 183 to 549 m (Barnard and Burt 2007).

2.5.3 Relevant Trophic Information

Unknown

2.5.4 Habitat and Biological Associations

Golden king crabs occur on hard bottom, over steep rocky slopes, and on narrow ledges. Strong currents are prevalent. Golden king crabs coexist with abundant quantities of epifauna: sponges, hydroids, coral, sea stars, bryozoans, and brittle stars.

Egg: See mature phase description; eggs are carried by adult female crab.

Larvae: Larvae are lecithotrophic and therefore do not require diel vertical migrations for feeding in shallow waters (Shirley and Zhou 1997). Depth distribution is unknown but is suspected to be deep and larvae are suspected to be more benthic than planktonic (Shirley and Zhou 1997). Larval period is relatively short (approximately 25 days), followed by a glaucothoe stage that lasts approximately 41 days before settlement (Shirley and Zhou 1997).

Early Juvenile: Information is not available, but apparently settle in deep water, given observations that juveniles become more abundant with increasing depth (Shirley 2006).

Late Juvenile: Late juvenile golden king crabs are found throughout the depth range of the species. Abundance of late juvenile crab increases with depth; in a 1991 pot survey in the Aleutian Islands juvenile crabs were most abundant at the deepest depths fished (548 to 913 m; Blau et al. 1996).

Mature: Large (legal) male crabs are at highest densities between 274 and 639 m whereas adult females are at highest densities between 274 and 456 m; large males and adult females are absent or at low densities greater than 730 m (Blau et al. 1996).

Habitat and Biological Associations: Golden king crab

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs		N/A		N/A	N/A	N/A		
Larvae	2 months	U	varies	U	demersal, semi-demersal	U		
Juveniles		mollusks, echinoderms, polychaetes, diatoms, crustaceans, algae, hydroids, sea stars		lower slope and basin (1,000 to >3,000 m)	demersal, semi-demersal	sand, gravel, cobble, rock		
Adults		mollusks, echinoderms, polychaetes, diatoms, crustaceans, algae, hydroids, sea stars, brittle stars	spawning Jan–Jul	outer shelf and upper slope (100–1,000 m)	demersal, semi-demersal	sand, gravel, cobble, rock		

N/A = not applicable

2.5.5 Literature

- Adams, C. F., and A. J. Paul. 1999. Phototaxis and geotaxis of light-adapted golden king crab zoeae, *Lithodes aequispinus* (Anomura: Lithodidae) in the laboratory. J. Crust. Biol. 19: 106–110.
- Barnard, D. R. and R. Burt. 2007. Alaska Department of Fish and Game summary of the 2005/2006 mandatory shellfish observer program database for the rationalized crab fisheries. Alaska Department of Fish and Game, Fishery Data Series No. 07-02, Anchorage.
- Blau, S. F., and D. Pengilly. 1994. Findings from the 1991 Aleutian Islands golden king crab survey in the Dutch Harbor and Adak management areas including analysis of recovered tagged crabs. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Regional Information Report 4K94-35, Kodiak.
- Blau, S. F., D. Pengilly, and D. Tracy. 1996. Distribution of golden king crabs by sex, size, and depth zones in the eastern Aleutian Islands, Alaska. Pages 167–185 in High latitude crabs: Biology, management, and economics. Alaska Sea Grant College Program Report No. 96-02, University of Alaska Fairbanks.
- Jewett, S. C., N. A. Sloan, and D. A. Somerton. 1985. Size at sexual maturity and fecundity of the fjord-dwelling golden king crab *Lithodes aequispinus* Benedict from northern British Columbia. J. Crust. Biol. 5: 377–385.
- McBride, J., D. Fraser, and J. Reeves. 1982. Information on the distribution and biology of the golden (brown) king crab in the Bering Sea and Aleutian Islands area. NOAA, NWAFC Proc. Rpt. 92-02.
- National Marine Fisheries Service (NMFS). 2004. Bering Sea Aleutian Islands Crab Fisheries Final Environmental Impact Statement. DOC, NOAA, National Marine Fisheries Service, AK Region, P.O. Box 21668, Juneau, AK 99802-1668, August 2004.
- Otto, R. S., and P. A. Cummiskey. 1985. Observations on the reproductive biology of golden king crab (*Lithodes aequispinus*) in the Bering Sea and Aleutian Islands. Pages 123–136 in Proceedings of the International King Crab Symposium. University of Alaska Sea Grant Report No. 85-12, Fairbanks.
- Paul, A. J., and J. M. Paul. 2000. Changes in chela heights and carapace lengths in male and female golden king crabs *Lithodes aequispinus* after molting in the laboratory. Alaska Fishery Research Bulletin 6(2): 70–77.
- Shirley, T. C. 2006. Cultivation potential of golden king crab, *Lithodes aequispinus*. Pages 47–54 in: Stevens, B. G., ed.. Alaska crab stock enhancement and rehabilitation: Workshop proceedings. Alaska Sea Grant College Program AK-SG-06-04.
- Shirley, T. C., and S. Zhou. 1997. Lecithotrophic development of the golden king crab *Lithodes aequispinus* (Anomura: Lithodidae). J. Crust. Biol. 17: 207–216.

- Siddeck, M.S.M., D. Pengilly, and J. Zheng. 2011. Aleutian Islands Golden King Crab Model Based Stock Assessment in Fall 2011. *In* 2011 Stock Assessment and Fishery Evaluation Report for the King and Tanner Crab Fisheries in the Bering Sea and Aleutian Islands. NPFMC, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.
- Sloan, N.A. 1985. Life history characteristics of fjord-dwelling golden king crabs *Lithodes aequispina*. *Mar. Ecol. Prog. Ser.* 22:219-228.
- Somerton, D. A., and R. S. Otto. 1986. Distribution and reproductive biology of the golden king crab, *Lithodes aequispina*, in the eastern Bering Sea. *Fishery Bulletin* 84(3): 571–584.

2.6 Tanner crab (*Chionoecetes bairdi*)

2.6.1 Life History and General Distribution

Tanner crab (*Chionoecetes bairdi*), originally described by Rathbun (1924), is one of five species in the genus *Chionoecetes*. The common name for *C. bairdi* of “Tanner crab” has been modified to “southern Tanner crab” (McLaughlin et al. 2005). Previously, the term “Tanner crab” has also been used to refer to other members of the genus, or to the genus as a whole.

Tanner crab are distributed on the continental shelf of the North Pacific Ocean and Bering Sea from Kamchatka to Oregon. In the east, their range extends as far south as Oregon (Hosie and Gaumer 1974), and in the west as far south as Hokkaido, Japan (Kon 1996). The northern extent of their range is in the Bering Sea (Somerton 1981a) where they are found along the Kamchatka peninsula (Slizkin 1990) to the west and in Bristol Bay to the east. Off Alaska, Tanner crab are concentrated around the Pribilof Islands and immediately north of the Alaska Peninsula. They are found in lower abundance in the Gulf of Alaska. The corresponding age of maturity for male and female Tanner crab is approximately 6 to 8 years. Natural mortality of adult Tanner crab is assumed to be about 20 percent per year ($M=0.23$).

In the eastern Bering Sea, the Tanner crab distribution may be limited by water temperature (Somerton 1981a). *C. bairdi* is common in the southern half of Bristol Bay, around the Pribilof Islands, and along the shelf break where water temperatures are generally warmer. The southern range of the cold water congener the snow crab, *C. opilio*, in the eastern Bering Sea is near the Pribilof Islands (Turnock and Rugolo 2009). The distributions of snow and Tanner crab overlap on the shelf from approximately 56° to 58° N., and in this area, the two species hybridize (Karinen and Hoopes 1971).

Tanner crabs in the eastern Bering Sea are considered to be a separate stock distinct stock from Tanner crabs in the eastern and western Aleutian Islands (NPFMC 1998). The unit stock is that defined across the geographic range of the eastern Bering Sea continental shelf, and managed as a single unit. Clinal differences in some biological characteristics may exist across the range of the unit stock (Somerton 1981a).

Reproduction

In most majid crabs, the molt to maturity is the final or terminal molt. For *C. bairdi*, it is now accepted that both males (Otto 1998, Tamone et al. 2007) and females (Donaldson and Adams 1989) undergo terminal molt at maturity. Females terminally molt from their last juvenile, or pubescent, instar usually while being grasped by a male (Donaldson and Adams 1989). Subsequent mating occurs annually in a hard shell state (Hilsinger 1976) and after extrusion of a clutch of eggs. Mating in old-shell adult females has been documented (Donaldson and Hicks 1977); fertile egg clutches can be produced in the absence of males by using stored sperm from the spermathacae (Adams and Paul 1983, Paul and Paul 1992). Two or more consecutive egg fertilization events can follow a single copulation using stored sperm to self-

fertilize (Paul 1982, Adams and Paul 1983); egg viability, however, decreases with time and age of the stored sperm (Paul 1984).

Maturity in males can be classified either physiologically or morphometrically. Physiological maturity is the presence of spermatophores in the male gonads whereas morphometric maturity is the presence of a large claw (Brown and Powell 1972). During the molt to morphometric maturity, there is a disproportionate increase in the size of the chelae in relation to the carapace (Somerton 1981a). Many earlier studies on Tanner crabs assumed that morphometrically mature male crabs continued to molt and grow throughout life, however, evidence is irrefutable supporting a terminal molt for males (Tamone et al. 2007). A consequence of the terminal molt in male Tanner crab is that a substantial portion of the population may never reach the legal harvest size of 138 mm carapace width.

While observations are lacking for the eastern Bering Sea, seasonal differences have been observed between mating periods for pubescent and multiparous Tanner crab females in the Gulf of Alaska and Prince William Sound. Pubescent molting and mating takes place over a protracted period from winter through early summer, whereas multiparous mating occurs over a relatively short period during mid-April to early June (Hilsinger 1976, Munk et al. 1996, and Stevens 2000). In the eastern Bering Sea, egg condition for multiparous Tanner crabs assessed between April and July 1976 also suggested that hatching and extrusion of new clutches for this maturity status began in April and ended sometime in mid-June (Somerton 1981a).

Fecundity

A variety of factors affect female Tanner crab fecundity including female size, maturity status, age post terminal molt, and egg loss (NMFS 2004). Among these factors, female size is the most important, with estimates of 89,000 to 424,000 eggs for eastern Bering Sea females 75 to 124 mm CW, respectively (Haynes et al. 1976). Maturity status is another significant factor affecting fecundity with primiparous females being only approximately 70 percent as fecund as equal size multiparous females (Somerton and Meyers 1983). The number of years post maturity molt and whether a female has had to use stored sperm from that first mating can also affect egg counts (Paul 1984, Paul and Paul 1992). Additionally, older senescent females often carry small clutches or no eggs (i.e., barren) suggesting that female Tanner crab reproductive output is a declining function of age (NMFS 2004).

Size at Maturity

Somerton (1981b) noted differences in the size of Tanner crab female maturity across its eastern Bering Sea range as seen in trawl survey data. Between 1975 and 1979 east of 167°15' W. longitude, the mean size of mature females in the stock ranged from 92.0 to 93.6 mm CW. West of that longitude, the size of 50 percent female maturity ranged from 78.0 to 82.0 mm CW. For Alaska Department of Fish and Game harvest strategy purposes, mature females are defined as females greater than or equal to 80 mm CW. For male Tanner crab during the same survey years, the observed mean size at maturity was 117.0 mm CW and 108.9 mm CW east and west of 167°15' W. longitude, respectively (Somerton 1981b). Size at 50 percent maturity, is 93.3 mm CW for males and 69.3 mm CW for females in the eastern Bering Sea.

Natural Mortality

Due to a lack of age information, Somerton (1981a) estimated mortality separately for individual eastern Bering Sea cohorts of juveniles and adults. Somerton postulated that because of net selectivity of the survey sampling gear, age 5 Tanner crab (mean CW=95 mm) were the first cohort to be fully recruited to the gear; he estimated an instantaneous natural mortality rate of 0.35 for this size class using catch curve analysis. Using a catch curve analysis with two different data sets, Somerton then estimated natural mortality rates of adults (fished population) from data from the eastern Bering Sea population survey of 0.20 to 0.28. When using catch per unit of effort data from the Japanese fishery, the estimated rates were 0.13 to 0.18. Somerton concluded that estimates (0.22 to 0.28) from models that used both the survey and

fishery data were the best. The natural mortality rate of eastern Bering Sea Tanner crab is set at 0.23 for the purpose of assessing stock status and setting the overfishing level based on the current expectation of longevity of at least 18 to 20 years.

2.6.2 Fishery

Management Unit

Fisheries have historically taken place for Tanner crab throughout their range in Alaska, but currently only the fishery in the eastern Bering Sea is managed under a federal fisheries management plan (NPFMC 1998). The plan defers certain management controls for Tanner crab to the state of Alaska with federal oversight (Bowers et al. 2008). The state manages Tanner crab based on registration areas, divided into districts. Under the plan, the state can adjust or further subdivide these districts as needed to avoid overharvest in a particular area, change size limits from other stocks in the registration area, change fishing seasons, or encourage exploration (NPFMC 1998).

The Bering Sea District of Tanner crab Registration Area J includes all waters of the Bering Sea north of Cape Sarichef at 54°36' N. latitude and east of the U.S.-Russia Maritime Boundary Line of 1991. This district is divided into the Eastern and Western Subdistricts at 173° W. longitude. The Eastern Subdistrict is further divided at the Norton Sound Section north of the latitude of Cape Romanzof and east of 168° W. longitude and the General Section to the south and west of the Norton Sound Section (Bowers et al. 2008).

The domestic Tanner crab (*C. bairdi*) pot fishery rapidly developed in the mid 1970s. For stock biomass and fishery data tabled in this document, “year” refers to the survey year, and fishery data are those subsequent to the survey, through prior to the survey in the following year. Other notation is explicit, for example, 2008/09 is the 2008 summer survey and the winter 2009 fishery. United States landings were first reported for Tanner crab in 1968 at 1.01 million pounds taken incidentally to the eastern Bering Sea red king crab fishery. Tanner crab was targeted thereafter by the domestic fleet and landings rose sharply in the early 1970s, reaching a high of 66.6 million pounds in 1977. Landings fell precipitously after the peak in 1977 through the early 1980s, and domestic fishing was closed in 1985 and 1986 as a result of depressed stock status. In 1987, the fishery reopened and landings rose again in the late 1980s to a second peak in 1990 at 40.1 million pounds, and then fell sharply through the mid 1990s. The domestic Tanner crab fishery closed between 1997 and 2004 as a result of severely depressed stock condition. The domestic Tanner crab fishery re-opened in 2005 and has averaged 1.7 million pounds retained catch between 2005 and 2007. Landings of Tanner crab in the foreign Japanese pot and tangle net fisheries were reported between 1965 and 1978, peaking at 44.0 million pounds in 1969. The Russian tangle net fishery was prosecuted between 1965 and 1971 with peak landings in 1969 at 15.6 million pounds. Both the Japanese and Russian Tanner crab fisheries were displaced by the domestic fishery by the late 1970s.

Discard and bycatch losses of Tanner crab originate from the directed pot fishery, non-directed pot fisheries (notably, for snow crab and red king crab), and the groundfish trawl fisheries. Discard/bycatch mortalities were estimated using post-release handling mortality rates of 50 percent for pot fishery discards and 80 percent for trawl fishery bycatch (Turnock and Rugolo 2009). The pattern of total discard/bycatch losses is similar to that of the retained catch. These losses were persistently high during the late 1960s through the late 1970s; male losses peaked in 1970 at 44.5 million pounds. A subsequent peak mode of discard/bycatch losses occurred in the late 1980s through the early 1990s, which, although briefer in duration, revealed higher losses for males than the earlier mode, peaking at 49.2 million pounds in 1990. From 1965 through 1975, the groundfish trawl fisheries contributed significantly to total bycatch losses, although the combined pot fisheries are the principal source of contemporaneous non-retained losses to the stock. Total Tanner crab retained catch plus non-directed losses of males and females, reflect the performance patterns in the directed and non-directed fisheries. Total male catch rose sharply with

fishery development in the early 1960s and reveals a bimodal distribution between 1965 and 1980 with peaks of 104.7 million pounds in 1969 and 115.5 million pounds in 1977. Total male catch rose sharply after the directed domestic fishery reopened in 1987 and reached a peak of 89.3 million pounds in 1990. Total male and female catch fell sharply thereafter with the collapse of the stock and the fishery closure in 1997.

Since re-opening of the domestic fishery in 2005, the relationship of total male discard/bycatch losses by all pot and trawl fisheries combined to retained catch shifted significantly relative to that between 1980 and 1996. For 2005 through 2008, the ratio of total male discard losses to retained catch was 4.3, 3.8, 4.6, and 2.4, respectively, and averaged 3.8 (statistical error = 0.5). The majority of these male losses are sub-legal sized crab, and a principal contributor to these non-retained losses is the directed Tanner crab fishery. This contrasts with the pre-closure performance of the domestic fishery between 1980 and 1996, which averaged 1.1 (statistical error = 0.1) pounds of non-retained male losses to each pound of retained catch. These ratios in terms of numbers of non-retained male losses to retained legal crab are more striking due to the contribution of sub-legal sized crab to total male discards. Discard and bycatch losses of male and female Tanner crab during the closures of the directed domestic fishery (1985 through 1986 and 1997 through 2004) reflect losses due to non-directed eastern Bering Sea pot fisheries and the domestic groundfish trawl fishery.

2.6.3 Relevant Trophic Information

Pacific cod is thought to be the main predator on Tanner crabs in terms of biomass (Livingston 1989, Livingston et al. 1993). Sculpins, while of lower stock biomass than the eastern Bering Sea Pacific cod, are also a significant predator of Tanner crabs of all sizes, and particularly large, mature crabs of both sexes. Predators consume primarily age 0 and 1 juvenile Tanner crab with a less than 70 mm CW. However, flathead sole, rock sole, halibut, skates, yellowfin sole, and eel pouts are important in terms of numbers of juvenile crab. Larval predators include salmon, herring, jellyfish, and chaetognaths. Cannibalism has been observed in laboratory environments among juvenile crabs during molting.

2.6.4 Habitat and Biological Associations

Egg: See mature phase description; eggs are carried by adult female crab.

Larvae: Larvae of *C. bairdi* Tanner crabs are typically found in the Bering Sea and Aleutian Islands water column from 0 to 100 m in early summer. They are strong swimmers and perform diel migrations in the water column (down at night). They usually stay near the depth of the chlorophyll maximum during the day. The last larval stage settles onto the bottom mud.

Early Juvenile: Early juvenile *C. bairdi* Tanner crabs occur at depths of 10 to 20 m in mud habitat in summer and are known to burrow or associate with many types of cover. Early juvenile *C. bairdi* Tanner crabs are not easily found in winter.

Late Juvenile: The preferred habitat for late juvenile *C. bairdi* Tanner crabs is mud. Late juvenile Tanner crab migrate offshore of their early juvenile nursery habitat.

Mature: Mature *C. bairdi* Tanner crabs migrate inshore, and mating is known to occur from February through June. Mature female *C. bairdi* Tanner crabs have been observed in high density mating aggregations, or pods, consisting of hundreds to thousands of crabs per mound. These mounds may provide protection from predators and also attract males for mating. Mating need not occur annually as female *C. bairdi* Tanner crabs can retain viable sperm in spermathecae and mobilize stored sperm in the absence of male for self-fertilization of a newly extruded clutch of eggs. Females carry clutches of 50,000 to 400,000 eggs and nurture the embryos for 1 year after fertilization before hatching. While the congener

C. opilio has been shown to exhibit biennial spawning in cold water realms less than or equal to 1.5 °C (Rugolo et al. 2005), this behavior has not been observed in *C. bairdi* presumptively since Tanner crab inhabit warmer waters than the snow crab. Primiparous females may carry the fertilized eggs for as long as 1.5 years. Brooding occurs in 100 to 150 m depths.

Habitat and Biological Associations: Tanner crab

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceano-graphic Features	Other
Eggs	1 year	N/A	April–March	N/A	N/A	N/A	fronts	
Larvae	2 to 7 mo.	diatoms, algae, zooplankton	summer	inner and middle continental shelf (1–100 m)	pelagic	N/A	fronts	
Juveniles	1 to 6 years	crustaceans, polychaetes, mollusks, diatoms, algae, hydroids	all year	inner and middle continental shelf (1–100 m), nearshore bays, beach (intertidal)	demersal	mud	fronts	
Adults	6+ years	polychaetes, crustaceans, mollusks, hydroids, algae, diatoms	spawning Jan–June (peak April–May)	inner and middle continental shelf (1–100 m)	demersal	mud	fronts	

N/A = not applicable

2.6.5 Literature

- Adams, A. E. and A. J. Paul. 1983. Male parent size, sperm storage and egg production in the Crab *Chionoecetes bairdi* (DECAPODA, MAJIDAE). International Journal of Invertebrate Reproduction. 6:181-187.
- Brown, R. B. and G. C. Powell. 1972. Size at maturity in the male Alaskan Tanner crab, *Chionoecetes bairdi*, as determined by chela allometry, reproductive tract weights, and size of precopulatory males. Journal of the Fisheries Research Board of Canada. 29:423-427.
- Donaldson, W. E. and D. M. Hicks. 1977. Technical report to industry on the Kodiak crab population surveys. Results, life history, information, and history of the fishery for Tanner crab. Alaska Dept. Fish and Game, Kodiak Tanner crab research. 46 p.
- Donaldson, W. E., and A. A. Adams. 1989. Ethogram of behavior with emphasis on mating for the Tanner crab *Chionoecetes bairdi* Rathbun. Journal of Crustacean Biology. 9:37-53.
- Donaldson, W. E., R. T. Cooney, and J. R. Hilsinger. 1981. Growth, age, and size at maturity of Tanner crab *Chionoecetes bairdi* M. J. Rathbun, in the northern Gulf of Alaska. Crustaceana. 40:286-302.
- Haynes, E., J. F. Karinen, J. Watson, and D. J. Hopson. 1976. Relation of number of eggs and egg length to carapace width in the brachyuran crabs *Chionoecetes bairdi* and *C. opilio* from the southeastern Bering Sea and *C. opilio* from the Gulf of St. Lawrence. J. Fish. Res. Board Can. 33:2592-2595.
- Hilsinger, J. R. 1976. Aspects of the reproductive biology of female snow crabs, *Chionoecetes bairdi*, from Prince William Sound and the adjacent Gulf of Alaska. Marine Science Communications. 2:201-225.
- Hosie, M. J. and T. F. Gaumer. 1974. Southern range extension of the Baird crab (*Chionoecetes bairdi* Rathbun). Calif. Fish and Game. 60:44-47.
- Karinen, J. F. and D. T. Hoopes. 1971. Occurrence of Tanner crabs (*Chionoecetes* sp.) in the eastern Bering Sea with characteristics intermediate between *C. bairdi* and *C. opilio*. Proc. Natl. Shellfish Assoc. 61:8-9.
- Kon, T. 1996. Overview of Tanner crab fisheries around the Japanese Archipelago, p. 13-24. In High

- Livingston, P. A. 1989. Interannual trends in Pacific cod, *Gadus macrocephalus*, predation on three commercially important crab species in the eastern Bering Sea. *Fishery Bulletin*. 87:807-827.
- Livingston, P. A., A. Ward, G. M. Lang, and M. S. Yang. 1993. Groundfish food habits and predation on commercially important prey species in the eastern Bering Sea from 1987 to 1989. NOAA Technical Memorandum, NMFS-AFSC-11, DOC, NOAA, NMFS, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115, 192 p.
- McLaughlin, P. A. and 39 coauthors. 2005. Common and scientific names of aquatic invertebrates from the United States and Canada: crustaceans. American Fisheries Society Special Publication 31. 545 p.
- Munk, J. E., S. A. Payne, and B. G. Stevens. 1996. Timing and duration of the mating and molting season for shallow water Tanner crab (*Chionoecetes bairdi*), p. 341 (abstract only). In *High Latitude Crabs: Biology, Management and Economics*. Alaska Sea Grant Report, AK-SG-96-02, University of Alaska Fairbanks.
- NMFS. 2004. Final Environmental Impact Statement for Bering Sea and Aleutian Islands Crab Fisheries. National Marine Fisheries Service, P.O. Box 21668, Juneau, AK 99802-1668.
- NPFMC. 1998. Fishery Management Plan for the King and Tanner Crab Fisheries of the Bering Sea and Aleutian Islands. North Pacific Fishery Management Council, 605 W. 4th Avenue, Suite, 306, Anchorage, AK 99501.
- NPFMC. 2007. Initial Review Draft Environmental Assessment, Amendment 24 to the Fishery Management Plan for Bering Sea and Aleutian Islands King and Tanner crabs to Revise Overfishing Definitions. North Pacific Fishery Management Council, 605 W. 4th Avenue, 306, Anchorage, AK 99501.
- Otto, R. S. 1998. Assessment of the eastern Bering Sea snow crab, *Chionoecetes opilio*, stock under the terminal molting hypothesis, p. 109-124. In G. S. Jamieson and A. Campbell, (editors), *Proceedings of the North Pacific Symposium on Invertebrate Stock Assessment and Management*. Canadian Special Publication of Fisheries and Aquatic Sciences.
- Paul, A. J. 1982. Mating frequency and sperm storage as factors affecting egg production in multiparous *Chionoecetes bairdi*, p. 273-281. In B. Melteff (editor), *Proceedings of the International Symposium on the Genus Chionoecetes: Lowell Wakefield Symposium Series*, Alaska Sea Grant Report, 82-10. University of Alaska Fairbanks.
- Paul, A. J. 1984. Mating frequency and viability of stored sperm in the Tanner crab *Chionoecetes bairdi* (DECAPODA, MAJIDAE). *Journal of Crustacean Biology*. 4:375-381.
- Paul, A. J. and J. M. Paul. 1992. Second clutch viability of *Chionoecetes bairdi* Rathbun (DECAPODA: MAJIDAE) inseminated only at the maturity molt. *Journal of Crustacean Biology*. 12:438-441.
- Rugolo, L.J. and B.J. Turnock. 2011. 2011 Stock Assessment and Fishery Evaluation Report for the Tanner Crab Fisheries of the Bering Sea and Aleutian Islands Regions. In *2011 Stock Assessment and Fishery Evaluation Report for the King and Tanner Crab Fisheries in the Bering Sea and Aleutian Islands*. NPFMC, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.
- Rugolo, L, D. Pengilly, R. MacIntosh and K. Gravel. 2005. Reproductive dynamics and life-history of snow crab (*Chionoecetes opilio*) in the eastern Bering Sea. Final Completion Report to the NOAA, Award NA17FW1274, Bering Sea Snow Crab Fishery Restoration Research.
- Rathbun, M. J. 1924. New species and subspecies of spider crabs. *Proceedings of U.S. Nat. Museum*. 64:1-5.
- Slizkin, A. G. 1990. Tanner crabs (*Chionoecetes opilio*, *C. bairdi*) of the northwest Pacific: distribution, biological peculiarities, and population structure, p. 27-33. In *Proceedings of the International Symposium on King and Tanner Crabs*. Lowell Wakefield Fisheries Symposium Series, Alaska Sea Grant College Program Report 90-04. University of Alaska Fairbanks.
- Somerton, D. A. 1981a. Life history and population dynamics of two species of Tanner crab, *Chionoecetes bairdi* and *C. opilio*, in the eastern Bering Sea with implications for the management of the commercial harvest, PhD Thesis, University of Washington, 220 p.

- Somerton, D. A. 1981b. Regional variation in the size at maturity of two species of Tanner Crab (*Chionoecetes bairdi* and *C. opilio*) in the eastern Bering Sea, and its use in defining management subareas. Canadian Journal of Fisheries and Aquatic Science. 38:163-174.
- Somerton, D. A. and W. S. Meyers. 1983. Fecundity differences between primiparous and multiparous female Alaskan Tanner crab (*Chionoecetes bairdi*). Journal of Crustacean Biology. 3:183-186.
- Sparks, A.K. 1982. Observations on the histopathology and probable progression of the disease caused by *Trichomaris invadens* in the Tanner crab, *Chionoecetes bairdi*. J. Invertebr. Pathol. 34:184-191.
- Stevens, B. G. 2000. Moonlight madness and larval launch pads: tidal synchronization of Mound Formation and hatching by Tanner crab, *Chionoecetes bairdi*. Journal of Shellfish Research. 19:640-641.
- Tamone, S. L., S. J. Taggart, A. G. Andrews, J. Mondragon, and J. K. Nielsen. 2007. The relationship between circulating ecdysteroids and chela allometry in male Tanner crabs: Evidence for a terminal molt in the genus *Chionoecetes*. J. Crust. Biol. 27:635-642.
- Turnock, B. and L. Rugolo. 2009. Stock assessment of eastern Bering Sea snow crab (*Chionoecetes opilio*). Report to the North Pacific Fishery Management Council, Crab Plan Team. 102 p.
- Zheng, J. 2008. Temporal Changes in Size at Maturity and Their Implications for Fisheries Management for Eastern Bering Sea Tanner Crab. J. Northw. Atl. Fish. Sci., 41: 137–149. doi:10.2960/J.v41.m623

2.7 Snow crab (*Chionoecetes opilio*)

2.7.1 Life History and General Distribution

Snow crab (*Chionoecetes opilio*) are distributed on the continental shelf of the Bering Sea, Chukchi Sea, and as far south as the Sea of Japan in the western Pacific Ocean. Snow crab occur in the western Atlantic Ocean as far south as Maine. Snow crab are not present in the Gulf of Alaska. In the Bering Sea, snow crab are common at depths less than 200 m. The eastern Bering Sea population within U.S. waters is managed as a single stock; however, the distribution of the population extends into Russian waters to an unknown degree. While 50 percent of the females are mature at 5 cm CW, the mean size of mature females varies from year to year over a range of 6.3 to 7.2 cm CW. Females cease growing with a terminal molt upon reaching maturity and rarely exceed 8 cm CW. The median size of maturity for males is about 8.5 cm CW (approximately 6 to 8 years old). Males larger than 6 cm grow at about 2 cm per molt, up to an estimated maximum size of 14.5 cm CW, but individual growth rates vary widely. Male snow crab have a terminal molt on reaching maturity. Natural mortality of adult snow crab is estimated at 0.23 using maximum observed age from tagging of about 18 years.

Maturity

Maturity for females is determined by visual examination during the survey and used to determine the fraction of females mature by size for each year. Female maturity is determined by the shape of the abdomen, by the presence of brooded eggs or egg remnants.

Morphometric maturity for males is determined by chela height measurements, which are available starting from the 1989 survey. The number of males with chela height measurements has varied between about 3,000 and 7,000 per year. A mature male refers to a morphometrically mature male. Morphometric maturity for males refers to a marked change in chelae size (thereafter termed “large claw”), after which males are assumed to be effective at mating. Males are functionally mature at smaller sizes than when they become morphometrically mature, although the contribution of these “small-clawed” males to annual reproductive output is negligible. The minimum legal size limit for the snow crab fishery is 78 mm; however, the size for males that are generally accepted by the fishery is greater than 101 mm. Historical quotas were based on the survey abundance of large males (greater than 101 mm).

One maturity curve for males was estimated using the average fraction mature based on chela height data and applied to all years of survey data to estimate mature survey numbers. The separation of mature and immature males by chela height at small widths may not be adequately refined given the current measurement to the nearest millimeter. Chela height measured to the nearest tenth of a millimeter (by Canadian researchers on North Atlantic snow crab) shows a clear break in chela height at small and large widths and shows fewer mature animals at small widths than the Bering Sea data measured to the nearest millimeter. Measurements taken in 2004 and 2005 on Bering Sea snow crab chela to the nearest tenth of a millimeter show a similar break in chela height to the Canadian data (Rugolo et al. 2005).

The probability of a new shell crab maturing was estimated in the model at a smooth function to move crab from immature to mature. The probability of maturing was estimated to match the observed fraction mature for all mature males and females observed in the survey data. The probability of maturing was fixed in the September 2009 assessment. The probability of maturing by size for female crab was about 50 percent at about 48 mm and increased to 100 percent at 60 mm. The probability of maturing for male crab was about 15 percent to 20 percent at 60 mm to 90 mm, increased sharply to 50 percent at about 98 mm, and was 100 percent at 108 mm.

Natural Mortality

Natural mortality (M) is an essential control variable in population dynamic modeling, and may have a large influence on derived optimal harvest rates. Natural mortality rates estimated in a population dynamics model may have high uncertainty and may be correlated with other parameters, and therefore are usually fixed. The ability to estimate natural mortality in a population dynamics model depends on how the true value varies over time as well as other factors (Fu and Quinn 2000, Schnute and Richards 1995).

Nevissi et al. (1995) used radiometric techniques to estimate shell age from last molt. The total sample size was 21 male crabs (a combination of Tanner and snow crab) from a collection of 105 male crabs from various hauls in the 1992 and 1993 NMFS Bering Sea survey. Fishing mortality rates before and during the time period when these crab were collected were relatively high, and therefore maximum age would represent Z (total mortality) rather than M. Representative samples for the five shell condition categories were collected that made up the 105 samples. The oldest looking crab within shell conditions 4 and 5 were selected from the total sample of SC4 and SC5 crabs to radiometrically age (Orensanz, School of Fisheries, University of Washington, personal communication). Shell condition 5 crab (SC5 = very, very old shell) had a maximum age of 6.85 years (standard deviation 0.58, 95 percent confidence interval approximately 5.69 to 8.01 years). The average age of six crabs with SC4 (very old shell) and SC5, was 4.95 years. The range of ages was 2.70 to 6.85 years for those same crabs. Given the small sample size, this maximum age may not represent the 1.5 percent percentile of the population that is approximately equivalent to Hoenig's (1983) method. Maximum life span defined for a virgin stock is reasonably expected to be longer than these observed maximum ages from exploited populations. Radiometric ages estimated by Nevissi et al. (1995) may be underestimated by several years, due to the continued exchange of material in crab shells even after shells have hardened (Craig Kestelle, Alaska Fisheries Science Center, Seattle, WA, personal communication).

Tag recovery evidence from eastern Canada reveals observed maximum ages in exploited populations of 17 to 19 years (Nevissi et al. 1995, Sainte-Marie 2002). A maximum time at large of 11 years for tag returns of terminally molted mature male snow crab in the North Atlantic has been recorded since tagging started about 1993 (Fonseca et al. 2008). Fonseca et al. (2008) estimated a maximum age of 7.8 years post terminal molt using data on dactal wear.

In a virgin population of snow crab, longevity would be at least 20 years. Hence 20 years is used as a proxy for longevity, and it is assumed that this age would represent the upper 99th percentile of the

distribution of ages in an unexploited population if observable. Under negative exponential depletion, the 99th percentile corresponding to age 20 of an unexploited population corresponds to a natural mortality rate of 0.23. Using Hoenig's (1983) method an $M=0.23$ corresponds to a maximum age of 18 years. $M=0.23$ was used for all crab in Model 1.

Model scenarios that estimated male natural mortality use mean $M=0.23$, with a statistical error equal to 0.054 estimated from using the 95 percent confidence interval of ± 1.7 years, on maximum age estimates from dactal wear and tag return analysis, in Fonseca et al. (2008).

2.7.2 Fishery

Snow crab were harvested in the Bering Sea by the Japanese from the 1960s until 1980 when the Magnuson Act prohibited foreign fishing. Retained catch in the domestic fishery increased in the late 1980s to a high of about 328 million pounds in 1991. During 2000/01 to 2006/07, however, fisheries retained low catches due to low abundance and a reduced harvest rate.

Several modifications to pot gear have been introduced to reduce bycatch mortality. In the 1978/79 season, pots used in the snow crab fishery first contained escape panels to prevent ghost fishing. Escape panels consisted of an opening with one-half the perimeter of the tunnel eye laced with untreated cotton twine. The size of the cotton laced panel to prevent ghost fishing was increased in 1991 to at least 18 inches in length. No escape mechanisms for undersized crab were required until the 1997 season when at least one-third of one vertical surface had to contain not less than 5 inches stretched mesh webbing or have no less than four circular rings of no less than 3 3/4 inches inside diameter. In the 2001 season the escapement for undersize crab was increased to at least eight escape rings of no less than 4 inches placed within one mesh measurement from the bottom of the pot, with four escape rings on each side of the two sides of a four-sided pot, or one-half of one side of the pot must have a side panel composed of not less than 5 1/4 inch stretched mesh webbing.

The snow crab fishery is prosecuted using mesh covered pots (generally 7 or 8 feet square) set on single lines. Male only crab greater than 7.8 cm CW may be harvested; however, a market minimum size of about 10.2 cm CW is generally observed. Most male snow crab probably enter the fishery at around age 8 to 10 years. Discard from the directed pot fishery was estimated from observer data since 1992 and ranged from 11 percent to 64 percent (average 33 percent) of the retained catch of male crab biomass. Female discard catch is very low and not a significant source of mortality. Size frequency data and catch per pot have been collected by observers on snow crab fishery vessels since 1992. Observer coverage was 10 percent on catcher vessels larger than 125 feet (since 2001), and 100 percent coverage on catcher/processors (since 1992).

Snow crab are probably one stock in the Bering Sea. The season opening date since the 2008 season is October 15, however, fishing usually occurs after January 15, which was the fishery opening date pre-2008. A 3-inch maximum tunnel height opening for snow crab pots is required to inhibit the bycatch of red king crab. A minimum of eight 4-inch escape rings are required on snow crab pots to reduce capture and handling mortality of smaller non-target crab. Bycatch in the snow crab fishery consists primarily of *C. bairdi* and *C. opilio* less than 10.2 cm CW.

Bottom trawls and dredges could disrupt nursery and adult feeding areas. In 1992 trawl discard mortality was about 4 million pounds, increased to about 7.8 million pounds in 1995, then declined to about 2 to 3 million pounds until 1999. Trawl bycatch in 2007 and 2008 was 0.97 and 0.66 million pounds, respectively. Discard in groundfish fisheries from highest to lowest snow crab bycatch is the yellow fin sole trawl fishery, flathead sole trawl fishery, Pacific cod bottom trawl fishery, rock sole trawl fishery, and the Pacific cod hook and line and pot fisheries.

2.7.3 Relevant Trophic Information

Pacific cod, sculpins, skates, eel pouts, and halibut are the main predators on snow crabs in terms of biomass. Snow crabs less than 7 cm CW are most commonly consumed. Other predators include yellowfin sole, flathead sole, Alaska plaice, walleye pollock, rock sole, bearded seals, and walrus. Juvenile snow crabs have been observed to be cannibalistic during molting in laboratory environments.

2.7.4 Habitat and Biological Associations

Egg: See mature phase description; eggs are carried by adult female crab.

Larvae: Larvae of *C. opilio* snow crab are found in early summer and exhibit diel migration. The last of three larval stages settles onto bottom in nursery areas.

Early Juvenile: Shallow water areas of the eastern Bering Sea are considered nursery areas for *C. opilio* snow crabs and are confined to the middle shelf area due to the thermal limits of early and late juvenile life stages.

Late Juvenile: A geographic cline in size of *C. opilio* snow crabs indicates that a large number of morphometrically immature crabs occur in shallow waters less than 80 m.

Mature: Female and male *C. opilio* snow crabs are acknowledged to attain terminal molt status at maturity. Primiparous female snow crabs mate January through June and may exhibit longer egg development period and lower fecundity than multiparous female crabs. Multiparous females release eggs and mate mainly in March and April (Rugolo et al. 2005). Multiparous female snow crabs can store spermatophores in seminal vesicles and fertilize subsequent egg clutches without mating. At least two clutches can be fertilized from stored spermatophores, but the frequency of this occurring in nature is not known. Females carry clutches of approximately 36,000 eggs and nurture the embryos for approximately 1 year after fertilization. However, fecundity may decrease between the time of egg extrusion and hatching, presumably due to predation, parasitism, abrasion, or decay of unfertilized eggs. Brooding probably occurs in depths greater than 50 m.

Habitat and Biological Associations: Snow crab

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceano-graphic Features	Other
Eggs	1 year	N/A		N/A	N/A	N/A	fronts	
Larvae	2 to 7 mo.	diatoms, algae, zooplankton	spring, summer	inner and middle continental shelf (1–100 m)	pelagic	N/A	fronts	
Juveniles	1 to 4 years	crustaceans, polychaetes, mollusks, diatoms, algae, hydroids	all year	inner, middle, and outer continental shelf (1–200 m)	demersal	mud	fronts	
Adults	4+ years	polychaetes, brittle stars, mollusks, crustaceans, hydroids, algae, diatoms	spawning Jan–June (peak April–May)	inner, middle, and outer continental shelf (1–200 m)	demersal	mud	fronts	

N/A = not applicable

2.7.5 Literature

- Fonseca, D. B., B. Sainte-Marie, and F. Hazel. 2008. Longevity and change in shell condition of adult male snow crab *Chionoecetes opilio* inferred from dactyl wear and mark-recapture data. *Transactions of the American Fisheries Society* 137:1029–1043.
- Fu, C. H., and T. J. Quinn II, 2000. Estimability of natural mortality and other population parameters in a length-based model: *Pandalus borealis* in Kachemak Bay, Alaska. *Can. J. Fish. Aquat. Sci.* 57: 2420–2432.
- Hoenig, J. 1983. Empirical use of longevity data to estimate mortality rates. *Fish. Bull.* 82: 898-903.
- Nevissi, A.E., J.M. Orensanz, A.J.Paul, and D.A. Armstrong. 1995. Radiometric Estimation of shell age in Tanner Crab, *Chionoecetes opilio* and *C. bairdi*, from the eastern Bering Sea, and its use to interpret indices of shell age/condition. Presented at the International symposium on biology, management and economics of crabs from high latitude habitats October 11-13, 1995, Anchorage, Alaska.
- Rugolo, L.J., D. Pengilly, R. MacIntosh and K. Gravel. 2005. Reproductive dynamics and life-history of snow crab (*Chionoecetes opilio*) in the eastern Bering Sea. Final Completion Report to the NOAA, Award NA17FW1274, Bering Sea Snow Crab Fishery Restoration Research.
- Sainte-Marie, B., J. Sevigny and M. Carpentier. 2002. Interannual variability of sperm reserves and fecundity of primiparous females of the snow crab (*Chionoecetes opilio*) in relation to sex ratio. *Can.J.Fish.Aquat.Sci.* 59:1932-1940.
- Schnute, J. and L. Richards. 1995. The influence of error on population estimates from catchage models. *Can. J. Fish. Aquat. Sci.* 52: 2063-2077.
- Turnock, B.J. and L.J. Rugolo. 2011. Stock Assessment of eastern Bering Sea snow crab. *In* 2011 Stock Assessment and Fishery Evaluation Report for the King and Tanner Crab Fisheries in the Bering Sea and Aleutian Islands. NPFMC, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

5.0 Non-fishing Activities that may Adversely Affect Essential Fish Habitat

The waters and substrates that comprise essential fish habitat (EFH) are susceptible to a wide array of human activities unrelated to fishing. Broad categories of such activities include, but are not limited to, mining, dredging, fill, impoundment, discharges, water diversions, thermal additions, actions that contribute to nonpoint source pollution and sedimentation, introduction of potentially hazardous materials, introduction of exotic species, and the conversion of aquatic habitat that may eliminate, diminish, or disrupt the functions of EFH. Non-fishing activities discussed in this document are subject to a variety of regulations and restrictions designed to limit environmental impacts under federal, state, and local laws. Listing all applicable environmental laws and management practices is beyond the scope of the document. Moreover, the coordination and consultation required by section 305(b) of the Magnuson-Stevens Conservation and Management Act (MSA) does not supersede the regulations, rights, interests, or jurisdictions of other federal or state agencies. NMFS may use the information in this document as a source when developing conservation recommendations for specific actions under section 305(b)(4)(A) of the MSA. NMFS will not recommend that state or federal agencies take actions beyond their statutory authority, and NMFS' EFH conservation recommendations are not binding.

Ideally, actions that are not water-dependent should not be located in EFH if such actions may have adverse impacts on EFH. Activities that may result in significant adverse effects on EFH should be avoided where less environmentally harmful alternatives are available. If there are no alternatives, the impacts of these actions should be minimized. Environmentally sound engineering and management practices should be employed for all actions that may adversely affect EFH. If avoidance or minimization is not practicable, or will not adequately protect EFH, compensatory mitigation as defined for section 404 of the Clean Water Act (CWA) should be considered to conserve and enhance EFH.

The potential for effects from larger, less readily managed processes associated with human activity also exists, such as climate change and ocean acidification. Climate change may lead to habitat changes that prompt shifts in the distribution of managed species. Likewise, should ocean conditions warm to allow for new shipping routes, new vectors may emerge for introducing invasive species in cargo and ballast waters. Ocean acidification could also alter species distributions and complicated food web dynamics. These larger ecosystem-level effects are discussed in this document where applicable, within each activity type.

This section of the fishery management plan (FMP) synthesizes a comprehensive review of the "Impacts to Essential Fish Habitat from Non-fishing Activities in Alaska" (NMFS 2011), which is incorporated in the FMP by reference. The general purpose of that document is to identify non-fishing activities that may adversely impact EFH and provide conservation recommendations that can be implemented for specific types of activities to avoid or minimize adverse impacts to EFH. This information must be included in FMPs under section 303(a)(7) of the MSA. It is also useful to NMFS biologists reviewing proposed actions that may adversely

affect EFH, and the comprehensive document (NMFS 2011) will be utilized by federal action agencies undertaking EFH consultations with NMFS, especially in preparing EFH assessments.

The conservation recommendations for each activity category are suggestions the action agency or others can undertake to avoid, offset, or mitigate impacts to EFH. NMFS develops EFH conservation recommendations for specific activities case-by-case based on the circumstances; therefore, the recommendations in this document may or may not apply to any particular project. Because many non-fishing activities have similar adverse effects on living marine resources, some redundancy in the descriptions of impacts and the accompanying conservation recommendations between sections in this report is unavoidable.

The comprehensive non-fishing activities document (NMFS 2011) updates and builds upon a collaborative evaluation of non-fishing effects to EFH completed in 2004 by the NMFS Alaska Region, Northwest Region, and Southwest Region and the respective Fisheries Science Centers. In April 2005, NMFS completed the Final Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska (EFH EIS; NMFS 2005) and the North Pacific Fishery Management Council amended its FMPs to address the EFH requirements of the MSA. The EFH EIS contained an Appendix (Appendix G) that addressed non-fishing impacts to EFH. A 5-year review of the Council's EFH provisions, including those addressing non-fishing impacts to EFH, was completed by the Council in April 2010 (NPFMC and NMFS 2010), on the basis of which this section has been updated.

The remainder of this section addresses non-fishing activities that may adversely affect EFH. These activities are grouped into the four different systems in which they usually occur: upland, river or riverine, estuary or estuarine, and coastal or marine.

5.1 Upland Activities

Upland activities can impact EFH through both point source and nonpoint source pollution. Nonpoint source impacts are discussed here. Technically, the term "nonpoint source" means anything that does not meet the legal definition of point source in section 502(14) of the CWA, which refers to discernible, confined, and discrete conveyance from which pollutants are or may be discharged. Land runoff, precipitation, atmospheric deposition, seepage, and hydrologic modification, generally driven by anthropogenic development, are the major contributors to nonpoint source pollution.

Nonpoint source pollution is usually lower in intensity than an acute point source event, but may be more damaging to fish habitat in the long term. It may affect sensitive life stages and processes, is often difficult to detect, and its impacts may go unnoticed for a long time. When population impacts are detected, they may not be tied to any one event or source, and may be difficult to correct, clean up, or mitigate.

The impacts of nonpoint source pollution on EFH may not necessarily represent a serious, widespread threat to all species and life history stages. The severity of the threat of any specific pollutant to aquatic organisms depends upon the type and concentration of the pollutant and the length of exposure for a particular species and its life history stage. For example, species that spawn in areas that are relatively deep with strong currents and well-mixed water may not be as susceptible to pollution as species that inhabit shallow, inshore areas near or within enclosed

bays and estuaries. Similarly, species whose egg, larval, and juvenile life history stages utilize shallow, inshore waters and rivers may be more prone to coastal pollution than are species whose early life history stages develop in offshore, pelagic waters.

5.1.1 Silviculture/Timber Harvest

Recent revisions to federal and state timber harvest regulations in Alaska and best management practices (BMPs) have resulted in increased protection of EFH on federal, state, and private timber lands (USDA 2008; <http://www.fs.fed.us/r10/tongass/projects/tlmp/>).

These revised regulations include forest management practices, which when fully implemented and effective, could avoid or minimize adverse effects to EFH. However, if these management practices are ineffective or not fully implemented, timber harvest could have both short and long term impacts on EFH throughout many coastal watersheds and estuaries. Historically, timber harvest in Alaska was not conducted under the current protective standards, and these past practices may have degraded EFH in some watersheds.

Potential Adverse Impacts

In both small and large watersheds there are many complex and important interactions between fish and forests (Northcote and Hartman 2004). Five major categories of silvicultural activities can adversely affect EFH if appropriate forestry practices are not followed: (1) construction of logging roads, (2) creation of fish migration barriers, (3) removal of streamside vegetation, (4) hydrologic changes and sedimentation, and (5) disturbance associated with log transfer facilities (LTFs). Possible effects to EFH include the following (Northcote and Hartman 2004):

- Removal of the dominant vegetation and conversion of mature and old-growth upland and riparian forests to tree stands or forests of early seral stage;
- Reduction of soil permeability and increase in the area of impervious surfaces;
- Increase in erosion and sedimentation due to surface runoff and mass wasting processes, also potentially affecting riparian areas;
- Impaired fish passage because of inadequate design, construction, and/or maintenance of stream crossings;
- Altered hydrologic regimes resulting in inadequate or excessive surface and stream flows, increased streambank and streambed erosion, loss of complex instream habitats;
- Changes in benthic macroinvertebrate populations,
- Loss of instream and riparian cover;
- Increased surface runoff with associated contaminants (e.g., herbicides, fertilizers, and fine sediments) and higher temperatures;
- Alterations in the supply of large woody debris (LWD) and sediment, which can have negative effects on the formation and persistence of instream habitat features; and
- Excess debris in the form of small pieces of wood and silt, which can cover benthic habitat and reduce dissolved oxygen levels.

Recommended Conservation Measures

The following recommended conservation measures for silviculture/timber harvest should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH. Additionally, management standards, guidelines, and BMPs are available from the Forest Service Region 10, the State of Alaska Division of Forestry, and forest plans for the Tongass and Chugach National Forests.

- **Stream Buffers:** For timber operations in watersheds with EFH, adhere to modern forest management practices and BMPs, including the maintenance of vegetated buffers along all streams to the extent practicable in order to reduce sedimentation and supply large wood.
- **Estuary and Beach Fringe:** For timber operations adjacent to estuaries or beaches, maintain vegetated buffers as needed to protect EFH.
- **Watershed Analysis:** A watershed analysis should be incorporated into timber and silviculture projects whenever practicable.
- **Forest Roads:** Forest roads can be a major cause of sediment into streams and road culverts can block or inhibit upstream fish passage. Roads need to be designed to minimize sediment transport problems and to avoid fish passage problems.

5.1.2 Pesticides

Pesticides are substances intended to prevent, destroy, control, repel, kill, or regulate the growth of undesirable biological organisms. Pesticides include the following: insecticides, herbicides, fungicides, rodenticides, repellents, bactericides, sanitizers, disinfectants, and growth regulators. More than 900 different active pesticide ingredients are currently registered for use in the United States and are formulated with a variety of other inert ingredients that may also be toxic to aquatic life. Legal mandates covering pesticides are the CWA and the Federal Insecticide, Fungicide, and Rodenticide Act. Water quality criteria for the protection of aquatic life have only been developed for a few of the currently used ingredients (EPA, Office of Pesticide Programs). While agricultural run-off is a major source of pesticide pollution in the lower 48 states, in Alaska, other human activities, such as fire suppression on forested lands, forest site preparation, noxious weed control, right-of-way maintenance (e.g., roads, railroads, power lines), algae control in lakes and irrigation canals, riparian habitat restoration, and urban and residential pest control, are the most common sources of these substances.

Pesticides are frequently detected in freshwater and estuarine systems that provide EFH. Pesticides can enter the aquatic environment as single chemicals or as complex mixtures. Direct applications, surface runoff, spray drift, agricultural return flows, and groundwater intrusions are all examples of transport processes that deliver pesticides to aquatic ecosystems. Habitat alteration from pesticides is different from more conventional water quality parameters because, unlike temperature or dissolved oxygen, the presence of pesticides can be difficult to detect due to limitations in proven methodologies. This monitoring may also be expensive. As analytical methodologies have improved in recent years, the number of pesticides documented in fish and their habitats has increased. In addition, pesticides may bioaccumulate in the ecosystem by retention in sediments and detritus, which are then ingested by macroinvertebrates, and which, in

turn, are eaten by larger invertebrates and fish (Atlantic States Marine Fisheries Commission 1992).

Potential Adverse Impacts

There are three basic ways that pesticides can adversely affect EFH. These are (1) a direct, lethal or sublethal, toxicological impact on the health or performance of exposed fish; (2) an indirect impairment of aquatic ecosystem structure and function; and (3) a loss of aquatic macroinvertebrates that are prey for fish and aquatic vegetation that provides physical shelter for fish.

Recommended Conservation Measures

The following recommended conservation measures regarding pesticides (including insecticides, herbicides, fungicides, rodenticides, repellents, bactericides, sanitizers, disinfectants, and growth regulators) should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Incorporate integrated pest management and BMPs as part of the authorization or permitting process (Scott et al. 1999). If pesticides must be applied, consider area, terrain, weather, droplet size, pesticide characteristics, and other conditions to avoid or reduce effects to EFH.
- Carefully review labels and ensure that application is consistent with the product's directions.
- Avoid the use of pesticides within 500 linear feet and/or 1,000 aerial feet of anadromous fish bearing streams.
- For forestry vegetation management projects, establish a 35-foot pesticide-free buffer area from any surface or marine water body and require that pesticides not be applied within 200 feet of a public water source (Alaska Department of Environmental Conservation guidelines).
- Consider current and recent meteorological conditions. Rain events may increase pesticide runoff into adjacent water bodies. Saturated soils may inhibit pesticide penetration.
- Do not apply pesticides when wind speeds exceed 10 mph.
- Begin application of pesticide products nearest to the aquatic habitat boundary and proceed away from the aquatic habitat; do not apply towards a water body.

5.1.3 Urban and Suburban Development

Urban and suburban development is most likely the greatest non-fishing threat to EFH (NMFS 1998 a, 1998b). Urban and suburban development and the corresponding infrastructure result in four broad categories of impacts to aquatic ecosystems: hydrological, physical, water quality, and biological (CWP 2003).

Potential Adverse Impacts

Potential impacts to EFH most directly related to general urban and suburban development discussed below are the watershed effects of land development, including stormwater runoff.

Other development-related impacts are discussed in later sections of this document, including dredging, wetland fill, and shoreline construction.

Development activities within watersheds and in coastal marine areas can impact EFH on both long and short timeframes. The Center for Watershed Protection (CWP) made a comprehensive review of the impacts associated with impervious cover and urban development and found a negative relationship between watershed development and 26 stream quality indicators (CWP 2003). The primary impacts include (1) the loss of hyporheic zones (the region beneath and next to streams where surface and groundwater mix), and riparian and shoreline habitat and vegetation; and (2) runoff. Removal of riparian and upland vegetation has been shown to increase stream water temperatures, reduce supplies of LWD, and reduce sources of prey and nutrients to the water system. An increase in impervious surfaces in a watershed, such as the addition of new roads, buildings, bridges, and parking facilities, results in a decreased infiltration to groundwater and increased runoff volumes. This also has the potential to adversely affect water quality and the shape of the hydrograph in downstream water bodies (i.e., estuaries and coastal waters).

Recommended Conservation Measures

The following recommended conservation measures should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH where threats of impacts from urban and suburban development exist.

- Implement BMPs for sediment control during construction and maintenance operations (USEPA 1993).
- Avoid using hard engineering structures for shoreline stabilization and channelization when possible.
- Encourage comprehensive planning for watershed protection, and avoid or minimize filling and building in coastal and riparian areas affecting EFH.
- Where feasible, remove obsolete impervious surfaces from riparian and shoreline areas, and reestablish water regime, wetlands, and native vegetation.
- Protect and restore vegetated buffer zones of appropriate width along streams, lakes, and wetlands that include or influence EFH.
- Manage stormwater to replicate the natural hydrologic cycle, maintaining natural infiltration and runoff rates to the maximum extent practicable.
- Where instream flows are insufficient to maintain water quality and quantity needed for EFH, establish conservation guidelines for water use permits, and encourage the purchase or lease of water rights and the use of water to conserve or augment instream flows.
- Use the best available technologies in upgrading wastewater systems to avoid combined sewer overflow problems and chlorinated sewage discharges into rivers, estuaries, and the ocean.
- Design and install proper wastewater treatment systems.
- Where vegetated swales are not feasible, install and maintain oil/water separators to treat runoff from impervious surfaces in areas adjacent to marine or anadromous waters.

5.1.4 Road Building and Maintenance

Roads and trails have always been part of man's impact on his environment (Luce and Crowe 2001). Federal, state, and local transportation departments devote huge budgets to construction and upgrading of roads. As in other places, roads play an important part in access and thus are vital to the economy of Alaska (Connor 2007).

Potential Adverse Impacts

Today's road design construction and management practices have improved from the past. Roads however, still have a negative effect on the biotic integrity of both terrestrial and aquatic ecosystems (Trombulak and Frissell 2000), and the effects of roads on aquatic habitat can be profound. Potential adverse impacts to aquatic habitats resulting from existence of roads in watersheds include (1) increased surface erosion, including mass wasting events, and deposition of fine sediments; (2) changes in water temperature; (3) elimination or introduction of migration barriers such as culverts; (4) changes in streamflow; (5) introduction of invasive species; and (6) changes in channel configuration, and (7) the concentration and introduction of polycyclic aromatic hydrocarbons, heavy metals and other pollutants.

Recommended Conservation Measures

The following conservation measures should be viewed as options to avoid and minimize adverse impacts from road building and maintenance and promote the conservation, enhancement, and proper functioning of EFH.

- Roads should be sited to avoid sensitive areas such as streams, wetlands, and steep slopes to the extent practicable.
- Build bridges rather than culverts for stream crossings when possible. If culverts are to be used, they should be sized, constructed, and maintained to match the gradient and width of the stream, so as to accommodate design flood flows; they should be large enough to provide for migratory passage of adult and juvenile fishes.
- Design bridge abutments to minimize disturbances to stream banks, and place abutments outside of the floodplain whenever possible.
- Specify erosion control measures in road construction plans.
- Avoid side casting of road materials on native surfaces and into streams.
- Use only native vegetation in stabilization plantings.
- Use seasonal restrictions to avoid impacts to habitat during species critical life history stages (e.g., spawning and egg development periods).
- Properly maintain roadway and associated stormwater collection systems.
- Limit roadway sanding and the use of deicing chemicals during the winter to minimize sedimentation and introduction of contaminants into nearby aquatic habitats.

5.2 Riverine Activities

5.2.1 Mining

Mining within riverine habitats may result in direct and indirect chemical, biological, and physical impacts to habitats within the mining site and surrounding areas during all stages of operations. On site mining activities include exploration, site preparation, mining and milling, waste management, decommissioning or reclamation, and abandonment (NMFS 2004, American Fisheries Society 2000). Mining and its associated activities have the potential to cause adverse effects to EFH from exploration through post-closure. The operation of metal, coal, rock quarries, and gravel pit mines in upland and riverine areas has caused varying degrees of environmental damage in urban, suburban, and rural areas. Some of the most severe damage, however, occurs in remote areas, where some of the most productive fish habitat is often located (Sengupta 1993). In Alaska, existing regulations, promulgated and enforced by other federal and state agencies, are designed to control and manage these changes to the landscape to avoid and minimize impacts. However, while environmental regulations may avoid, limit, control, or offset many potential impacts, mining will, to some degree, always alter landscapes and environmental resources (National Research Council 1999). (Additional information on mining impacts in the marine environment is covered later in this synthesis.)

5.2.1.1 Mineral Mining

Mining and mineral extraction activities take many forms, such as commercial and recreational suction dredging, placer, open pit and surface mining, and contour operations. The process for mineral extraction involves exploration, mine development, mining (extraction), processing and reclamation.

Potential Adverse Impacts

The potential adverse effects of mineral mining on fish populations and EFH are well documented (Farag et al. 2003, Hansen et al. 2002, Brix et al. 2001, Goldstein et al. 1999) and depend on the type, extent, and location of the activities. Impacts associated with the extraction of material from within or near a stream or river bed may include (1) alteration in channel morphology, hydraulics, lateral migration and natural channel meander; (2) increases in channel incision and bed degradation; (3) disruption in pre-existing balance of suspended sediment transport and turbidity; (4) direct impacts to fish spawning and nesting habitats (redds), juveniles, and prey items; (5) simplification of in-channel fluvial processes and LWD deposition; (6) altered surface and ground water regimes and hydro-geomorphic and hyporheic processes; and (7) destruction of the riparian zone during extraction operations. Additional impacts may include mining-related pollution, acid mine drainage, habitat fragmentation and conversion, altered temperature regimes, reduction in oxygen concentration, the release of toxic materials (NMFS 2008), and additional impacts to wetland and riverine habitats. Many of these types of impacts have been previously introduced in the document. The additional discussion that follows is intended to round out the discussion of impacts that have not been previously introduced.

Recommended Conservation Measures

The following measures are adapted from recommendations in Spence et al. (1996), NMFS (2004), and Washington Department of Fish and Wildlife (2009). These conservation

recommendations for mineral mining should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- To the extent practicable, avoid mineral mining in waters, water sources and watersheds, riparian areas, hyporheic zones, and floodplains providing habitat for federally managed species.
- Schedule necessary in-water activities when the fewest species/least vulnerable life stages of federally managed species will be present.
- Minimize spillage of dirt, fuel, oil, toxic materials, and other contaminants into EFH. Prepare a spill prevention plan if appropriate.
- Treat and test wastewater (acid neutralization, sulfide precipitation, reverse osmosis, electrochemical, or biological treatments) and recycle on site to minimize discharge to streams.
- Minimize the effects of sedimentation on fish habitat, using methods such as contouring, mulching, construction of settling ponds, and sediment curtains. Monitor turbidity during operations, and cease operations if turbidity exceeds predetermined threshold levels.
- If possible, reclaim, rather than bury, mine waste that contains heavy metals, acid materials, or other toxic compounds to limit the possibility of leachate entering groundwater.
- Restore natural contours and use native vegetation to stabilize and restore habitat function to the extent practicable. Monitor the site to evaluate performance.
- Minimize the aerial extent of ground disturbance and stabilize disturbed lands to reduce erosion.
- For large scale mining operations, stochastic models should be employed to make predictions of ground and surface hydrologic impacts and acid generating potential in mine pits and tailing impoundments.

5.2.1.2 Sand and Gravel Mining

In Alaska, riverine sand and gravel mining is extensive and can involve several methods: wet-pit mining (i.e., removal of material from below the water table); dry-pit mining on beaches, exposed bars, and ephemeral streambeds; and subtidal mining.

Potential Adverse Impacts

Primary impacts associated with riverine sand and gravel mining activities include (1) turbidity plumes and re-suspension of sediment and nutrients, (2) removal of spawning habitat, and (3) alteration of channel morphology. These often lead to secondary impacts including alteration of migration patterns, physical and thermal barriers to upstream and downstream migration, increased fluctuation in water temperature, decrease in dissolved oxygen, high mortality of early life stages, increased susceptibility to predation, loss of suitable habitat (Packer et al. 2005), decreased nutrients (from loss of floodplain connection and riparian vegetation), and decreased food production (loss of invertebrates) (Spence et al. 1996).

Recommended Conservation Measures

The following recommended conservation measures for sand and gravel mining are adapted from NMFS (2004) and OWRRI (1995). They should be viewed as options to avoid and minimize adverse impacts to EFH due to sand and gravel mining and promote the conservation, enhancement, and proper functioning of EFH.

- To the extent practicable, avoid sand/gravel mining in waters, water sources and watersheds, riparian areas, hyporheic zones and floodplains providing habitat for federally managed species.
- Identify upland or off-channel (where the channel will not be captured) gravel extraction sites as alternatives to gravel mining in or adjacent to EFH, if possible.
- If operations in EFH cannot be avoided, design, manage, and monitor sand and gravel mining operations to minimize potential direct and indirect impacts to living marine resources and habitat. For example, minimize the areal extent and depth of extraction.
- Include restoration, mitigation, and monitoring plans, as appropriate, in sand/gravel extraction plans.
- Implement seasonal restrictions to avoid impacts to habitat during species critical life history stages.

5.2.2 Organic and Inorganic Debris

Organic and inorganic debris, and its impacts to EFH, extend beyond riverine systems into estuarine coastal and marine systems. To reduce duplication, impacts to other systems are also addressed here.

Natural occurring flotsam, such as LWD and macrophyte wrack (i.e., kelp), plays an important role in aquatic ecosystems, including EFH. LWD and wrack promote habitat complexity and provide structure to various aquatic and shoreline habitats.

The natural deposition of LWD creates habitat complexity by altering local hydrologic conditions, nutrient availability, sediment deposition, turbidity, and other structural habitat conditions. In riverine systems, the physical structure of LWD provides cover for managed species, creates habitats and microhabitats (e.g., pools, riffles, undercut banks, and side channels), retains gravels, and helps maintain underlying channel structure (Abbe and Montgomery 1996, Montgomery et al. 1995, Ralph et al. 1994, Spence et al. 1996). LWD also plays similar role in salt marsh habitats (Maser and Sedell 1994). In benthic ocean habitats, LWD enriches local nutrient availability as deep-sea wood borers convert the wood to fecal matter, providing terrestrially-based carbon to the ocean food chain (Maser and Sedell 1994). When deposited on coastal shorelines, macrophyte wrack creates microhabitats and provides a food source for aquatic and terrestrial organisms such as isopods and amphipods, which play an important role in marine food webs.

Conversely, inorganic flotsam and jetsam debris can negatively impact EFH. Inorganic marine debris is a problem along much of the coastal United States, where it litters shorelines, fouls estuaries, entangles fish and wildlife, and creates hazards in the open ocean. Marine debris consists of a wide variety of man-made materials, including general litter, plastics, hazardous

wastes, and discarded or lost fishing gear. The debris enters waterbodies indirectly through rivers and storm water outfalls, as well as directly via ocean dumping and accidental release. Although laws and regulatory programs exist to prevent or control the problem, marine debris continues to affect aquatic resources.

5.2.2.1 Organic Debris Removal

Natural occurring flotsam, such as LWD and macrophyte wrack (i.e., kelp), is sometimes intentionally removed from streams, estuaries, and coastal shores. This debris is removed for a variety of reasons, including dam operations, aesthetic concerns, and commercial and recreational purposes (e.g., active beach log harvests, garden mulch, and fertilizer). However, the presence of organic debris is important for maintaining aquatic habitat structure and function.

Potential Adverse Impacts

The removal of organic debris from natural systems can reduce habitat function, adversely impacting habitat quality. Reductions in LWD inputs to estuaries may also affect the ecological balance of estuarine systems by altering rates and patterns of nutrient transport, sediment deposition, and availability of in-water cover for larval and juvenile fish. In rivers and streams of the Pacific Northwest, the historic practice of removing LWD to improve navigability and facilitate log transport has altered channel morphology and reduced habitat complexity, thereby negatively affecting habitat quality for spawning and rearing salmonids (Koski 1992, Sedell and Luchessa 1982).

Beach grooming and wrack removal can substantially alter the macrofaunal community structure of exposed sand beaches (Dugan et al. 2000). Species richness, abundance, and biomass of macrofauna associated with beach wrack (e.g., sand crabs, isopods, amphipods, and polychaetes) are higher on ungroomed beaches than on those that are groomed (Dugan et al. 2000). The input and maintenance of wrack can strongly influence the structure of macrofauna communities, including the abundance of sand crabs (*Emerita analoga*) (Dugan et al. 2000), an important prey species for some managed species of fish.

Recommended Conservation Measures

The recommended conservation measures for organic debris removal are listed below. They should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Encourage the preservation of LWD whenever possible, removing it only when it presents a threat to life or property.
- Encourage appropriate federal, state, and local agencies to aid in the downstream movement of LWD around dams, culverts, and bridges wherever possible, rather than removing it from the system.
- Educate landowners and recreationalists about the benefits of maintaining LWD.
- Localize beach grooming practices, and minimize them whenever possible.
- Advise gardeners to only harvest dislodged, dead kelp and leave live, growing kelp (whether dislodged or not).

5.2.2.2 Inorganic Debris

Inorganic debris in the marine environment is a chronic problem along much of the U.S. coast, resulting in littered shorelines and estuaries with varying degrees of negative effects to coastal ecosystems. Nationally, land-based sources of marine debris account for about 80 percent of the marine debris on beaches and in U.S. waters. Debris can originate from combined sewer overflows and storm drains, stormwater runoff, landfills, solid waste disposal, poorly maintained garbage bins, floating structures, and general littering of beaches, rivers, and open waters. It generally enters waterways indirectly through rivers and storm drains or by direct ocean dumping. Ocean-based sources of debris also create problems for managed species. These include discarded or lost fishing gear (NMFS 2008), and galley waste and trash from commercial merchant, fishing, military, and other vessels.

Potential Adverse Impacts

Land and ocean sourced inorganic marine debris is a very diverse problem, and adverse effects to EFH are likewise varied. Floating or suspended trash can directly affect managed species that consume or are entangled in it. Toxic substances in plastics can kill or impair fish and invertebrates that use habitat polluted by these materials. The chemicals that leach from plastics can persist in the environment and can bioaccumulate through the food web.

Once floatable debris settles to the bottom of estuaries, coastal and open ocean areas, it can continue to cause environmental problems. Plastics and other materials with a large surface area can cover and suffocate immobile animals and plants, creating large spaces devoid of life. Currents can carry suspended debris to underwater reef habitats where the debris can become snagged, damaging these sensitive habitats. The typical floatable debris from combined sewer overflows includes street litter, sewage containing viral and bacterial pathogens, pharmaceutical by-products from human excretion, and pet wastes. Pathogens can also contaminate shellfish beds and reefs.

Recommended Conservation Measures

Pollution prevention and improved waste management can occur through regulatory controls and best management practices. The recommended conservation measures for minimizing inorganic debris listed in the section below should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Encourage proper trash disposal, particularly in coastal and ocean settings, and participate in coastal cleanup activities.
- Advocate for local, state and national legislation that rewards proper disposal of debris.
- Encourage enforcement of regulations addressing marine debris pollution and proper disposal.
- Provide resources and technical guidance for development of studies and solutions addressing the problem of marine debris.
- Educate the public on the impact of marine debris and provide guidance on how to reduce or eliminate the problem.
- Implement structural controls that collect and remove trash before it enters nearby waterways.

- Consider the use of centrifugal separation to physically separate solids and floatables from water in combined sewer outflows.
- Encourage the development of incentives and funding mechanisms to recover lost fishing gear.
- Require all existing and new commercial construction projects near the coast to develop and implement refuse disposal plans.

5.2.3 Dam Operation

Dams provide sources of hydropower, water storage, and flood control. Construction and operation of dams can affect basic hydrologic and geomorphic function including the alteration of physical, biological, and chemical processes that, in turn, can have effects on water quality, timing, quantity, and alter sediment transport.

Potential Adverse Impacts (adapted from NMFS 2008)

The effects of dam construction and operation on fish and aquatic habitat include (1) complete or partial upstream and downstream migratory impediment; (2) water quality and flow pattern alteration; (3) alteration to distribution and function of ice, sediment and nutrient budgets; (4) alterations to the floodplain, including riparian and coastal wetland systems and associated functions and values; and (5) thermal impacts. Dam construction and operations can impede or block anadromous fish passage and other aquatic species migration in streams and rivers. Unless proper fish passage structures or devices are operational, dams can either prevent access to productive upstream spawning and rearing habitat or can alter downstream juvenile migration. Turbines, spillways, bypass systems, and fish ladders also affect the quality and quantity of EFH available for salmon passage in streams and rivers (Pacific Fishery Management Council 1999). The construction of a dam can fragment habitat, resulting in alterations to both upstream and downstream biogeochemical processes.

Recommended Conservation Measures (adapted from NMFS 2008)

The following conservation recommendations regarding dams should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Avoid construction of new dam facilities, where possible.
- Construct and design facilities with efficient and functional upstream and downstream adult and juvenile fish passage which ensures safe, effective, and timely passage.
- Operate dams within the natural flow fluctuations rates and timing and, when possible, mimic the natural hydrograph, allow for sediment and wood transport, and consider and allow for natural ice function. Monitor water flow and reservoir flow fluctuation.
- Understand longer term climatic and hydrologic patterns and how they affect habitat; plan project design and operation to minimize or mitigate for these changes.
- Use seasonal restrictions for construction, maintenance, and operation of dams to avoid impacts to habitat during species' critical life history stages.
- Develop and implement monitoring protocols for fish passage.
- Retrofit existing dams with efficient and functional upstream and downstream fish

passage structures.

- Construct dam facilities with the lowest hydraulic head practicable for the project purpose. Site the project at a location where dam height can be reduced.
- Downstream passage should prevent adults and juveniles from passing through the turbines and provide sufficient water downstream for safe passage.
- Coordinate maintenance and operations that require drawdown of the impoundment with state and federal resource agencies to minimize impacts to aquatic resources.
- Develop water and energy conservation guidelines for integration into dam operation plans and into regional and watershed-based water resource plans.
- Encourage the preservation of LWD, whenever possible.
- Develop a sediment transport and geomorphic maintenance plan to allow for peak flow mimicking that will result in sediment pulses through the reservoir/dam system and allow high flow geomorphic processes.

5.2.4 Commercial and Domestic Water Use

An increasing demand for potable water, combined with inefficient use of freshwater resources and natural events (e.g., droughts) have led to serious ecological damage worldwide (Deegan and Buchsbaum 2005). Because human populations are expected to continue increasing in Alaska, it is reasonable to assume that water uses, including water impoundments and diversion, will similarly increase (Gregory and Bisson 1997). Groundwater supplies 87 percent of Alaska's 3,500 public drinking water systems. Ninety percent of the private drinking water supplies are groundwater. Each day, roughly 275 million gallons of water derived from aquifers, which directly support riverine systems, are used for domestic, commercial, industrial, and agricultural purposes in Alaska (Groundwater Protection Council 2010). Surface water sources serve a large number of people from a small number of public water systems (e.g., Anchorage and several southeastern communities).

Potential Adverse Impacts

The diversion of freshwater for domestic and commercial uses can affect EFH by (1) altering natural flows and the process associated with flow rates, (2) altering riparian habitats by removing water or by submersion of riparian areas, (3) removing the amount and altering the distribution of prey bases, (4) affecting water quality, and (5) entrapping fishes. Water diversions can involve either withdrawals (reduced flow) or discharges (increased flow).

Recommended Conservation Measures

These conservation measures for commercial and domestic water use should be viewed as options to avoid and minimize adverse impacts from commercial and domestic water use and promote the conservation, enhancement, and proper functioning of EFH.

- Design water diversion and impoundment projects to create flow conditions that provide for adequate fish passage, particularly during critical life history stages. Avoid low water levels that strand juveniles and dewater redds. Incorporate juvenile and adult fish passage facilities on all water diversion projects (e.g., fish bypass systems). Install screens at water diversions on fish-bearing streams, as needed.

- Maintain water quality necessary to support fish populations by monitoring and adjusting water temperature, sediment loads, and pollution levels.
- Maintain appropriate flow velocity and water levels to support continued stream functions. Maintain and restore channel, floodplain, riparian, and estuarine conditions.
- Where practicable, ensure that mitigation is provided for unavoidable impacts to fish and their habitat.

5.3 Estuarine Activities

A large portion of Alaska's population resides near the state's 33,904-mile coastline (NOAA 2010). The dredging and filling of coastal wetlands for commercial and residential development, port, and harbor development directly removes important wetland habitat and alters the habitat surrounding the developed area. Physical changes from shoreline construction can result in secondary impacts such as increased suspended sediment loading, shading from piers and wharves, as well as introduction of chemical contamination from land-based human activities (Robinson and Pederson 2005). Even development projects that appear to have minimal individual impacts can have significant cumulative effects on the aquatic ecosystem (NMFS 2008).

5.3.1 Dredging

The construction of ports, marinas, and harbors typically involves dredging sediments from intertidal and subtidal habitats to create navigational channels, turning basins, anchorages, and berthing docks. Additionally, periodic dredging is used to maintain the required depths after sediment is deposited into these facilities. Dredging is also used to create deepwater navigable channels or to maintain existing channels that periodically fill with sediments. (Impacts from dredging from marine mining are also addressed later.)

Potential Adverse Impacts

Dredging activities can adversely affect benthic and water-column habitat. The environmental effects of dredging on managed species and their habitat can include (1) direct removal/burial of organisms; (2) turbidity and siltation, including light attenuation from turbidity; (3) contaminant release and uptake, including nutrients, metals, and organics; (4) release of oxygen consuming substances (e.g., chemicals and bacteria); (5) entrainment; (6) noise disturbances; and (7) alteration to hydrodynamic regimes and physical habitat.

Recommended Conservation Measures

The recommended conservation measures for dredging are listed in the following section. They should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Avoid new dredging in sensitive habitat areas to the maximum extent practicable.
- Reduce the area and volume of material to be dredged to the maximum extent practicable.
- Avoid dredging and placement of equipment used in conjunction with dredging operations in special aquatic sites and other high value habitat areas.

- Implement seasonal restrictions to avoid impacts to habitat during species critical life history stages (e.g., spawning season, egg, and larval development period).
- Utilize BMPs to limit and control the amount and extent of turbidity and sedimentation.
- For new dredging projects, undertake multi-season, pre-, and post-dredging biological surveys to assess the cumulative impacts to EFH and allow for implementation of adaptive management techniques.
- Prior to dredging, test sediments for contaminants as per U.S. Environmental Protection Agency (EPA) and U.S. Army Corps of Engineers (USACE) requirements.
- Provide appropriate compensation for significant impacts (short-term, long-term, and cumulative) to benthic environments resulting from dredging.
- Identify excess sedimentation in the watershed that prompts excessive maintenance dredging activities, and implement appropriate management actions, if possible.

5.3.2 Material Disposal and Filling Activities

Material disposal and filling activities can directly remove important habitat and alter the habitat surrounding the developed area. The discharge of dredged materials or the use of fill material in aquatic habitats can result in covering or smothering existing submerged substrates, loss of habitat function, and adverse effects on benthic communities.

5.3.2.1 *Disposal of Dredged Material*

Potential Adverse Impacts (adapted from NMFS 2008)

The disposal of dredged material can reduce the suitability of water bodies for managed species and their prey by (1) reducing floodwater retention in wetlands; (2) reducing nutrients uptake and release; (3) decreasing the amount of detrital input, an important food source for aquatic invertebrates (Mitsch and Gosselink 1993); (4) habitat conversion through alteration of water depth or substrate type; (5) removing aquatic vegetation and preventing natural revegetation; (6) impeding physiological processes to aquatic organisms (e.g., photosynthesis, respiration) caused by increased turbidity and sedimentation (Arruda et al. 1983, Cloern 1987, Dennison 1987, Barr 1993, Benfield and Minello 1996, Nightingale and Simenstad 2001a); (7) directly eliminating sessile or semi-mobile aquatic organisms via entrainment or smothering (Larson and Moehl 1990, McGraw and Armstrong 1990, Barr 1993, Newell et al. 1998); (8) altering water quality parameters (i.e., temperature, oxygen concentration, and turbidity); and (9) releasing contaminants such as petroleum products, metals, and nutrients (USEPA 2000a).

Recommended Conservation Measures

The following recommended conservation measures for dredged material disposal should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Avoid disposing dredged material in wetlands, submerged aquatic vegetation (SAV) and other special aquatic sites whenever possible.
- Test sediment compatibility for open-water disposal per EPA and USACE requirements.

- Ensure that disposal sites are properly managed and monitored to minimize impacts associated with dredge material.
- Where long-term maintenance dredging is anticipated, acquire and maintain disposal sites for the entire project life.
- Encourage beneficial uses of dredged materials.

5.3.2.2 Fill Material

Like the discharge of dredged material, the discharge of fill material to create upland areas can remove productive habitat and eliminate important habitat functions.

Potential Adverse Impacts

Adverse impacts to EFH from the introduction of fill material include (1) loss of habitat function and (2) changes in hydrologic patterns.

Recommended Conservation Measures

The following recommended conservation measures for the discharge of fill material should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Federal, state, and local resource management and permitting agencies should address the cumulative impacts of fill operations on EFH.
- Minimize the areal extent of any fill in EFH, or avoid it entirely.
- Consider alternatives to the placement of fill into areas that support managed species.
- Fill should be sloped to maintain shallow water, photic zone productivity; allow for unrestricted fish migration; and provide refugia for juvenile fish.
- In marine areas of kelp and other aquatic vegetation, fill (including artificial structure fill reefs) should be designed to maximize kelp colonization and provide areas for juvenile fish to find shelter from higher currents and exposure to predators.
- Fill materials should be tested and be within the neutral range of 7.5 to 8.4 pH.

5.3.3 Vessel Operations, Transportation, and Navigation

In Alaska, the growth in coastal communities is putting demands on port districts to increase infrastructure to accommodate additional vessel operations for cargo handling and marine transportation. Port expansion has become an almost continuous process due to economic growth, competition between ports, and significant increases in vessel size. In addition, increasing boat sales have put more pressure on improving and building new harbors, an important factor in Alaska because of the limited number of roads.

Potential Adverse Impacts

Activities associated with the expansion of port facilities, vessel/ferry operations, and recreational marinas can directly and indirectly impact EFH. Impacts include (1) loss and conversion of habitat; (2) altered light regimes and loss of submerged aquatic vegetation; (3)

altered temperature regimes; (4) siltation, sedimentation, and turbidity; (5) contaminant releases; and; and (6) altered tidal, current, and hydrologic regimes.

Recommended Conservation Measures

The following recommended conservation measures for vessel operations, transportation infrastructure, and navigation, should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Locate marinas in areas of low biological abundance and diversity.
- Leave riparian buffers in place to help maintain water quality and nutrient input.
- Include low-wake vessel technology, appropriate routes, and BMPs for wave attenuation structures as part of the design and permit process.
- Incorporate BMPs to prevent or minimize contamination from ship bilge waters, antifouling paints, shipboard accidents, shipyard work, maintenance dredging and disposal, and nonpoint source contaminants from upland facilities related to vessel operations and navigation.
- Locate mooring buoys in water deep enough to avoid grounding and to minimize the effects of prop wash.
- Use catchment basins for collecting and storing surface runoff to remove contaminants prior to delivery to any receiving waters.
- Locate facilities in areas with enough water velocity to maintain water quality levels within acceptable ranges.
- Locate marinas where they do not interfere with natural processes so as to affect adjacent habitats.
- To facilitate movement of fish around breakwaters, breach gaps and construct shallow shelves to serve as “fish benches,” as appropriate.
- Harbor facilities should be designed to include practical measures for reducing, containing, and cleaning up petroleum spills.

5.3.4 Invasive Species

Introductions of invasive species into estuarine, riverine, and marine habitats have been well documented (Rosecchi et al. 1993, Kohler and Courtenay 1986, Spence et al. 1996) and can be intentional (e.g., for the purpose of stock or pest control) or unintentional (e.g., fouling organisms). Exotic fish, shellfish, pathogens, and plants can be spread via shipping, recreational boating, aquaculture, biotechnology, and aquariums. The introduction of nonindigenous organisms to new environments can have many severe impacts on habitat (Omori et al. 1994).

Invasive aquatic species that are considered high priority threats to Alaska’s marine waters include Atlantic salmon (*Salmo salar*), green crab (*Carcinus maenas*), Chinese mitten crab (*Eriocheir sinensis*), signal crayfish (*Pacifastacus leniuculus*), zebra mussels (*Dreissena polymorpha*), New Zealand mudsnail (*Potamopyrgus antipodarum*), saltmarsh cordgrass

(*Spartina alterniflora*), purple loosestrife (*Lythrum salicaria*), and tunicates (*Botrylloides violaceus* and *Didemnum vexillum*).¹

Potential Adverse Impacts

Invasive species can create five types of negative effects on EFH: (1) habitat alteration, (2) trophic alteration, (3) gene pool alteration, (4) spatial alteration, and (5) introduction of diseases.

Recommended Conservation Measures

The following recommended conservation measures for invasive species should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Uphold fish and game regulations of the Alaska Board of Fisheries (AS 16.05.251) and Board of Game (AS 16.05.255), which prohibit and regulate the live capture, possession, transport, or release of native or exotic fish or their eggs.
- Adhere to regulations and use best management practices outlined in the State of Alaska Aquatic Nuisance Species Management Plan (Fay 2002).
- Encourage vessels to perform a ballast water exchange in marine waters to minimize the possibility of introducing invasive estuarine species into similar habitats.
- Discourage vessels that have not performed a ballast water exchange from discharging their ballast water into estuarine receiving waters.
- Require vessels brought from other areas over land via trailer to clean any surfaces that may harbor non-native plant or animal species (e.g., propellers, hulls, anchors, fenders).
- Treat effluent from public aquaria displays and laboratories and educational institutes using non-native species before discharge.
- Encourage proper disposal of seaweeds and other plant materials used for packing purposes when shipping fish or other animals.
- Undertake a thorough scientific review and risk assessment before any non-native species are introduced.

5.3.5 Pile Installation and Removal (From NMFS 2005)

Pilings are an integral component of many overwater and in-water structures. They provide support for the decking of piers and docks, function as fenders and dolphins to protect structures, support navigation markers, and help in the construction of breakwaters and bulkheads. Materials used in pilings include steel, concrete, wood (both treated and untreated), plastic, or a combination thereof. Piles are usually driven into the substrate by using either impact or vibratory hammers.

¹ <http://www.adfg.state.ak.us/special/invasive/invasive.ph>

5.3.5.1 *Pile Driving*

Potential Adverse Impacts

Pile driving can generate intense underwater sound pressure waves that may adversely affect EFH. These pressure waves have been shown to injure and kill fish (CalTrans 2001, Longmuir and Lively 2001, Stotz and Colby 2001, Stadler, pers. obs. 2002). Fish injuries associated directly with pile driving are poorly studied, but include rupture of the swim bladder and internal hemorrhaging (CalTrans 2001, Abbott and Bing-Sawyer 2002, Stadler pers. obs. 2002). Sound pressure levels (SPLs) 100 decibels (dB) above the threshold for hearing are thought to be sufficient to damage the auditory system in many fishes (Hastings 2002).

The type and intensity of the sounds produced during pile driving depend on a variety of factors, including the type and size of the pile, the firmness of the substrate into which the pile is being driven, the depth of water, and the type and size of the pile-driving hammer. Driving large hollow steel piles with impact hammers produces intense, sharp spikes of sound that can easily reach levels injurious to fish. Vibratory hammers, on the other hand, produce sounds of lower intensity, with a rapid repetition rate. A key difference between the sounds produced by impact hammers and those produced by vibratory hammers is the responses they evoke in fish. The differential responses to these sounds are due to the differences in the duration and frequency of the sounds.

Systems using air bubbles have been successfully designed to reduce the adverse effects of underwater SPLs on fish. Confined (i.e., metal or fabric sleeve) and unconfined air bubble systems have been shown to attenuate underwater sound pressures (Longmuir and Lively 2001, Christopherson and Wilson 2002, Reyff and Donovan 2003).

5.3.5.2 *Recommended Conservation Measures*

The following recommended conservation measures for pile driving should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Install hollow steel piles with an impact hammer at a time of year when larval and juvenile stages of fish species with designated EFH are not present.

If the first measure is not possible, then the following measures regarding pile driving should be incorporated when practicable to minimize adverse effects:

- Drive piles during low tide when they are located in intertidal and shallow subtidal areas.
- Use a vibratory hammer when driving hollow steel piles.
- Implement measures to attenuate the sound should SPLs exceed the 180 dB (re: 1 μ Pa) threshold.
- Surround the pile with an air bubble curtain system or air-filled coffer dam.
- Use a smaller hammer to reduce sound pressures.
- Use a hydraulic hammer if impact driving cannot be avoided.

- Drive piles when the current is reduced in areas of strong current, to minimize the number of fish exposed to adverse levels of underwater sound.

5.3.5.3 Pile Removal

Potential Adverse Impacts

The primary adverse effect of removing piles is the suspension of sediments, which may result in harmful levels of turbidity and release of contaminants contained in those sediments (see earlier). Vibratory pile removal tends to cause the sediments to slough off at the mudline, resulting in relatively low levels of suspended sediments and contaminants. Breaking or cutting the pile below the mudline may suspend only small amounts of sediment, providing that the stub is left in place, and little digging is required to access the pile. Direct pull or use of a clamshell to remove broken piles may, however, suspend large amounts of sediment and contaminants. When the piling is pulled from the substrate using these two methods, sediments clinging to the piling will slough off as it is raised through the water column, producing a potentially harmful plume of turbidity and/or contaminants. The use of a clamshell may suspend additional sediment if it penetrates the substrate while grabbing the piling.

While there is a potential to adversely affect EFH during the removal of piles, many of the piles removed in Alaska are old creosote-treated timber piles. In some cases, the long-term benefits to EFH obtained by removing a chronic source of contamination may outweigh the temporary adverse effects of turbidity.

Recommended Conservation Measures

The following recommended conservation measures for pile removal should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Remove piles completely rather than cutting or breaking them off, if they are structurally sound.
- Minimize the suspension of sediments and disturbance of the substrate when removing piles. Measures to help accomplish this include, but are not limited to, the following:
 - When practicable, remove piles with a vibratory hammer.
 - Remove the pile slowly to allow sediment to slough off at, or near, the mudline.
 - The operator should first hit or vibrate the pile to break the bond between the sediment and the pile.
 - Encircle the pile, or piles, with a silt curtain that extends from the surface of the water to the substrate.
- Complete each pass of the clamshell to minimize suspension of sediment if pile stubs are removed with a clamshell.
- Place piles on a barge equipped with a basin to contain attached sediment and runoff water after removal.

- Using a pile driver, drive broken/cut stubs far enough below the mudline to prevent release of contaminants into the water column as an alternative to their removal.

5.3.6 Overwater Structures (from NMFS 2005)

Overwater structures include commercial and residential piers and docks, floating breakwaters, barges, rafts, booms, and mooring buoys. These structures typically are located in intertidal areas out to about 49 feet (15 meters) below the area exposed by the mean lower low tide (i.e., the shallow subtidal zone).

Potential Adverse Impacts

Overwater structures and associated developments may adversely affect EFH in a variety of ways, primarily by (1) changes in ambient light conditions, (2) alteration of the wave and current energy regime, (3) introduction of contaminants into the marine environment, and (4) activities associated with the use and operation of the facilities (Nightingale and Simenstad 2001b).

Recommended Conservation Measures

The following recommended conservation measures for overwater structures should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Use upland boat storage whenever possible to minimize need for overwater structures.
- Locate overwater structures in deep enough waters to avoid intertidal and shade impacts, minimize or preclude dredging, minimize groundings, and avoid displacement of submerged aquatic vegetation, as determined by a preconstruction survey.
- Design piers, docks, and floats to be multiuse facilities to reduce the overall number of such structures and to limit impacted nearshore habitat.
- Incorporate measures that increase the ambient light transmission under piers and docks.
 - Maximize the height and minimize the width to decrease the shade footprint.
 - Use reflective materials on the underside of the dock to reflect ambient light.
 - Use the fewest number of pilings necessary to support the structures.
 - Align piers, docks, and floats in a north-south orientation to allow the arc of the sun to cross perpendicular to the structure and to reduce the duration of light limitation.
- Use floating rather than fixed breakwaters whenever possible, and remove them during periods of low dock use. Encourage seasonal use of docks and off-season haul-out.
- Locate floats in deep water to avoid light limitation and grounding impacts to the intertidal or shallow subtidal zone.
- Maintain at least 1 foot (0.30 meter) of water between the substrate and the bottom of the float at extreme low tide.
- Conduct in-water work when managed species and prey species are least likely to be impacted.

- To the extent practicable, avoid the use of treated wood timbers or pilings.
- Mitigate for unavoidable impacts to benthic habitats.

5.3.7 Flood Control/Shoreline Protection (from NMFS 2005)

Structures designed to protect humans from flooding events can result in varying degrees of change in the physical, chemical, and biological characteristics of shoreline and riparian habitat. These structures also can have long-term adverse effects on tidal marsh and estuarine habitats. Tidal marshes are highly variable, but typically have freshwater vegetation at the landward side, saltwater vegetation at the seaward side, and gradients of species in between that are in equilibrium with the prevailing climatic, hydrographic, geological, and biological features of the coast. These systems normally drain through tidal creeks that empty into the bay or estuary. Freshwater entering along the upper edges of the marsh drains across the surface and enters the tidal creeks. Structures placed for coastal shoreline protection may include concrete or wood seawalls, rip-rap revetments (sloping piles of rock placed against the toe of the dune or bluff in danger of erosion from wave action), dynamic cobble revetments (natural cobble placed on an eroding beach to dissipate wave energy and prevent sand loss), vegetative plantings, and sandbags.

Potential Adverse Impacts

Dikes, levees, ditches, or other water controls at the upper end of a tidal marsh can cut off all tributaries feeding the marsh, preventing the flow of freshwater, annual renewal of sediments and nutrients, and the formation of new marshes. Water controls within the marsh can intercept and carry away freshwater drainage, thus blocking freshwater from flowing across seaward portions of the marsh, or conversely increase the speed of runoff of freshwater to the bay or estuary. This can result in lowering the water table, which may permit saltwater intrusion into the marsh, and create migration barriers for aquatic species. In deeper channels where anoxic conditions prevail, large quantities of hydrogen sulfide may be produced that are toxic to marsh grasses and other aquatic life (NMFS 2008). Acid conditions of these channels can also result in release of heavy metals from the sediments.

Long-term effects of shoreline protection structures on tidal marshes include land subsidence (sometimes even submergence), soil compaction, conversion to terrestrial vegetation, greatly reduced invertebrate populations, and general loss of productive wetland characteristics (NMFS 2005). Alteration of the hydrology of coastal salt marshes can reduce estuarine productivity, restrict suitable habitat for aquatic species, and result in salinity extremes during droughts and floods (NMFS 2008). Armoring shorelines to prevent erosion and to maintain or create shoreline real estate can reduce the amount of intertidal habitat, and affects nearshore processes and the ecology of numerous species (Williams and Thom 2001). Hydraulic effects on the shoreline include increased energy seaward of the armoring, reflected wave energy, dry beach narrowing, substrate coarsening, beach steepening, changes in sediment storage capacity, loss of organic debris, and downdrift sediment starvation (Williams and Thom 2001). Installation of breakwaters and jetties can result in community changes from burial or removal of resident biota, changes in cover and preferred prey species, and predator attraction (Williams and Thom 2001). As with armoring, breakwaters and jetties modify hydrology and nearshore sediment transport, as well as movement of larval forms of many species (Williams and Thom 2001).

Recommended Conservation Measures

The following recommended conservation measures for flood and shoreline protection should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Avoid or minimize the loss of coastal wetlands as much as possible.
- Do not dike or drain tidal marshlands or estuaries.
- Wherever possible, use soft in lieu of “hard” shoreline stabilization and modifications.
- Ensure that the hydrodynamics and sedimentation patterns are properly modeled and that the design avoids erosion to adjacent properties when “hard” shoreline stabilization is deemed necessary.
- Include efforts to preserve and enhance fishery habitat to offset impacts.
- Avoid installing new water control structures in tidal marshes and freshwater streams.
- Ensure water control structures are monitored for potential alteration of water temperature, dissolved oxygen concentration, and other parameters.
- Use seasonal restrictions to avoid impacts to habitat during critical life history stages.
- Address the cumulative impacts of development activities in the review process for flood control and shoreline protection projects.
- Use an adaptive management plan with ecological indicators to oversee monitoring and to ensure that mitigation objectives are met. Take corrective action as needed.

5.3.8 Log Transfer Facilities/In-Water Log Storage (from NMFS 2005)

Rivers, estuaries, and bays were historically the primary ways to transport and store logs in the Pacific Northwest, and log storage continues in some tidal areas today. Using estuaries and bays and nearby uplands for storage of logs is common in Alaska, with most log transfer facilities (LTFs) found in Southeast Alaska and a few located in Prince William Sound. LTFs are facilities that are constructed wholly or in part in waterways and used to transfer commercially harvested logs to or from a vessel or log raft, or for consolidating logs for incorporation into log rafts (USEPA 2000b). LTFs may use a crane, A-frame structure, conveyor, slide, or ramp to move logs from land into the water. Logs can also be placed in the water at the site by helicopters.

Potential Adverse Impacts

Log handling and storage in the estuaries and intertidal zones can result in modification of benthic habitat and water quality degradation within the area of bark deposition (Levings and Northcote 2004). EFH may be physically impacted by activities associated with LTFs. LTFs may cause shading and other indirect effects similar in many ways to those of floating docks and other over-water structures (see earlier).

Recommended Conservation Measures

The following recommended conservation measures for log transfer and storage facilities should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

The physical, chemical, and biological impacts of LTF operations can be substantially reduced by adherence to appropriate siting and operational constraints. Adherence to the Alaska Timber Task Force (ATTF) operational and siting guidelines and BMPs in the National Pollutant Discharge Elimination System (NPDES) General Permit will reduce (1) the amount of bark and wood debris that enters the marine and coastal environment, (2) the potential for displacement or harm to aquatic species, and (3) the accumulation of bark and wood debris on the ocean floor. The following conservation measures reflect those guidelines.²

- Restrict or eliminate storage and handling of logs from waters where state and federal water quality standards cannot be met at all times outside of the authorized zone of deposition.
- Minimize potential impacts of log storage by employing effective bark and wood debris control, collection, and disposal methods at log dumps, raft building areas, and mill-side handling zones; avoiding free-fall dumping of logs; using easy let-down devices for placing logs in the water; and bundling logs before water storage (bundles should not be broken except on land and at millside).
- Do not store logs in the water if they will ground at any time or shade sensitive aquatic vegetation such as eelgrass.
- Avoid siting log-storage areas and LTFs in sensitive habitat and areas important for specified species, as required by the ATTF guidelines.
- Site log storage areas and LTFs in areas with good currents and tidal exchanges.
- Use land-based storage sites where possible.

5.3.9 Utility Line, Cables, and Pipeline Installation

With the continued development of coastal regions comes greater demand for the installation of cables, utility lines for power and other services, and pipelines for water, sewage, and other utilities. The installation of pipelines, utility lines, and cables can have direct and indirect impacts on the offshore, nearshore, estuarine, wetland, beach, and rocky shore coastal zone habitats. Many of the direct impacts occur during construction, such as ground disturbance in the clearing of the right-of-way, access roads, and equipment staging areas. Indirect impacts can include increased turbidity, saltwater intrusion, accelerated erosion, and introduction of urban and industrial pollutants due to ground clearing and construction.

Potential Adverse Impacts

Adverse effects on EFH from the installation of pipelines, utility lines, and cables can occur through (1) destruction of organisms and habitat, (2) turbidity impacts, (3) resuspension and

² See also http://www.fs.fed.us/r10/TLMP/F_PLAN/APPEND_G.PDF.

release of contaminants, (4) changes in hydrology, and (5) destruction of vertically complex hard bottom habitat (e.g., hard corals and vegetated rocky reef).

Recommended Conservation Measures

The following recommended conservation measures for cable and utility line installation should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Align crossings along the least environmentally damaging route.
- Use horizontal directional drilling where cables or pipelines would cross anadromous fish streams, salt marsh, vegetated inter-tidal zones, or steep erodible bluff areas adjacent to the intertidal zone.
- Store and contain excavated material on uplands.
- Backfill excavated wetlands with either the same or comparable material capable of supporting similar wetland vegetation, and at original marsh elevations.
- Use existing rights-of-way whenever possible.
- Bury pipelines and submerged cables where possible.
- Remove inactive pipelines and submerged cables unless they are located in sensitive areas (e.g., marsh, reefs, sea grass).
- Use silt curtains or other barriers to reduce turbidity and sedimentation whenever possible.
- Limit access for equipment to the immediate project area. Tracked vehicles are preferred over wheeled vehicles.
- Limit construction equipment to the minimum size necessary to complete the work.
- Conduct construction during the time of year when it will have the least impact on sensitive habitats and species.
- Suspend transmission lines beneath existing bridges or conduct directional boring under streams to reduce the environmental impact.
- For activities on the Continental Shelf, implement the following to the extent practicable:
 - Shunt drill cuttings through a conduit and either discharge the cuttings near the sea floor, or transport them ashore.
 - Locate drilling and production structures, including pipelines, at least 1 mile (1.6 kilometers) from the base of a hard-bottom habitat.
 - Bury pipelines at least 3 feet (0.9 meter) beneath the sea floor whenever possible.
 - Locate alignments along routes that will minimize damage to marine and estuarine habitat.

5.3.10 Mariculture

Productive embayments are often used for commercial culturing and harvesting operations. These locations provide protected waters for geoduck, oyster, and mussel culturing. In 1988, Alaska passed the Alaska Aquatic Farming Act (AAF Act) which is designed to encourage establishment and growth of an aquatic farming industry in the state. The AAF Act establishes four criteria for issuance of an aquatic farm permit, including the requirement that the farm may not significantly affect fisheries, wildlife, or other habitats in an adverse manner. Aquatic farm permits are issued by the Alaska Department of Natural Resources (ADNR).

Potential Adverse Impacts

Shellfish aquaculture tends to have less impact on EFH than finfish aquaculture because the shellfish generally are not fed or treated with chemicals (OSPAR Commission 2009). Adverse impacts to EFH by mariculture operations include (1) risk of introducing undesirable species and disease; (2) physical disturbance of intertidal and subtidal areas; and (3) impacts on estuarine food webs, including disruption of eelgrass habitat (e.g., dumping of shell on eelgrass beds, repeated mechanical raking or trampling, and impacts from predator exclusion netting, though few studies have documented impacts). Hydraulic dredges used to harvest oysters in coastal bays can cause long-term adverse impacts to eelgrass beds by reducing or eliminating the beds (Phillips 1984).

Recommended Conservation Measures

The following recommended conservation measures for mariculture facilities should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Site mariculture operations away from kelp or eelgrass beds.
- Do not enclose or impound tidally influenced wetlands for mariculture.
- Undertake a thorough scientific review and risk assessment before any non-native species are introduced.
- Encourage development of harvesting methods to minimize impacts on plant communities and the loss of food and/or habitat to fish populations during harvesting operations.
- Provide appropriate mitigation for the unavoidable, extensive, or permanent loss of plant communities.
- Ensure that mariculture facilities, spat, and related items transported from other areas are free of nonindigenous species.

5.4 Coastal/Marine Activities

5.4.1 Point-Source Discharges

Point source pollutants are generally introduced via some type of pipe, culvert, or similar outfall structure. These discharge facilities typically are associated with domestic or industrial activities, or in conjunction with collected runoff from roadways and other developed portions of

the coastal landscape. Waste streams from sewage treatment facilities and watershed runoff may be combined in a single discharge. Point source discharges introduce inorganic and organic contaminants into aquatic habitats, where they may become bioavailable to living marine resources.

Potential Adverse Impacts (adopted from NMFS 2008)

The Clean Water Act (CWA) includes important provisions to address acute or chronic water pollution emanating from point source discharges. Under the NPDES program, most point-source discharges are regulated by the state or EPA. While the NPDES program has led to ecological improvements in U.S. waters, point sources continue to introduce pollutants into the aquatic environment, albeit at reduced levels.

Determining the fate and effect of natural and synthetic contaminants in the environment requires an interdisciplinary approach to identify and evaluate all processes sensitive to pollutants. This is critical as adverse effects may be manifested at the biochemical level in organisms (Luoma 1996) in a manner particular to the species or life stage exposed. Exposure to pollutants can inhibit (1) basic detoxification mechanisms, e.g., production of metallothioneins or antioxidant enzymes; (2) disease resistance; (3) the ability of individuals or populations to counteract pollutant-induced metabolic stress; (4) reproductive processes including gamete development and embryonic viability; (5) growth and successful development through early life stages; (6) normal processes including feeding rate, respiration, osmoregulation; and (7) overall Darwinian fitness (Capuzzo and Sassner 1977; Widdows et al. 1990; Nelson et al. 1991; Stiles et al. 1991; Luoma 1996; Thurberg and Gould 2005).

Recommended Conservation Measures

The following recommended conservation measures for point source discharges should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Locate discharge points in coastal waters well away from shellfish beds, sea grass beds, corals, and other similar fragile and productive habitats.
- Reduce potentially high velocities by diffusing effluent to acceptable velocities.
- Determine baseline benthic productivity by sampling before any construction activity.
- Provide for mitigation when degradation or loss of habitat occurs.
- Institute source-control programs that effectively reduce noxious materials.
- Ensure compliance with pollutant discharge permits, which set effluent limitations and/or specify operation procedures, performance standards, or BMPs.
- Treat discharges to the maximum extent practicable.
- Use land-treatment and upland disposal/storage techniques where possible.
- Avoid siting pipelines and treatment facilities in wetlands and streams.

5.4.2 Seafood Processing Waste—Shoreside and Vessel Operation

Seafood processing is conducted throughout much of coastal Alaska. Processing facilities may be vessel-based or located onshore (ADEC 2010a). Seafood processing facilities generally consist of mechanisms to offload the harvest from fishing boats; tanks to hold the seafood until the processing lines are ready to accept them; processing lines, process water, and waste collection systems; treatment and discharge facilities; processed seafood storage areas; and necessary support facilities such as electrical generators, boilers, retorts, water desalinators, offices, and living quarters. In addition, recreational fish cleaning at marinas and small harbors can produce a large quantity of fish waste.

Pollutants of concern from seafood processing wastewater are primarily components of the biological wastes generated by processing raw seafood into a marketable form, chemicals used to maintain sanitary conditions for processing equipment and fish containment structures, and refrigerants (ammonia and freon) that may leak from refrigeration systems used to preserve seafood (ADEC 2010b). Biological wastes include fish parts (e.g., heads, fins, bones, and entrails) and chemicals, which are primarily disinfectants that must be used in accordance with EPA specifications.

Potential Adverse Impacts

Seafood processing operations have the potential to adversely affect EFH through the discharge of nutrients, chemicals, fish byproducts, and “stickwater” (water and entrained organics originating from the draining or pressing of steam-cooked fish products). Seafood processing discharges influence nutrient loading, eutrophication, and anoxic and hypoxic conditions significantly influencing marine species diversity and water quality (Theriault et al. 2006, Roy Consultants 2003, Lotze et al. 2003). Although fish waste is biodegradable, fish parts that are ground to fine particles may remain suspended for some time, thereby overburdening habitats from particle suspension (NMFS 2005). Scum and foam from seafood waste deposits can also occur on the water surface and/or increase turbidity. Turbidity decreases light penetration into the water column, reducing primary production. In addition, stickwater takes the form of a fine gel or slime that can concentrate on surface waters and move onshore to cover intertidal areas.

Recommended Conservation Measures

The following recommended conservation measures for fish processing waste should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- To the maximum extent practicable, base effluent limitations on site-specific water quality concerns.
- Encourage the use of secondary or wastewater treatment systems where possible.
- Do not allow designation of new zones of deposit for fish processing waste and instead seek disposal options that avoid an accumulation of waste.
- Promote sound recreational fish waste management through a combination of fish-cleaning restrictions, public education, and proper disposal of fish waste.
- Encourage alternative uses of fish processing wastes.

- Explore options for additional research.
- Monitor biological and chemical changes to the site of processing waste discharges.

5.4.3 Water Intake Structures/Discharge Plumes

Withdrawals of riverine, estuarine, and marine waters are common for a variety of uses such as to cool power-generating stations and create temporary ice roads and ice ponds. In the case of power plants, the subsequent discharge of heated and/or chemically treated discharge water can also occur.

Potential Adverse Impacts

Water intake structures and effluent discharges can interfere with or disrupt EFH functions in the source or receiving waters by (1) entrainment, (2) impingement, (3) degrading water quality, (4) operation and maintenance, and (5) construction-related impacts.

Recommended Conservation Measures

The following recommended conservation measures for water intakes and discharges should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Locate facilities that rely on surface waters for cooling in areas other than estuaries, inlets, heads of submarine canyons, rock reefs, or small coastal embayments where managed species or their prey concentrate.
- Design intake structures to minimize entrainment or impingement.
- Design power plant cooling structures to meet the best technology available requirements as developed pursuant to section 316(b) of the CWA.
- Regulate discharge temperatures so they do not appreciably alter the ambient temperature to an extent that could cause a change in species assemblages and ecosystem function in the receiving waters.
- Avoid the use of biocides (e.g., chlorine) to prevent fouling where possible.
- Treat all discharge water from outfall structures to meet state water quality standards at the terminus of the pipe.

5.4.4 Oil and Gas Exploration, Development, and Production

Two agencies, the Bureau of Ocean Energy Management and the Bureau of Safety and Environmental Enforcement are responsible for regulating oil and gas operations on the Outer Continental Shelf (OCS). The ADNOR Division of Oil and Gas exercises similar authority over State waters (ADNR1999). Offshore petroleum exploration, development, and production activities have been conducted in Alaska waters or on the Alaska OCS in since the 1960s (Kenai Peninsula Borough 2004). As demand for energy resources grows, the debate over trying to balance the development of oil and gas resources and the protection of the environment will also continue.

Potential Adverse Impacts

Offshore oil and gas operations can be classified into exploration, development, and production activities (which includes transportation). These activities occur at different depths in a variety of habitats, and can cause an assortment of physical, chemical, and biological disturbances (NMFS 2005, Helvey 2002). (Some of these disturbances are listed below; however, not all of the potential disturbances in this list apply to every type of activity.)

Noise from seismic surveys, vessel traffic, and construction of drilling platforms or islands

Physical alterations to habitat from the construction, presence, and eventual decommissioning and removal of facilities such as islands or platforms, storage and production facilities, and pipelines to onshore common carrier pipelines, storage facilities, or refineries

Waste discharges, including well drilling fluids, produced waters, surface runoff and deck drainage, domestic waste waters generated from the offshore facility, solid waste from wells (drilling muds and cuttings), and other trash and debris from human activities associated with the facility

Oil spills

Platform storage and pipeline decommissioning

The potential disturbances and associated adverse impacts on the marine environment have been reduced through operating procedures required by regulatory agencies and, in many cases, self-imposed by facilities operators. Most of the activities associated with oil and gas operations are conducted under permits and regulations that require companies to minimize impacts or avoid construction in sensitive marine habitats. New technological advances in operating procedures also reduce the potential for impacts.

Recommended Conservation Measures

The following recommended conservation measures for oil and gas exploration and development should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH:

- Avoid the discharge of produced waters into marine waters and estuaries.
- Avoid discharge of muds and cuttings into the marine and estuarine environment.
- To the extent practicable, avoid the placement of fill to support construction of causeways or structures in the nearshore marine environment.
- As required by federal and state regulatory agencies, encourage the use of geographic response strategies that identify EFH and environmentally sensitive areas.
- Evaluate potential impacts to EFH that may result from activities carried out during the decommissioning phase of oil and gas facilities.
- Vessel operations and shipping activities should be familiar with Alaska Geographic Response Strategies which detail environmentally sensitive areas of Alaska's coastline.

5.4.5 Habitat Restoration and Enhancement

Habitat loss and degradation are major, long-term threats to the sustainability of fishery resources (NMFS 2002). Viable coastal and estuarine habitats are important to maintaining healthy fish stocks. Good water quality and quantity, appropriate substrate, ample food sources, and adequate shelter from predators are needed to sustain fisheries. Restoration and/or enhancement of coastal and riverine habitat that supports managed fisheries and their prey will assist in sustaining and rebuilding fish stocks by increasing or improving ecological structure and functions. Habitat restoration and enhancement may include, but is not limited to, improvement of coastal wetland tidal exchange or reestablishment of natural hydrology; dam or berm removal; fish passage barrier removal or modification; road-related sediment source reduction; natural or artificial reef, substrate, or habitat creation; establishment or repair of riparian buffer zones; improvement of freshwater habitats that support anadromous fishes; planting of native coastal wetland and submerged aquatic vegetation; and improvements to feeding, shade or refuge, spawning, and rearing areas that are essential to fisheries.

Potential Adverse Impacts

The implementation of restoration and enhancement activities may have localized and temporary adverse impacts on EFH. Possible impacts can include (1) localized nonpoint source pollution such as influx of sediment or nutrients, (2) interference with spawning and migration periods, (3) temporary removal feeding opportunities, (4) indirect effects from construction phase of the activity, (5) direct disturbance or removal of native species, and (6) temporary or permanent habitat disturbance.

Recommended Conservation Measures

The following recommended conservation measures for habitat restoration and enhancement should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Use BMPs to minimize and avoid potential impacts to EFH during restoration activities.
 - Use turbidity curtains, hay bales, and erosion mats.
 - Plan staging areas in advance, and keep them to a minimum size.
 - Establish buffer areas around sensitive resources.
 - Remove invasive plant and animal species from the proposed action area before starting work. Plant only native plant species.
 - Establish temporary access pathways before restoration activities.
- Avoid restoration work during critical life stages for fish such as spawning, nursery, and migration.
- Provide adequate training and education for volunteers and project contractors to ensure minimal impact to the restoration site.
- Conduct monitoring before, during, and after project implementation.
- To the extent practicable, mitigate any unavoidable damage to EFH.

- Remove and, if necessary, restore any temporary access pathways and staging areas used.
- Determine benthic productivity by sampling before any construction activity in the case of subtidal enhancement (e.g., artificial reefs). Avoid areas of high productivity to the maximum extent possible.

5.4.6 Marine Mining

Mining activities, which are also described in Sections 3.1.1 and 3.1.2 of the EFH EIS (NMFS 2005), can lead to the direct loss or degradation of EFH for certain species. Offshore mining, such as the extraction of gravel and gold in the Bering Sea, can increase turbidity, and resuspension of organic materials could impact eggs and recently hatched larvae in the area. Mining large quantities of beach gravel can also impact turbidity, and may significantly affect the transport and deposition of sand and gravel along the shore, both at the mining site and down-current (NMFS 2005).

Potential Adverse Impacts

Impacts from mining on EFH include both physical impacts (i.e., intertidal dredging) and chemical impacts (i.e., additives such as flocculants) (NMFS 2005). Physical impacts may include the removal of substrates that serve as habitat for fish and invertebrates; habitat creation or conversion in less productive or uninhabitable sites, such as anoxic holes or silt bottom; burial of productive habitats, such as in near-shore disposal sites (as in beach nourishment); release of harmful or toxic materials either in association with actual mining, or in connection with machinery and materials used for mining; creation of harmful turbidity levels; and adverse modification of hydrologic conditions so as to cause erosion of desirable habitats. Submarine disposal of mine tailings can also alter the behavior of marine organisms.

Recommended Conservation Measures

The following recommended conservation measures for marine mining should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- To the extent practicable, avoid mining in waters containing sensitive marine benthic habitat, including EFH (e.g., spawning, migrating, and feeding sites).
- Minimize the areal extent and depth of extraction to reduce recolonization times.
- Monitor turbidity during operations, and cease operations if turbidity exceeds predetermined threshold levels.
- Monitor individual mining operations to avoid and minimize cumulative impacts.
- Use seasonal restrictions as appropriate; to avoid and minimize impacts to EFH during critical life history stages of managed species (e.g., migration and spawning).
- Deposit tailings within as small an area as possible.

5.5 References

- Abbe, T.B. and D.R. Montgomery. 1996. "Large woody debris jams, channel hydraulics, and habitat formation in large rivers." *Regulated Rivers: Research and Management*. 12:201-221.
<http://www.cems.uvm.edu/ce361/papers/abbe1996.pdf>
- Abbott, R. and E. Bing-Sawyer. 2002. Assessment of pile driving impacts on the Sacramento blackfish (*Othodon microlepidotus*). Draft report prepared for Caltrans District 4. October 10, 2002.
- Alaska Department of Environmental Conservation (ADEC). 2010a. Ocean Discharge Criteria Evaluation Alaska Offshore Seafood Processors APDES General Permit AKG523000. Prepared by Tetra Tech, 10306 Eaton Place Suite 340, Fairfax, VA 22030. 152 pp.
- ADEC. 2010b. Wastewater Discharge Authorization Program, 555 Cordova Street, Anchorage, AK 99501. Fact Sheet Alaska Offshore Seafood Processors General Permit AKG523000. 43 pp.
- Alaska Department of Natural Resources (ADNR). 1999. Cook Inlet Areawide 1999 Oil and Gas Lease Sale, Final Finding of the Director. Volume II. Appendix B: "Laws and Regulations Pertaining to Oil and Gas Exploration, Development, Production, and Transportation."
- American Fisheries Society (AFS). 2000. AFS Policy Statement #13: Effects of Surface Mining on Aquatic Resources in North America (Revised). (Abbreviated) http://www.fisheries.org/afs/docs/policy_13f.pdf
- Arruda, J.A., G.R. Marzolf, R.T. Faulk. 1983. The role of suspended sediments in the nutrition of zooplankton in turbid reservoirs. *Ecology* 64(5):1225-35.
- Atlantic States Marine Fisheries Commission. 1992. Fishery management plan for inshore stocks of winter flounder. Washington (DC): ASMFC. FMR No. 21. 138 p.
- Barr BW. 1993. Environmental impacts of small boat navigation: vessel/sediment interactions and management implications. In: Magoon OT, editor. Coastal Zone '93: proceedings of the eighth Symposium on Coastal and Ocean Management; 1993 Jul 19-23; New Orleans, LA. American Shore and Beach Preservation Association. p 1756-70.
- Benfield, M.C. and T. J. Minello. 1996. "Relative effects of turbidity and light intensity on reactive distance and feeding of an estuarine fish." *Environmental Biology of Fishes*. 46:211-216.
- Brix, K.V., D.K. DeForest, and W.J. Adams 2001. Assessing acute and chronic copper risks to freshwater aquatic life using species sensitivity distributions for different taxonomic groups. *Environmental Toxicology and Chemistry*. 20(8): 1846-1856.
- Caltrans. 2001. Fisheries Impact Assessment, Pile Installation Demonstration Project for the San Francisco - Oakland Bay Bridge, East Span Seismic Safety Project, August 2001. 59 pp.
- Capuzzo J.M., and J.J. Sassner Jr. 1977. The effect of chromium on filtration rates and metabolic activity of *Mytilus edulis* L. and *Mya arenaria* L. In: Vernberg FJ, and others, editors. Physiological responses of marine biota to pollutants. San Diego (CA): Academic Press. p 225-37.
- Center for Watershed Protection (CWP). 2003. Impacts of Impervious Cover on Aquatic Systems. Elliott City, MD, www.cwp.org. 141 pp.
- Christopherson, A. and J. Wilson. 2002. Technical Letter Report Regarding the San Francisco-Oakland Bay Bridge East Span Project Noise Energy Attenuation Mitigation. Peratrovich, Nottingham & Drage, Inc. Anchorage, Alaska. 27 pp.

- Cloern, J.E. 1987. "Turbidity as a control on phytoplankton biomass and productivity in estuaries." *Continental Shelf Research*. 7:1367-1381.
- Conner, Billy, Director Alaska University Transportation Center. University of Alaska, Fairbanks PO Box 755900. 2007 Interview in Building Alaska. http://www.buildingalaskamovie.com/interviews_billy.html
- Deegan, L.A. and R.N. Buchsbaum. 2005. The effect of habitat loss and degradation on fisheries. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline on fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 67-96.
- Dennison, W.C. 1987. "Effect of light on seagrass photosynthesis, growth and depth distribution." *Aquatic Botany*. 27:15-26.
- Dugan, J.E., D.M. Hubbard, D.L. Martin, J.M. Engle, D.M. Richards, G.E. Davis, K.D. Lafferty, and R.F. Ambrose. 2000. Macrofauna communities of exposed sandy beaches on the Southern California mainland and Channel Islands. pp 339-346. In Brown, D.R., K.L. Mitchell, and H.W. Chang, eds. Proceedings of the Fifth California Islands Symposium. Minerals Management Service Publication # 99-0038.
- Frag, A.M., D.A. Skaar, E. Nimick, C. MacConnell, and C. Hogstrand. 2003. Characterizing aquatic health using salmonids mortality, physiology, and biomass estimates in streams with elevated concentrations of arsenic, cadmium, copper, lead, and zinc in the Boulder River Watershed, Montana. Transaction of the American Fisheries Society 132(3): 450-457.
- Fay, V. 2002. Alaska Aquatic Nuisance Species Management Plan. Alaska Department of Fish and Game Publication. Juneau, AK. http://www.adfg.state.ak.us/special/invasive/ak_ansmp.pdf.
- Goldstein, J.N., D.F. Woodward, and A.M. Frag. 1999. Movement of adult Chinook salmon during spawning migration in a metals-contaminated system, Coeur d'Alene River, Idaho. Transactions of the American Fisheries Society 128:121-129.
- Gregory, S.V. and P.A. Bisson. 1997. Degradation and loss of anadromous salmonid habitat in the Pacific Northwest. In Stouder, J.D., P.A. Bisson, and R.J. Naiman, eds. Pacific Salmon and Their Ecosystems: Status and Future Options, pp. 277-314. Chapman and Hall, New York.
- Groundwater Protection Council. 2010. State Groundwater Fact Sheets. http://www.gwpc.org/e-library/documents/state_fact_sheets/alaska.pdf. Ground Water Protection Council, 13308 N. MacArthur Blvd., Oklahoma City, OK 73142.
- Hansen, J.A., Lipton J., and Welsh P.G. 2002. Environmental toxicology and chemistry. 21 (3): 633-639
- Hastings, M.C. 2002. Clarification of the meaning of sound pressure levels and the known effects of sound on fish. Document in support of Biological Assessment for San Francisco-Oakland Bay Bridge East Span Seismic Safety Project. August 26, 2002. Revised August 27, 2002. 8 pp.
- Helvey, M. 2002. "Are southern California oil and gas platforms essential fish habitat?" *ICES Journal of Marine Science*. 59:S266-S271.
- Kenai Peninsula Borough. 2004. Cook Inlet Oil and Gas, Kenai Peninsula Borough Oil and Gas History. <http://www.cookinletoilandgas.org/kpb/history.htm>
- Kohler, C.C. and W.R. Courtenay, Jr. 1986. "Introduction of aquatic species." *Fisheries*. 11(2):39-42. Proceedings of the Seventh International Zebra Mussel and Aquatic Nuisance Species Conference. 1997.

- Koski, K.V. 1992. Restoring stream habitats affected by logging activities. Pages 343-404 in G. W. Thayer (editor) Restoring the nation's marine environment. Publication UM-SG-TS-92-06. Maryland Sea Grant College, College Park, MD.
- Larson, K. and C. Moehl. 1990. Entrainment of anadromous fish by hopper dredge at the mouth of the Columbia River. In C.A. Simenstad, ed. Effects of dredging on anadromous Pacific coast fishes. University of Washington Sea Grant. pp. 102-112.
- Levings, C.D. and T. G. Northcote. 2004. Effects of forestry on estuarine ecosystems supporting fishes. In T.G. Northcote and G.F. Hartman, editors, Fishes and Forestry Worldwide Watershed Interactions and Management, Blackwell Publishing, pp 320 -335.
- Longmuir, C. and T. Lively. 2001. Bubble curtain systems for use during marine pile driving. Report by Fraser River Pile & Dredge Ltd., New Westminster, British Columbia. 9 pp.
- Lotze, H., I. Milewski, B. Worm, and Z. Koller. 2003 Nutrient Pollution: A Eutrophication Survey of Eelgrass Beds in Estuaries and Coastal Bays in Northern and Eastern New Brunswick. Conservation Council of New Brunswick Inc.
- Luce, A. and M. Crowe. 2001. "Invertebrate terrestrial diversity along a gravel road on Barrie Island, Ontario, Canada." *Great Lakes Entomologist*. 34(1):55-60 SPR-SUM.
- Luoma, S.N. 1996. The developing framework of marine ecotoxicology: pollutants as a variable in marine ecosystems. *Journal of Experimental Marine Biology and Ecology* 200:29-55.
- Maser, C. and J.R. Sedell. 1994. From the Forest to the Sea: the Ecology of Wood in Streams, Estuaries and Oceans. St. Lucie Press, Delray Beach, FL. 200 pp.
- McGraw, K. and D. Armstrong. 1990. Fish entrainment by dredges in Grays Harbor, Washington. In C.A. Simenstad, ed. Effects of dredging on anadromous Pacific coast fishes. University of Washington Sea Grant. pp. 113-131.
- Mitsch WJ, Gosselink JG. 1993. Wetlands. 2nd ed. New York (NY): Van Nostrand Reinhold. 722 pp.
- Montgomery, D.R., R.D. Smith, K.M. Schmidt, and G.R. Pess. 1995. "Pool Spacing in Forest Channels." *Water Resources Research*. 31:1097-1105.
- NMFS. 2011. Impacts to Essential Fish Habitat from Non-fishing Activities in Alaska. National Marine Fisheries Service, Alaska Region. Juneau, Alaska. November, 2011.
- NMFS. 2008. Impacts to Marine Fisheries Habitat from Nonfishing Activities in the Northeastern United States. Northeast Regional Office Gloucester, Massachusetts NOAA Technical Memorandum NMFS-NE-209.
- NMFS. 2005. Final Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska, Appendix G Non-fishing Impacts to Essential Fish Habitat and Recommended Conservation Measures.
- NMFS. 2004. Draft National Gravel Extraction Policy. 1335 East-West Highway, Silver Spring, MD 20910. <http://www.nmfs.noaa.gov/habitat/habitatprotection/pdf/gravelguidance.pdf>
- NMFS. 2002. Environmental Assessment, NMFS' Restoration Plan for the Community-Based Restoration Program. Prepared by the NOAA Restoration Center, Office of Habitat Conservation. Silver Spring, MD.
- NMFS. 1998a. Draft document - Non-fishing threats and water quality: A reference for EFH consultation

- NMFS. 1998b. Final recommendations: Essential Fish Habitat for Pacific Coast Groundfish. Prepared by: The Core Team for EFH for Pacific Coast Groundfish June 3, 1998. 2725 Montlake Blvd. E. Seattle, WA 98112. http://www.psmfc.org/efh/groundfish_desc.pdf.
- National Oceanic and Atmospheric Agency (NOAA). 2010. Office of Ocean and Coastal Resource Management. Ocean and Coastal Management in Alaska. <http://coastalmanagement.noaa.gov/mystate/ak.html>.
- National Research Council. 1999. Committee on Hardrock Mining. Hardrock Mining on Federal Lands. Appendix B. Potential Environmental Impacts of Hardrock Mining. (http://www.nap.edu/html/hardrock_fed_lands/appB.html).
- Nelson D, Miller J, Rusanowsky D, Greig R, Sennefelder G, Mercaldo-Allen R, Kuropat C, Gould E, Thurberg F, Calabrese A. 1991. Comparative reproductive success of winter flounder in Long Island Sound: a three-year study (biology, biochemistry, and chemistry). *Estuaries* 14(3):318-31.
- Newell, R.C., L.J. Seiderer, and D.R. Hitchcock. 1998. "The impact of dredging on biological resources of the sea bed." *Oceanography and Marine Biology Annual Review*. 36:127-178.
- Nightingale, B. and C.A. Simenstad. 2001a. Dredging activities: Marine issues. Washington State Transportation Center, University of Washington, Seattle, WA 98105. (Document available through the National Technical Information Service, Springfield, VA 22616).
- Nightingale, B. and C.A. Simenstad. 2001b. Overwater Structures: Marine Issues. White paper submitted to Washington Department of Fish and Wildlife, Washington Department of Ecology and Washington Department of Transportation. www.wa.gov/wdfw/hab. 133 pp.
- North Pacific Fishery Management Council and NMFS. 2010. Essential Fish Habitat (EFH) 5-year Review for 2010 Summary Report: Final. April 2010. <http://alaskafisheries.noaa.gov/habitat/efh/review.htm>.
- Northcote, T.G. and G.F. Hartman. 2004. Fishes and Forestry - Worldwide Watershed Interactions and Management, Blackwell Publishing, Oxford, UK, 789 pp.
- Omori, M., S. Van der Spoel, C.P. Norman. 1994. Impact of human activities on pelagic biogeography. *Progress in Oceanography* 34 (2-3):211-219.
- Oregon Water Resource Research Institute (OWRRI). 1995. Gravel disturbance impacts on salmon habitat and stream health, volume 1. Summary report. Oregon State University, Corvallis, Oregon. (Also available Vol. II: Technical background report). Available from Oregon Division of State Lands, Salem, Oregon, 503-378-3805.
- OSPAR Commission. 2009. Assessment of Impacts of Mariculture . Publication Number: 442/2009. London, UK
- Pacific Fishery Management Council. 1999. Appendix A: Identification and description of essential fish habitat, adverse impacts, and recommended conservation measures for salmon. Amendment 14 to the Pacific Coast Salmon Plan. Portland, OR. 146 pp.
- Packer, D.B., Griffin K., McGlynn K.E. 2005. National Marine Fisheries Service national gravel extraction guidance. Washington (DC): US Department of Commerce. NOAA Technical Memorandum NMFS-F/SPO-70. [cited 2008 Jul 15]. 27 p. Available from: <http://www.nmfs.noaa.gov/habitat/habitatprotection/anadfish/gravel.htm>.
- Phillips, R.C. 1984. The ecology of eelgrass meadows in the Pacific Northwest: a community profile. U.S. Fish and Wildlife Service. FWS/OBS-84/24. 85 pp.

- Ralph, S., G. Poole, L. Conquest, and R. Naiman. 1994. "Stream channel morphology and woody debris in logged and unlogged basins in western Washington." *Can. J. Fish. Aquatic Sciences*. 51:37-51.
- Reyff, J.A and P. Donovan. 2003. Benicia-Martinez Bridge Bubble Curtain Test - Underwater Sound Measurement Data. Memo to Caltrans dated January 31, 2003. 3 pp.
- Robinson W.E., and Pederson J. 2005. Contamination, habitat degradation, overfishing - An "either-or" debate? In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 1-10.
- Rosecchi, E., A.J. Crivelli, G. Catsadorakis. 1993. The establishment and impact of *Pseudorabiosa parva*, an exotic fish species introduced into lake Mikri Prespa (northwestern Greece). *Aquatic Conservation: Marine and Freshwater Ecosystems* 3:223-231.
- Roy Consultants Ltd., NATECH Environmental Services Inc. and OCL Group. Environmental Management Consultants. 2003. Lamèque Bay environmental management study. Report No. 133-01.
- Scott G.I., M.H. Fulton, D.W. Moore, E.F. Wirth, G.T. Chandler, P.B. Key, J.W. Daugomah, E.D. Strozier, J. Devane, J.R. Clark, M.A. Lewis, D.B. Finley, W. Ellenberg, and K.J. Karnaky. 1999. "Assessment of risk reduction strategies for the management of agricultural nonpoint source pesticide runoff in estuarine ecosystems." *Toxicology and Industrial Health*. 15:200-213.
- Sedell, J.R., and K.J. Luchessa. 1982. Using the historical record as an aid to salmonid habitat enhancement. In Armantrout, N.B. (ed.), Acquisition and utilization of aquatic habitat inventory information, p. 210-222. American Fisheries Society, Western Division, Bethesda, MD.
- Sengupta, M. 1993. Environmental Impacts of Mining: Monitoring, Restoration, and Control. CRC Press, Inc. 2000 Corporate Blvd., N.W. Boca Raton, FL. 33431. p.1.
- Spence, B.C., G.A. Lomnický, R.M. Hughes, and R.P. Novitzki. 1996. An ecosystem approach to salmonid conservation. TR-4501-96-6057. ManTech Environmental Research Services Corp., Corvallis, OR. 356 pp. (Available from the NMFS Habitat Branch, Portland, OR).
- Stadler, J.H. 2002. Personal observation of fish-kill occurring during pile driving activity at the Winslow Ferry Terminal, Winslow, WA. October 7, 2002. Fish Biologist, DOC/NOAA/National Marine Fisheries Service/HCD, Lacey, WA.
- Stiles, S., J. Choromanski, D. Nelson, J. Miller, R. Grieg, and G. Sennefelder. 1991. Early reproductive success of the hard clam (*Mercenaria mercenaria*) from five sites in Long Island Sound. *Estuaries* 14(3):332-42.
- Stotz, T. and J. Colby. 2001. January 2001 dive report for Mukilteo wingwall replacement project. Washington State Ferries Memorandum. 5 pp. + appendices.
- Theriault, M.H., S.C. Courtenay, C. Godin and W.B. Ritchie. 2006. Evaluation of the Community Aquatic Monitoring Program (CAMP) to assess the health of four coastal areas within the southern Gulf of St. Lawrence with special reference to the impacts of effluent from seafood processing plants. *Can. Tech. Rep. Fish. Aquat. Sci.* 2649: vii + 60 p.
- Thurberg, F.P., and E. Gould. 2005. Pollutant effects upon cod, haddock, pollock, and flounder of the inshore fisheries of Massachusetts and Cape Cod Bays. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 43-66.

- Trombulak, S.C. and C.A. Frissell. 2000. "Review of ecological effects of roads on terrestrial and aquatic communities." *Conservation Biology*. 14(10):18-30. February.
- USDA Forest Service. 2008. Tongass Monitoring and Evaluation Report – Appendix B
http://www.fs.fed.us/r10/tongass/projects/tlmp/2008_monitoring_report/index2008.shtml
- USEPA. 2000a. Environmental Screening Checklist and Workbook for the Water Transportation Industry. August 2000.
- USEPA, Region 10. 2000b. Authorization to discharge under the National Pollutant Discharge Elimination System (NPDES) for Section 402 modifications of Section 404 permits for log Transfer Facilities which received a Section 404 permit prior to October 22, 1985. NPDES Permit Number AK-G70-0000. March 2000. 1200 Sixth Avenue, OW-130 Seattle, Washington 98101.
- USEPA. 1993. Guidance for specifying management measures for sources of nonpoint pollution in coastal waters. EPA Office of Water. 840-B-92-002. 500+ pp.
- Washington Department of Fish and Wildlife. 2009. Gold and fish. Rules for mineral prospecting and placer mining. 2nd edition. April 2009. Olympia, WA.
- Widdows J, Burns KA, Menon NR, Page D, Soria S. 1990. Measurement of physiological energetics (scope for growth) and chemical contaminants in mussel (*Arca zebra*) 220 transplanted along a contamination gradient in Bermuda. *Journal of Experimental Marine Biology and Ecology* 138:99-117.
- Williams, G.D. and R.M. Thom. 2001. Marine and estuarine shoreline modification issues. White paper submitted to Washington Department of Fish and Wildlife, Washington Department of Ecology and Washington Department of Transportation. www.wa.gov/wdfw/hab/ahg. 99 pp.

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Appendix 4 Scallop FMP Amendment 15 - amendment text for updating EFH description and non-fishing impacts to EFH, changing HAPC timeline, and updating EFH research objectives (EFH Omnibus Amendment)

1. In Section 1.1, Amendments to the Fishery Management Plan, insert the following descriptions of EFH amendments in sequential order, and include the effective date and FR reference of the approved Amendment 15.

Amendment 12: Aleutian Islands Habitat Conservation Area Revision

Amendment 12 revised the Aleutian Islands Habitat Conservation Area boundaries near Agattu and Buldir Islands. The amendment was approved on February 4, 2008 (73 FR 9035).

Amendment 15: Revisions to EFH

Amendment 15, approved on _____, revised Amendments 7 and 9 based on the outcome of the 2010 EFH 5-year review. The amendment revised EFH descriptions and identifications by species, and updated life history, distribution, and habitat association information; updated descriptions of EFH impacts from non-fishing activities, and EFH conservation recommendations for non-fishing activities; revised the timeline associated with the HAPC process to a 5-year timeline; and updated EFH research priority objectives.

1. In Section 3.1.3.2, Description of Habitat Areas of Particular Concern, insert the following two new paragraphs before the paragraph beginning “In 2005...”:

Proposed HAPCs, identified on a map, must meet at least two of the four considerations established in 50 CFR 600.815(a)(8), and rarity of the habitat is a mandatory criterion. HAPCs may be developed to address identified problems for FMP species, and they must meet clear, specific, adaptive management objectives.

The Council will initiate the HAPC process by setting priorities and issuing a request for HAPC proposals. Any member of the public may submit a HAPC proposal. HAPC proposals may be solicited every 5 years, to coincide with the EFH 5-year review, or may be initiated at any time by the Council. The Council will establish a process to review the proposals. The Council may periodically review existing HAPCs for efficacy and considerations based on new scientific research.

2. In Section 3.1.3.4, Review of EFH, revise the second paragraph as follows (note, delete text indicated with strikeout, insert text that is underlined):

Additionally, the Council may ~~use the FMP amendment cycle every three years to~~ solicit proposals for HAPCs and/or conservation and enhancement measures to minimize the potential adverse effects of fishing. Any proposal endorsed by the Council would be implemented by FMP amendment. HAPC proposals may be solicited every 5 years, coinciding with the EFH 5-year review, or may be initiated at any time by the Council.

3. In Appendix D, Section 1.0, insert the following new paragraph at the end of the section:

In 2009 and 2010, the Council undertook a five-year review of EFH for the Council’s managed species, which was documented in the Final EFH 5-year Review for 2010 Summary Report published in April

2010 (NPFMC and NMFS 2010). The review evaluated new information on EFH, including EFH descriptions and identification, and fishing and non-fishing activities that may adversely affect EFH. The review also assessed information gaps and research needs, and identified whether any revisions to EFH are needed or suggested. The Council identified various elements of the EFH descriptions meriting revision, and approved omnibus amendments 98/90/40/15/11 to the BSAI Groundfish FMP, the GOA Groundfish FMP, the BSAI King and Tanner Crab FMP, the Scallop FMP, and the Salmon FMP, respectively, in 2011. Amendment 15 to the Scallop FMP revised the EFH description for weathervane scallop; updated the description of EFH impacts from non-fishing activities, and EFH conservation recommendations for non-fishing activities; revised the timeline associated with the HAPC process to a 5-year timeline coinciding with the EFH 5-year review; and updated EFH research objectives in the FMP.

2. *In Appendix D, Section 2.0, revise the table references in the first paragraph as follows (note, delete text indicated with ~~strikeout~~, insert text that is underlined), and insert new Tables 1-3 directly afterward.*

This section describes habitat requirements and life histories of the scallops managed by this FMP. Information contained in this appendix details life history information for federally managed scallop species. Each species or species group is described individually; however, summary tables that denote habitat associations (Table ~~12~~), biological associations ~~reproductive traits~~ (Table ~~23~~), and predator and prey associations (Table ~~34~~) are also provided. In each section, a species-specific table summarizes habitat requirements.

Table 1. Summary of habitat associations for scallops.

[illegible]

Table 2. Summary of biological associations for scallops.

[illegible]

Table 3. Summary of predator and prey associations for scallops.

[illegible]

3. *In Appendix D, Section 2.1, following the caption for Figure 2, delete the sentence “The following abbreviations are used in the habitat tables to specify location, position in the water column, bottom type, and other oceanographic features.”, and the two following textboxes that list abbreviations.*
4. *In Appendix D, Section 2.1, delete existing Tables 2, 3, and 4.*
5. *In Appendix D, Section 2.2, revise the text in the subsections entitled “Relevant Trophic Information”, “Approximate Upper Size Limit of Juvenile Scallops (in cm)”, and “Habitat and Biological Associations” as follows, where deletions are marked with ~~strikeout~~, and insertions are underlined:*

Relevant Trophic Information

Scallop predators have not been well studied. Scallops are likely prey to various fish and invertebrates during the early part of their life cycle. Flounders are known to prey on juvenile weathervane scallops, and octopus and seastars ~~may~~ are also ~~be~~ important predators.

Approximate Upper Size Limit of Juvenile Scallops (in cm): Weathervane scallops begin to mature by age ~~23~~ at about 7.6 cm (3 inches) in shell height (SH), and virtually all scallops are mature by age 4. Growth, maximum size, and size at maturity vary significantly within and between beds and geographic areas. Weathervane scallops are long-lived; individuals may live 28 years or more. The natural mortality rate is thought to be about 15% annually ($M = 0.16$).

Habitat and Biological Associations

Scallops are found from intertidal waters and to 300 m. Abundance tends to be greatest between ~~4540~~ and 130 m on beds of mud, clay, sand, and gravel (Hennick 1973). Weathervane scallops are associated with other benthic species, such as red king crabs, Tanner crabs, shrimps, octopi, flatfishes, Pacific cod, and other species of benthic invertebrates and fishes.

6. In Appendix D, Section 2.2, Subsection “Habitat and Biological Associations”, replace the existing table and caption with the following table, caption, and note:

SPECIES: Weathervane Scallops off Alaska

Stage - EFH Level	Duration or Age	Diet/ Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	several days	None	May–July	inner and middle continental shelf	demersal		unknown	
Larvae	2–3 weeks		May–August	inner, middle, and outer continental shelf	pelagic		unknown	
Early juveniles	Age 0 to Age 3		August +	inner, middle, and outer continental shelf	demersal	mud, sand, gravel, sandy mud, muddy sand	unknown	
Late Juveniles/ Adults	Age 3 - 28		Spawning May–July	inner, middle, and outer continental shelf	demersal	mud, sand, gravel, sandy mud, muddy sand	unknown	

Note, inner continental shelf = 1–50 m, middle continental shelf = 50–100 m, outer continental shelf = 100–200 m.

7. In Appendix D, Section 2.2, insert a new subsection at the end of this section entitled “Literature References”, and include the following content:

Literature References

- Bechtol, W. R., R. L. Gustafson and T. R. Kerns. 2009. A survey of weathervane scallops in Kamishak Bay, 2003. Alaska Department of Fish and Game, Fishery Data Series No. 09-24, Anchorage.
- Lauth, R. R. 2010. Results of the 2009 eastern Bering Sea continental shelf bottom trawl survey of groundfish and invertebrate resources. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC 204, 228 p.
- Rosenkranz, G.E., Gallager, S.M., Shepard, R.W., Blakeslee, M. 2008. Development of a high-speed, megapixel benthic imaging system for coastal fisheries research in Alaska. Fisheries Research 92:340–344
- Rosenkranz, G. and R. Burt. 2009. Summary of observer data collected during the 2006/07 Alaska weathervane scallop fishery. Alaska Department of Fish and Game, Fishery Data Series No. 09 49, Anchorage.
- Rosenkranz, G. E. 2010. Summary of observer data collected during the 2007/08 Alaska weathervane scallop fishery. Alaska Department of Fish and Game, Fishery Data Series No. 10-36, Anchorage.
- Spalinger, K. 2009. Bottom trawl survey of crab and groundfish: Kodiak, Chignik, South Peninsula, and Eastern Aleutians Management Districts, 2008. Alaska Department of Fish and Game, Fishery Management Report No. 09-25, Anchorage.
- Spalinger, K. 2010. Bottom trawl survey of crab and groundfish: Kodiak, Chignik, South Peninsula, and Eastern Aleutians Management Districts, 2009. Alaska Department of Fish and Game, Fishery Management Report No. 10-23, Anchorage.

8. In Appendix D, Section 3.0, make the following edits to the existing second and third paragraphs (note, delete text indicated with ~~strikeout~~, insert text that is underlined), and insert a new fourth paragraph:

EFH for groundfish species is determined to be the general distribution of a species described by life stage. General distribution is a subset of a species’ total population distribution, and is identified as the distribution of 95 percent of the species population, for a particular life stage, if life history data are available for the species. Where information is insufficient and a suitable proxy cannot be inferred, EFH is not described. General distribution is used to describe EFH for all stock conditions whether or not

higher levels of information exist, because the available higher level data are not sufficiently comprehensive to account for changes in stock distribution (and thus habitat use) over time.

EFH is described for FMP-managed species by life stage as general distribution using ~~new~~ guidance from the EFH Final Rule (50 CFR 600.815), ~~such as including the updated~~ EFH Level of Information definitions. New analytical tools are used and recent scientific information is incorporated for each life history stage from updated scientific habitat assessment reports. EFH descriptions include both text (see section 3.1) and maps (see section 3.2), if information is available for a species' particular life stage. ~~These descriptions are risk averse, supported by scientific rationale, and accounts for changing oceanographic conditions. The methodology and data sources for the EFH descriptions are described in Appendix D to the EFH EIS (NMFS 2005).~~

EFH descriptions are interpretations of the best scientific information. In support of this information, a thorough review of FMP species is contained in the Environmental Impact Statement for Essential Fish Habitat Identification and Conservation (NMFS 2005) (EFH EIS) is contained in Section 3.2.1, Biology, Habitat Usage, and Status of Magnuson-Stevens Act Managed Species and detailed by life history stage in Appendix F: EFH Habitat Assessment Reports. This EIS was supplemented in 2010 by a 5-year review, which re-evaluated EFH descriptions and fishing and non-fishing impacts on EFH in light of new information (NPFMC and NMFS 2010). The EFH descriptions are risk averse, supported by scientific rationale, and account for changing oceanographic conditions and regime shifts.

9. *In Appendix D, Section 3.1, Description of Essential Fish Habitat, revise the text description of EFH for weathervane scallop for the late juvenile and adult stages as follows (note, text to be inserted is indicated with underline):*

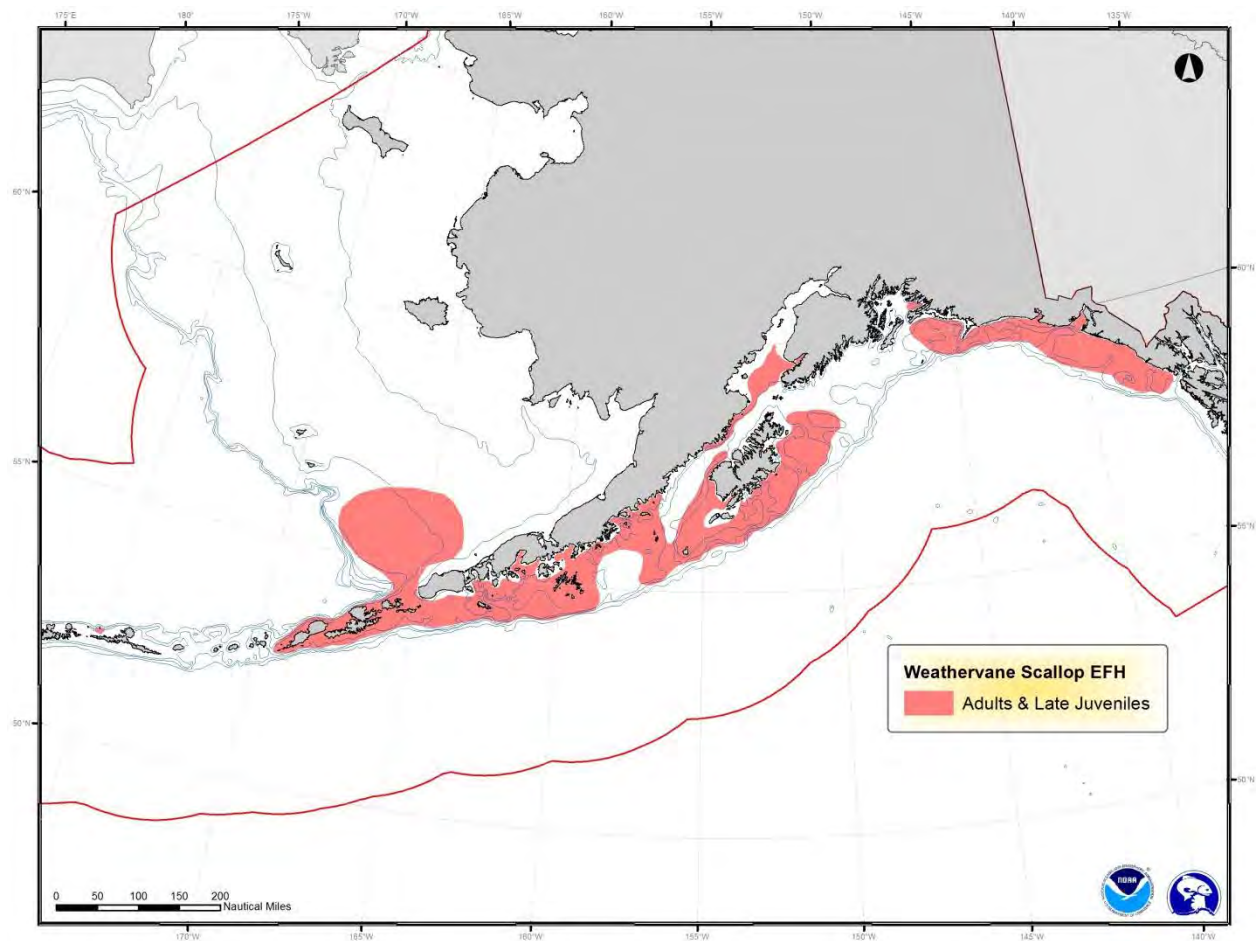
Late Juveniles

EFH for late juvenile weathervane scallops is the general distribution area for this life stage, located in the sea floor along the inner (1 to 50 m), middle (50 to 100 m) and outer (100 to 200 m) shelf in concentrated areas of the GOA and BSAI where there are substrates of clay, mud, sand, and gravel that are generally elongated in the direction of current flow, as depicted in Figure 3.

Adults

EFH for adult weathervane scallops is the general distribution area for this life stage, located in the sea floor along the inner (1 to 50 m), middle (50 to 100 m) and outer (100 to 200 m) shelf in concentrated areas of the GOA and BSAI where there are substrates of clay, mud, sand, and gravel that are generally elongated in the direction of current flow, as depicted in Figure 3.

10. In Appendix D, Section 3.2, Maps of Essential Fish Habitat, delete the existing Figure 3 and replace with the revised Figure 3 below (note, the figure caption should be retained unchanged):



4. In Appendix D, delete Section 3.3.7 HAPC Process.

5. In Appendix D, Section 3.3 Essential Fish Habitat Conservation and Habitat Areas of Particular Concern, delete the second paragraph, beginning “HAPCs are specific sites within EFH...”.

6. In Appendix D, retitle Section 3.3 as “EFH Conservation and HAPC Restrictions”. Renumber Section 3.3 as Section 3.4, and renumber all subsections in the new Section 3.4 accordingly.

7. In Appendix D, create a new Section 3.3, entitled Habitat Areas of Particular Concern, and insert the following content:

Habitat Areas of Particular Concern (HAPCs) are specific sites within EFH that are of particular ecological importance to the long-term sustainability of managed species, are of a rare type, or are especially susceptible to degradation or development. HAPCs are meant to provide greater focus to conservation and management efforts, and may require additional protection from adverse effects.

3.3.1 HAPC Process

The Council may designate specific sites as HAPCs and may develop management measures to protect habitat features within HAPCs.

50 CFR 600.815(a)(8) provides guidance to the regional fishery management councils in identifying HAPCs. FMPs should identify specific types or areas of habitat within EFH as habitat areas of particular concern based on one or more of the following considerations:

- (i) The importance of the ecological function provided by the habitat.
- (ii) The extent to which the habitat is sensitive to human-induced environmental degradation.
- (iii) Whether, and to what extent, development activities are, or will be, stressing the habitat type.
- (iv) The rarity of the habitat type.

Proposed HAPCs, identified on a map, must meet at least two of the four considerations established in 50 CFR 600.815(a)(8), and rarity of the habitat is a mandatory criterion. HAPCs may be developed to address identified problems for FMP species, and they must meet clear, specific, adaptive management objectives.

The Council will initiate the HAPC process by setting priorities and issuing a request for HAPC proposals. Any member of the public may submit a HAPC proposal. HAPC proposals may be solicited every 5 years, to coincide with the EFH 5-year review, or may be initiated at any time by the Council. The Council will establish a process to review the proposals. The Council may periodically review existing HAPCs for efficacy and considerations based on new scientific research.

3.3.2 Designation of HAPCs

In 2005, the Council identified the following areas as HAPCs within EFH:

- Alaska Seamount Habitat Protection Areas
- Bowers Ridge Habitat Conservation Zone
- GOA Coral

Maps of these areas, as well as their coordinates, and any fishing restrictions that apply in these areas, are described in Section 3.4.

8. *In Appendix D, Section 4.0, Effects of Fishing on Essential Fish Habitat, insert the following new paragraph at the end of the section:*

The evaluation of fishing effects on EFH for BSAI groundfish species was reconsidered as part of the Council's EFH 5-year Review for 2010, and is documented in the Final Summary Report for that review (NPFMC and NMFS 2010). The review evaluated new information since the development of the EFH EIS, for individual species and their habitat needs, as well as the distribution of fishing intensity, spatial habitat classifications, classification of habitat features, habitat- and feature-specific recovery rates, and gear- and habitat-specific sensitivity of habitat features. Based on the review, the Council concluded that recent research results are consistent with the habitat sensitivity and recovery parameters and distributions of habitat types used in the analysis of fishing effects documented in the EFH EIS. The review noted that fishing intensity has decreased overall, gear regulations have been designated to reduce habitat damage, and area closures have limited the expansion of effort into areas of concern.

9. In Appendix D, delete existing text in Section 5.0 Non-fishing Impacts, and replace with the revised Section 5.0 in the attached file.

10. In Appendix D, Section 7.0 Research Approach for EFH, revise the first paragraph as follows (note, delete text indicated with strikeout, insert text that is underlined):

The EFH EIS (NMFS 2005) identified ~~a the following~~ research approach for EFH regarding minimizing fishing impacts. The research approach was revised in 2010 following the Council's EFH 5-year Review for 2010, documented in a Final Summary Report (NPFMC and NMFS 2010).

11. In Appendix D, Section 7.0 Research Approach for EFH, delete existing text under the heading "Objectives" and replace with the following:

Establish a scientific research and monitoring program to understand the degree to which impacts have been reduced within habitat closure areas, and to understand how benthic habitat recovery of key species is occurring.

12. In Appendix D, Section 7.0 Research Approach for EFH, delete existing text under the heading "Research Activities" and replace with the following:

- Fishing effort data from observers and remote sensing would be used to study changes in bottom trawl and other fishing gear activity in the closed (and open) areas. Effects of displaced fishing effort would have to be considered. The basis of comparison would be changes in the structure and function of benthic communities and populations, as well as important physical features of the seabed, after comparable harvests of target species are taken with each gear type.
- Monitor the structure and function of benthic communities and populations in the newly closed areas, as well as important physical features of the seabed, for changes that may indicate recovery of benthic habitat. Whether these changes constitute recovery from fishing or just natural variability/shifts requires comparison with an area that is undisturbed by fishing and otherwise comparable.
- Validate the LEI model and improve estimates of recovery rates, particularly for the more sensitive habitats, including coral and sponge habitats in the Aleutian Islands region, possibly addressed through comparisons of benthic communities in trawled and untrawled areas.
- Obtain high resolution mapping of benthic habitats, particularly in the on-shelf regions of the Aleutian Islands.
- Time series of maturity at age should be collected to facilitate the assessment of whether habitat conditions are suitable for growth to maturity.
- In the case of red king crab spawning habitat in southern Bristol Bay, research the current impacts of trawling on habitat in spawning areas and the relationship of female crab distribution with respect to bottom temperature.

13. In Appendix D, Section 8.0, insert the following reference alphabetically.

NPFMC and NMFS. 2010. Essential Fish Habitat (EFH) 5-year Review for 2010 Summary Report: Final. April 2010. <http://www.alaskafisheries.noaa.gov/habitat/efh/review.htm>

14. Update the Table of Contents for Appendix D.

5.0 Non-fishing Activities that may Adversely Affect Essential Fish Habitat

The waters and substrates that comprise essential fish habitat (EFH) are susceptible to a wide array of human activities unrelated to fishing. Broad categories of such activities include, but are not limited to, mining, dredging, fill, impoundment, discharges, water diversions, thermal additions, actions that contribute to nonpoint source pollution and sedimentation, introduction of potentially hazardous materials, introduction of exotic species, and the conversion of aquatic habitat that may eliminate, diminish, or disrupt the functions of EFH. Non-fishing activities discussed in this document are subject to a variety of regulations and restrictions designed to limit environmental impacts under federal, state, and local laws. Listing all applicable environmental laws and management practices is beyond the scope of the document. Moreover, the coordination and consultation required by section 305(b) of the Magnuson-Stevens Conservation and Management Act (MSA) does not supersede the regulations, rights, interests, or jurisdictions of other federal or state agencies. NMFS may use the information in this document as a source when developing conservation recommendations for specific actions under section 305(b)(4)(A) of the MSA. NMFS will not recommend that state or federal agencies take actions beyond their statutory authority, and NMFS' EFH conservation recommendations are not binding.

Ideally, actions that are not water-dependent should not be located in EFH if such actions may have adverse impacts on EFH. Activities that may result in significant adverse effects on EFH should be avoided where less environmentally harmful alternatives are available. If there are no alternatives, the impacts of these actions should be minimized. Environmentally sound engineering and management practices should be employed for all actions that may adversely affect EFH. If avoidance or minimization is not practicable, or will not adequately protect EFH, compensatory mitigation as defined for section 404 of the Clean Water Act (CWA) should be considered to conserve and enhance EFH.

The potential for effects from larger, less readily managed processes associated with human activity also exists, such as climate change and ocean acidification. Climate change may lead to habitat changes that prompt shifts in the distribution of managed species. Likewise, should ocean conditions warm to allow for new shipping routes, new vectors may emerge for introducing invasive species in cargo and ballast waters. Ocean acidification could also alter species distributions and complicated food web dynamics. These larger ecosystem-level effects are discussed in this document where applicable, within each activity type.

This section of the fishery management plan (FMP) synthesizes a comprehensive review of the "Impacts to Essential Fish Habitat from Non-fishing Activities in Alaska" (NMFS 2011), which is incorporated in the FMP by reference. The general purpose of that document is to identify non-fishing activities that may adversely impact EFH and provide conservation recommendations that can be implemented for specific types of activities to avoid or minimize adverse impacts to EFH. This information must be included in FMPs under section 303(a)(7) of the MSA. It is also useful to NMFS biologists reviewing proposed actions that may adversely

affect EFH, and the comprehensive document (NMFS 2011) will be utilized by federal action agencies undertaking EFH consultations with NMFS, especially in preparing EFH assessments.

The conservation recommendations for each activity category are suggestions the action agency or others can undertake to avoid, offset, or mitigate impacts to EFH. NMFS develops EFH conservation recommendations for specific activities case-by-case based on the circumstances; therefore, the recommendations in this document may or may not apply to any particular project. Because many non-fishing activities have similar adverse effects on living marine resources, some redundancy in the descriptions of impacts and the accompanying conservation recommendations between sections in this report is unavoidable.

The comprehensive non-fishing activities document (NMFS 2011) updates and builds upon a collaborative evaluation of non-fishing effects to EFH completed in 2004 by the NMFS Alaska Region, Northwest Region, and Southwest Region and the respective Fisheries Science Centers. In April 2005, NMFS completed the Final Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska (EFH EIS; NMFS 2005) and the North Pacific Fishery Management Council amended its FMPs to address the EFH requirements of the MSA. The EFH EIS contained an Appendix (Appendix G) that addressed non-fishing impacts to EFH. A 5-year review of the Council's EFH provisions, including those addressing non-fishing impacts to EFH, was completed by the Council in April 2010 (NPFMC and NMFS 2010), on the basis of which this section has been updated.

The remainder of this section addresses non-fishing activities that may adversely affect EFH. These activities are grouped into the four different systems in which they usually occur: upland, river or riverine, estuary or estuarine, and coastal or marine.

5.1 Upland Activities

Upland activities can impact EFH through both point source and nonpoint source pollution. Nonpoint source impacts are discussed here. Technically, the term "nonpoint source" means anything that does not meet the legal definition of point source in section 502(14) of the CWA, which refers to discernible, confined, and discrete conveyance from which pollutants are or may be discharged. Land runoff, precipitation, atmospheric deposition, seepage, and hydrologic modification, generally driven by anthropogenic development, are the major contributors to nonpoint source pollution.

Nonpoint source pollution is usually lower in intensity than an acute point source event, but may be more damaging to fish habitat in the long term. It may affect sensitive life stages and processes, is often difficult to detect, and its impacts may go unnoticed for a long time. When population impacts are detected, they may not be tied to any one event or source, and may be difficult to correct, clean up, or mitigate.

The impacts of nonpoint source pollution on EFH may not necessarily represent a serious, widespread threat to all species and life history stages. The severity of the threat of any specific pollutant to aquatic organisms depends upon the type and concentration of the pollutant and the length of exposure for a particular species and its life history stage. For example, species that spawn in areas that are relatively deep with strong currents and well-mixed water may not be as susceptible to pollution as species that inhabit shallow, inshore areas near or within enclosed

bays and estuaries. Similarly, species whose egg, larval, and juvenile life history stages utilize shallow, inshore waters and rivers may be more prone to coastal pollution than are species whose early life history stages develop in offshore, pelagic waters.

5.1.1 Silviculture/Timber Harvest

Recent revisions to federal and state timber harvest regulations in Alaska and best management practices (BMPs) have resulted in increased protection of EFH on federal, state, and private timber lands (USDA 2008; <http://www.fs.fed.us/r10/tongass/projects/tlmp/>).

These revised regulations include forest management practices, which when fully implemented and effective, could avoid or minimize adverse effects to EFH. However, if these management practices are ineffective or not fully implemented, timber harvest could have both short and long term impacts on EFH throughout many coastal watersheds and estuaries. Historically, timber harvest in Alaska was not conducted under the current protective standards, and these past practices may have degraded EFH in some watersheds.

Potential Adverse Impacts

In both small and large watersheds there are many complex and important interactions between fish and forests (Northcote and Hartman 2004). Five major categories of silvicultural activities can adversely affect EFH if appropriate forestry practices are not followed: (1) construction of logging roads, (2) creation of fish migration barriers, (3) removal of streamside vegetation, (4) hydrologic changes and sedimentation, and (5) disturbance associated with log transfer facilities (LTFs). Possible effects to EFH include the following (Northcote and Hartman 2004):

- Removal of the dominant vegetation and conversion of mature and old-growth upland and riparian forests to tree stands or forests of early seral stage;
- Reduction of soil permeability and increase in the area of impervious surfaces;
- Increase in erosion and sedimentation due to surface runoff and mass wasting processes, also potentially affecting riparian areas;
- Impaired fish passage because of inadequate design, construction, and/or maintenance of stream crossings;
- Altered hydrologic regimes resulting in inadequate or excessive surface and stream flows, increased streambank and streambed erosion, loss of complex instream habitats;
- Changes in benthic macroinvertebrate populations,
- Loss of instream and riparian cover;
- Increased surface runoff with associated contaminants (e.g., herbicides, fertilizers, and fine sediments) and higher temperatures;
- Alterations in the supply of large woody debris (LWD) and sediment, which can have negative effects on the formation and persistence of instream habitat features; and
- Excess debris in the form of small pieces of wood and silt, which can cover benthic habitat and reduce dissolved oxygen levels.

Recommended Conservation Measures

The following recommended conservation measures for silviculture/timber harvest should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH. Additionally, management standards, guidelines, and BMPs are available from the Forest Service Region 10, the State of Alaska Division of Forestry, and forest plans for the Tongass and Chugach National Forests.

- **Stream Buffers:** For timber operations in watersheds with EFH, adhere to modern forest management practices and BMPs, including the maintenance of vegetated buffers along all streams to the extent practicable in order to reduce sedimentation and supply large wood.
- **Estuary and Beach Fringe:** For timber operations adjacent to estuaries or beaches, maintain vegetated buffers as needed to protect EFH.
- **Watershed Analysis:** A watershed analysis should be incorporated into timber and silviculture projects whenever practicable.
- **Forest Roads:** Forest roads can be a major cause of sediment into streams and road culverts can block or inhibit upstream fish passage. Roads need to be designed to minimize sediment transport problems and to avoid fish passage problems.

5.1.2 Pesticides

Pesticides are substances intended to prevent, destroy, control, repel, kill, or regulate the growth of undesirable biological organisms. Pesticides include the following: insecticides, herbicides, fungicides, rodenticides, repellents, bactericides, sanitizers, disinfectants, and growth regulators. More than 900 different active pesticide ingredients are currently registered for use in the United States and are formulated with a variety of other inert ingredients that may also be toxic to aquatic life. Legal mandates covering pesticides are the CWA and the Federal Insecticide, Fungicide, and Rodenticide Act. Water quality criteria for the protection of aquatic life have only been developed for a few of the currently used ingredients (EPA, Office of Pesticide Programs). While agricultural run-off is a major source of pesticide pollution in the lower 48 states, in Alaska, other human activities, such as fire suppression on forested lands, forest site preparation, noxious weed control, right-of-way maintenance (e.g., roads, railroads, power lines), algae control in lakes and irrigation canals, riparian habitat restoration, and urban and residential pest control, are the most common sources of these substances.

Pesticides are frequently detected in freshwater and estuarine systems that provide EFH. Pesticides can enter the aquatic environment as single chemicals or as complex mixtures. Direct applications, surface runoff, spray drift, agricultural return flows, and groundwater intrusions are all examples of transport processes that deliver pesticides to aquatic ecosystems. Habitat alteration from pesticides is different from more conventional water quality parameters because, unlike temperature or dissolved oxygen, the presence of pesticides can be difficult to detect due to limitations in proven methodologies. This monitoring may also be expensive. As analytical methodologies have improved in recent years, the number of pesticides documented in fish and their habitats has increased. In addition, pesticides may bioaccumulate in the ecosystem by retention in sediments and detritus, which are then ingested by macroinvertebrates, and which, in

turn, are eaten by larger invertebrates and fish (Atlantic States Marine Fisheries Commission 1992).

Potential Adverse Impacts

There are three basic ways that pesticides can adversely affect EFH. These are (1) a direct, lethal or sublethal, toxicological impact on the health or performance of exposed fish; (2) an indirect impairment of aquatic ecosystem structure and function; and (3) a loss of aquatic macroinvertebrates that are prey for fish and aquatic vegetation that provides physical shelter for fish.

Recommended Conservation Measures

The following recommended conservation measures regarding pesticides (including insecticides, herbicides, fungicides, rodenticides, repellents, bactericides, sanitizers, disinfectants, and growth regulators) should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Incorporate integrated pest management and BMPs as part of the authorization or permitting process (Scott et al. 1999). If pesticides must be applied, consider area, terrain, weather, droplet size, pesticide characteristics, and other conditions to avoid or reduce effects to EFH.
- Carefully review labels and ensure that application is consistent with the product's directions.
- Avoid the use of pesticides within 500 linear feet and/or 1,000 aerial feet of anadromous fish bearing streams.
- For forestry vegetation management projects, establish a 35-foot pesticide-free buffer area from any surface or marine water body and require that pesticides not be applied within 200 feet of a public water source (Alaska Department of Environmental Conservation guidelines).
- Consider current and recent meteorological conditions. Rain events may increase pesticide runoff into adjacent water bodies. Saturated soils may inhibit pesticide penetration.
- Do not apply pesticides when wind speeds exceed 10 mph.
- Begin application of pesticide products nearest to the aquatic habitat boundary and proceed away from the aquatic habitat; do not apply towards a water body.

5.1.3 Urban and Suburban Development

Urban and suburban development is most likely the greatest non-fishing threat to EFH (NMFS 1998 a, 1998b). Urban and suburban development and the corresponding infrastructure result in four broad categories of impacts to aquatic ecosystems: hydrological, physical, water quality, and biological (CWP 2003).

Potential Adverse Impacts

Potential impacts to EFH most directly related to general urban and suburban development discussed below are the watershed effects of land development, including stormwater runoff.

Other development-related impacts are discussed in later sections of this document, including dredging, wetland fill, and shoreline construction.

Development activities within watersheds and in coastal marine areas can impact EFH on both long and short timeframes. The Center for Watershed Protection (CWP) made a comprehensive review of the impacts associated with impervious cover and urban development and found a negative relationship between watershed development and 26 stream quality indicators (CWP 2003). The primary impacts include (1) the loss of hyporheic zones (the region beneath and next to streams where surface and groundwater mix), and riparian and shoreline habitat and vegetation; and (2) runoff. Removal of riparian and upland vegetation has been shown to increase stream water temperatures, reduce supplies of LWD, and reduce sources of prey and nutrients to the water system. An increase in impervious surfaces in a watershed, such as the addition of new roads, buildings, bridges, and parking facilities, results in a decreased infiltration to groundwater and increased runoff volumes. This also has the potential to adversely affect water quality and the shape of the hydrograph in downstream water bodies (i.e., estuaries and coastal waters).

Recommended Conservation Measures

The following recommended conservation measures should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH where threats of impacts from urban and suburban development exist.

- Implement BMPs for sediment control during construction and maintenance operations (USEPA 1993).
- Avoid using hard engineering structures for shoreline stabilization and channelization when possible.
- Encourage comprehensive planning for watershed protection, and avoid or minimize filling and building in coastal and riparian areas affecting EFH.
- Where feasible, remove obsolete impervious surfaces from riparian and shoreline areas, and reestablish water regime, wetlands, and native vegetation.
- Protect and restore vegetated buffer zones of appropriate width along streams, lakes, and wetlands that include or influence EFH.
- Manage stormwater to replicate the natural hydrologic cycle, maintaining natural infiltration and runoff rates to the maximum extent practicable.
- Where instream flows are insufficient to maintain water quality and quantity needed for EFH, establish conservation guidelines for water use permits, and encourage the purchase or lease of water rights and the use of water to conserve or augment instream flows.
- Use the best available technologies in upgrading wastewater systems to avoid combined sewer overflow problems and chlorinated sewage discharges into rivers, estuaries, and the ocean.
- Design and install proper wastewater treatment systems.
- Where vegetated swales are not feasible, install and maintain oil/water separators to treat runoff from impervious surfaces in areas adjacent to marine or anadromous waters.

5.1.4 Road Building and Maintenance

Roads and trails have always been part of man's impact on his environment (Luce and Crowe 2001). Federal, state, and local transportation departments devote huge budgets to construction and upgrading of roads. As in other places, roads play an important part in access and thus are vital to the economy of Alaska (Connor 2007).

Potential Adverse Impacts

Today's road design construction and management practices have improved from the past. Roads however, still have a negative effect on the biotic integrity of both terrestrial and aquatic ecosystems (Trombulak and Frissell 2000), and the effects of roads on aquatic habitat can be profound. Potential adverse impacts to aquatic habitats resulting from existence of roads in watersheds include (1) increased surface erosion, including mass wasting events, and deposition of fine sediments; (2) changes in water temperature; (3) elimination or introduction of migration barriers such as culverts; (4) changes in streamflow; (5) introduction of invasive species; and (6) changes in channel configuration, and (7) the concentration and introduction of polycyclic aromatic hydrocarbons, heavy metals and other pollutants.

Recommended Conservation Measures

The following conservation measures should be viewed as options to avoid and minimize adverse impacts from road building and maintenance and promote the conservation, enhancement, and proper functioning of EFH.

- Roads should be sited to avoid sensitive areas such as streams, wetlands, and steep slopes to the extent practicable.
- Build bridges rather than culverts for stream crossings when possible. If culverts are to be used, they should be sized, constructed, and maintained to match the gradient and width of the stream, so as to accommodate design flood flows; they should be large enough to provide for migratory passage of adult and juvenile fishes.
- Design bridge abutments to minimize disturbances to stream banks, and place abutments outside of the floodplain whenever possible.
- Specify erosion control measures in road construction plans.
- Avoid side casting of road materials on native surfaces and into streams.
- Use only native vegetation in stabilization plantings.
- Use seasonal restrictions to avoid impacts to habitat during species critical life history stages (e.g., spawning and egg development periods).
- Properly maintain roadway and associated stormwater collection systems.
- Limit roadway sanding and the use of deicing chemicals during the winter to minimize sedimentation and introduction of contaminants into nearby aquatic habitats.

5.2 Riverine Activities

5.2.1 Mining

Mining within riverine habitats may result in direct and indirect chemical, biological, and physical impacts to habitats within the mining site and surrounding areas during all stages of operations. On site mining activities include exploration, site preparation, mining and milling, waste management, decommissioning or reclamation, and abandonment (NMFS 2004, American Fisheries Society 2000). Mining and its associated activities have the potential to cause adverse effects to EFH from exploration through post-closure. The operation of metal, coal, rock quarries, and gravel pit mines in upland and riverine areas has caused varying degrees of environmental damage in urban, suburban, and rural areas. Some of the most severe damage, however, occurs in remote areas, where some of the most productive fish habitat is often located (Sengupta 1993). In Alaska, existing regulations, promulgated and enforced by other federal and state agencies, are designed to control and manage these changes to the landscape to avoid and minimize impacts. However, while environmental regulations may avoid, limit, control, or offset many potential impacts, mining will, to some degree, always alter landscapes and environmental resources (National Research Council 1999). (Additional information on mining impacts in the marine environment is covered later in this synthesis.)

5.2.1.1 Mineral Mining

Mining and mineral extraction activities take many forms, such as commercial and recreational suction dredging, placer, open pit and surface mining, and contour operations. The process for mineral extraction involves exploration, mine development, mining (extraction), processing and reclamation.

Potential Adverse Impacts

The potential adverse effects of mineral mining on fish populations and EFH are well documented (Farag et al. 2003, Hansen et al. 2002, Brix et al. 2001, Goldstein et al. 1999) and depend on the type, extent, and location of the activities. Impacts associated with the extraction of material from within or near a stream or river bed may include (1) alteration in channel morphology, hydraulics, lateral migration and natural channel meander; (2) increases in channel incision and bed degradation; (3) disruption in pre-existing balance of suspended sediment transport and turbidity; (4) direct impacts to fish spawning and nesting habitats (redds), juveniles, and prey items; (5) simplification of in-channel fluvial processes and LWD deposition; (6) altered surface and ground water regimes and hydro-geomorphic and hyporheic processes; and (7) destruction of the riparian zone during extraction operations. Additional impacts may include mining-related pollution, acid mine drainage, habitat fragmentation and conversion, altered temperature regimes, reduction in oxygen concentration, the release of toxic materials (NMFS 2008), and additional impacts to wetland and riverine habitats. Many of these types of impacts have been previously introduced in the document. The additional discussion that follows is intended to round out the discussion of impacts that have not been previously introduced.

Recommended Conservation Measures

The following measures are adapted from recommendations in Spence et al. (1996), NMFS (2004), and Washington Department of Fish and Wildlife (2009). These conservation

recommendations for mineral mining should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- To the extent practicable, avoid mineral mining in waters, water sources and watersheds, riparian areas, hyporheic zones, and floodplains providing habitat for federally managed species.
- Schedule necessary in-water activities when the fewest species/least vulnerable life stages of federally managed species will be present.
- Minimize spillage of dirt, fuel, oil, toxic materials, and other contaminants into EFH. Prepare a spill prevention plan if appropriate.
- Treat and test wastewater (acid neutralization, sulfide precipitation, reverse osmosis, electrochemical, or biological treatments) and recycle on site to minimize discharge to streams.
- Minimize the effects of sedimentation on fish habitat, using methods such as contouring, mulching, construction of settling ponds, and sediment curtains. Monitor turbidity during operations, and cease operations if turbidity exceeds predetermined threshold levels.
- If possible, reclaim, rather than bury, mine waste that contains heavy metals, acid materials, or other toxic compounds to limit the possibility of leachate entering groundwater.
- Restore natural contours and use native vegetation to stabilize and restore habitat function to the extent practicable. Monitor the site to evaluate performance.
- Minimize the aerial extent of ground disturbance and stabilize disturbed lands to reduce erosion.
- For large scale mining operations, stochastic models should be employed to make predictions of ground and surface hydrologic impacts and acid generating potential in mine pits and tailing impoundments.

5.2.1.2 Sand and Gravel Mining

In Alaska, riverine sand and gravel mining is extensive and can involve several methods: wet-pit mining (i.e., removal of material from below the water table); dry-pit mining on beaches, exposed bars, and ephemeral streambeds; and subtidal mining.

Potential Adverse Impacts

Primary impacts associated with riverine sand and gravel mining activities include (1) turbidity plumes and re-suspension of sediment and nutrients, (2) removal of spawning habitat, and (3) alteration of channel morphology. These often lead to secondary impacts including alteration of migration patterns, physical and thermal barriers to upstream and downstream migration, increased fluctuation in water temperature, decrease in dissolved oxygen, high mortality of early life stages, increased susceptibility to predation, loss of suitable habitat (Packer et al. 2005), decreased nutrients (from loss of floodplain connection and riparian vegetation), and decreased food production (loss of invertebrates) (Spence et al. 1996).

Recommended Conservation Measures

The following recommended conservation measures for sand and gravel mining are adapted from NMFS (2004) and OWRRI (1995). They should be viewed as options to avoid and minimize adverse impacts to EFH due to sand and gravel mining and promote the conservation, enhancement, and proper functioning of EFH.

- To the extent practicable, avoid sand/gravel mining in waters, water sources and watersheds, riparian areas, hyporheic zones and floodplains providing habitat for federally managed species.
- Identify upland or off-channel (where the channel will not be captured) gravel extraction sites as alternatives to gravel mining in or adjacent to EFH, if possible.
- If operations in EFH cannot be avoided, design, manage, and monitor sand and gravel mining operations to minimize potential direct and indirect impacts to living marine resources and habitat. For example, minimize the areal extent and depth of extraction.
- Include restoration, mitigation, and monitoring plans, as appropriate, in sand/gravel extraction plans.
- Implement seasonal restrictions to avoid impacts to habitat during species critical life history stages.

5.2.2 Organic and Inorganic Debris

Organic and inorganic debris, and its impacts to EFH, extend beyond riverine systems into estuarine coastal and marine systems. To reduce duplication, impacts to other systems are also addressed here.

Natural occurring flotsam, such as LWD and macrophyte wrack (i.e., kelp), plays an important role in aquatic ecosystems, including EFH. LWD and wrack promote habitat complexity and provide structure to various aquatic and shoreline habitats.

The natural deposition of LWD creates habitat complexity by altering local hydrologic conditions, nutrient availability, sediment deposition, turbidity, and other structural habitat conditions. In riverine systems, the physical structure of LWD provides cover for managed species, creates habitats and microhabitats (e.g., pools, riffles, undercut banks, and side channels), retains gravels, and helps maintain underlying channel structure (Abbe and Montgomery 1996, Montgomery et al. 1995, Ralph et al. 1994, Spence et al. 1996). LWD also plays similar role in salt marsh habitats (Maser and Sedell 1994). In benthic ocean habitats, LWD enriches local nutrient availability as deep-sea wood borers convert the wood to fecal matter, providing terrestrially-based carbon to the ocean food chain (Maser and Sedell 1994). When deposited on coastal shorelines, macrophyte wrack creates microhabitats and provides a food source for aquatic and terrestrial organisms such as isopods and amphipods, which play an important role in marine food webs.

Conversely, inorganic flotsam and jetsam debris can negatively impact EFH. Inorganic marine debris is a problem along much of the coastal United States, where it litters shorelines, fouls estuaries, entangles fish and wildlife, and creates hazards in the open ocean. Marine debris consists of a wide variety of man-made materials, including general litter, plastics, hazardous

wastes, and discarded or lost fishing gear. The debris enters waterbodies indirectly through rivers and storm water outfalls, as well as directly via ocean dumping and accidental release. Although laws and regulatory programs exist to prevent or control the problem, marine debris continues to affect aquatic resources.

5.2.2.1 Organic Debris Removal

Natural occurring flotsam, such as LWD and macrophyte wrack (i.e., kelp), is sometimes intentionally removed from streams, estuaries, and coastal shores. This debris is removed for a variety of reasons, including dam operations, aesthetic concerns, and commercial and recreational purposes (e.g., active beach log harvests, garden mulch, and fertilizer). However, the presence of organic debris is important for maintaining aquatic habitat structure and function.

Potential Adverse Impacts

The removal of organic debris from natural systems can reduce habitat function, adversely impacting habitat quality. Reductions in LWD inputs to estuaries may also affect the ecological balance of estuarine systems by altering rates and patterns of nutrient transport, sediment deposition, and availability of in-water cover for larval and juvenile fish. In rivers and streams of the Pacific Northwest, the historic practice of removing LWD to improve navigability and facilitate log transport has altered channel morphology and reduced habitat complexity, thereby negatively affecting habitat quality for spawning and rearing salmonids (Koski 1992, Sedell and Luchessa 1982).

Beach grooming and wrack removal can substantially alter the macrofaunal community structure of exposed sand beaches (Dugan et al. 2000). Species richness, abundance, and biomass of macrofauna associated with beach wrack (e.g., sand crabs, isopods, amphipods, and polychaetes) are higher on ungroomed beaches than on those that are groomed (Dugan et al. 2000). The input and maintenance of wrack can strongly influence the structure of macrofauna communities, including the abundance of sand crabs (*Emerita analoga*) (Dugan et al. 2000), an important prey species for some managed species of fish.

Recommended Conservation Measures

The recommended conservation measures for organic debris removal are listed below. They should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Encourage the preservation of LWD whenever possible, removing it only when it presents a threat to life or property.
- Encourage appropriate federal, state, and local agencies to aid in the downstream movement of LWD around dams, culverts, and bridges wherever possible, rather than removing it from the system.
- Educate landowners and recreationalists about the benefits of maintaining LWD.
- Localize beach grooming practices, and minimize them whenever possible.
- Advise gardeners to only harvest dislodged, dead kelp and leave live, growing kelp (whether dislodged or not).

5.2.2.2 Inorganic Debris

Inorganic debris in the marine environment is a chronic problem along much of the U.S. coast, resulting in littered shorelines and estuaries with varying degrees of negative effects to coastal ecosystems. Nationally, land-based sources of marine debris account for about 80 percent of the marine debris on beaches and in U.S. waters. Debris can originate from combined sewer overflows and storm drains, stormwater runoff, landfills, solid waste disposal, poorly maintained garbage bins, floating structures, and general littering of beaches, rivers, and open waters. It generally enters waterways indirectly through rivers and storm drains or by direct ocean dumping. Ocean-based sources of debris also create problems for managed species. These include discarded or lost fishing gear (NMFS 2008), and galley waste and trash from commercial merchant, fishing, military, and other vessels.

Potential Adverse Impacts

Land and ocean sourced inorganic marine debris is a very diverse problem, and adverse effects to EFH are likewise varied. Floating or suspended trash can directly affect managed species that consume or are entangled in it. Toxic substances in plastics can kill or impair fish and invertebrates that use habitat polluted by these materials. The chemicals that leach from plastics can persist in the environment and can bioaccumulate through the food web.

Once floatable debris settles to the bottom of estuaries, coastal and open ocean areas, it can continue to cause environmental problems. Plastics and other materials with a large surface area can cover and suffocate immobile animals and plants, creating large spaces devoid of life. Currents can carry suspended debris to underwater reef habitats where the debris can become snagged, damaging these sensitive habitats. The typical floatable debris from combined sewer overflows includes street litter, sewage containing viral and bacterial pathogens, pharmaceutical by-products from human excretion, and pet wastes. Pathogens can also contaminate shellfish beds and reefs.

Recommended Conservation Measures

Pollution prevention and improved waste management can occur through regulatory controls and best management practices. The recommended conservation measures for minimizing inorganic debris listed in the section below should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Encourage proper trash disposal, particularly in coastal and ocean settings, and participate in coastal cleanup activities.
- Advocate for local, state and national legislation that rewards proper disposal of debris.
- Encourage enforcement of regulations addressing marine debris pollution and proper disposal.
- Provide resources and technical guidance for development of studies and solutions addressing the problem of marine debris.
- Educate the public on the impact of marine debris and provide guidance on how to reduce or eliminate the problem.
- Implement structural controls that collect and remove trash before it enters nearby waterways.

- Consider the use of centrifugal separation to physically separate solids and floatables from water in combined sewer outflows.
- Encourage the development of incentives and funding mechanisms to recover lost fishing gear.
- Require all existing and new commercial construction projects near the coast to develop and implement refuse disposal plans.

5.2.3 Dam Operation

Dams provide sources of hydropower, water storage, and flood control. Construction and operation of dams can affect basic hydrologic and geomorphic function including the alteration of physical, biological, and chemical processes that, in turn, can have effects on water quality, timing, quantity, and alter sediment transport.

Potential Adverse Impacts (adapted from NMFS 2008)

The effects of dam construction and operation on fish and aquatic habitat include (1) complete or partial upstream and downstream migratory impediment; (2) water quality and flow pattern alteration; (3) alteration to distribution and function of ice, sediment and nutrient budgets; (4) alterations to the floodplain, including riparian and coastal wetland systems and associated functions and values; and (5) thermal impacts. Dam construction and operations can impede or block anadromous fish passage and other aquatic species migration in streams and rivers. Unless proper fish passage structures or devices are operational, dams can either prevent access to productive upstream spawning and rearing habitat or can alter downstream juvenile migration. Turbines, spillways, bypass systems, and fish ladders also affect the quality and quantity of EFH available for salmon passage in streams and rivers (Pacific Fishery Management Council 1999). The construction of a dam can fragment habitat, resulting in alterations to both upstream and downstream biogeochemical processes.

Recommended Conservation Measures (adapted from NMFS 2008)

The following conservation recommendations regarding dams should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Avoid construction of new dam facilities, where possible.
- Construct and design facilities with efficient and functional upstream and downstream adult and juvenile fish passage which ensures safe, effective, and timely passage.
- Operate dams within the natural flow fluctuations rates and timing and, when possible, mimic the natural hydrograph, allow for sediment and wood transport, and consider and allow for natural ice function. Monitor water flow and reservoir flow fluctuation.
- Understand longer term climatic and hydrologic patterns and how they affect habitat; plan project design and operation to minimize or mitigate for these changes.
- Use seasonal restrictions for construction, maintenance, and operation of dams to avoid impacts to habitat during species' critical life history stages.
- Develop and implement monitoring protocols for fish passage.
- Retrofit existing dams with efficient and functional upstream and downstream fish

passage structures.

- Construct dam facilities with the lowest hydraulic head practicable for the project purpose. Site the project at a location where dam height can be reduced.
- Downstream passage should prevent adults and juveniles from passing through the turbines and provide sufficient water downstream for safe passage.
- Coordinate maintenance and operations that require drawdown of the impoundment with state and federal resource agencies to minimize impacts to aquatic resources.
- Develop water and energy conservation guidelines for integration into dam operation plans and into regional and watershed-based water resource plans.
- Encourage the preservation of LWD, whenever possible.
- Develop a sediment transport and geomorphic maintenance plan to allow for peak flow mimicking that will result in sediment pulses through the reservoir/dam system and allow high flow geomorphic processes.

5.2.4 Commercial and Domestic Water Use

An increasing demand for potable water, combined with inefficient use of freshwater resources and natural events (e.g., droughts) have led to serious ecological damage worldwide (Deegan and Buchsbaum 2005). Because human populations are expected to continue increasing in Alaska, it is reasonable to assume that water uses, including water impoundments and diversion, will similarly increase (Gregory and Bisson 1997). Groundwater supplies 87 percent of Alaska's 3,500 public drinking water systems. Ninety percent of the private drinking water supplies are groundwater. Each day, roughly 275 million gallons of water derived from aquifers, which directly support riverine systems, are used for domestic, commercial, industrial, and agricultural purposes in Alaska (Groundwater Protection Council 2010). Surface water sources serve a large number of people from a small number of public water systems (e.g., Anchorage and several southeastern communities).

Potential Adverse Impacts

The diversion of freshwater for domestic and commercial uses can affect EFH by (1) altering natural flows and the process associated with flow rates, (2) altering riparian habitats by removing water or by submersion of riparian areas, (3) removing the amount and altering the distribution of prey bases, (4) affecting water quality, and (5) entrapping fishes. Water diversions can involve either withdrawals (reduced flow) or discharges (increased flow).

Recommended Conservation Measures

These conservation measures for commercial and domestic water use should be viewed as options to avoid and minimize adverse impacts from commercial and domestic water use and promote the conservation, enhancement, and proper functioning of EFH.

- Design water diversion and impoundment projects to create flow conditions that provide for adequate fish passage, particularly during critical life history stages. Avoid low water levels that strand juveniles and dewater redds. Incorporate juvenile and adult fish passage facilities on all water diversion projects (e.g., fish bypass systems). Install screens at water diversions on fish-bearing streams, as needed.

- Maintain water quality necessary to support fish populations by monitoring and adjusting water temperature, sediment loads, and pollution levels.
- Maintain appropriate flow velocity and water levels to support continued stream functions. Maintain and restore channel, floodplain, riparian, and estuarine conditions.
- Where practicable, ensure that mitigation is provided for unavoidable impacts to fish and their habitat.

5.3 Estuarine Activities

A large portion of Alaska's population resides near the state's 33,904-mile coastline (NOAA 2010). The dredging and filling of coastal wetlands for commercial and residential development, port, and harbor development directly removes important wetland habitat and alters the habitat surrounding the developed area. Physical changes from shoreline construction can result in secondary impacts such as increased suspended sediment loading, shading from piers and wharves, as well as introduction of chemical contamination from land-based human activities (Robinson and Pederson 2005). Even development projects that appear to have minimal individual impacts can have significant cumulative effects on the aquatic ecosystem (NMFS 2008).

5.3.1 Dredging

The construction of ports, marinas, and harbors typically involves dredging sediments from intertidal and subtidal habitats to create navigational channels, turning basins, anchorages, and berthing docks. Additionally, periodic dredging is used to maintain the required depths after sediment is deposited into these facilities. Dredging is also used to create deepwater navigable channels or to maintain existing channels that periodically fill with sediments. (Impacts from dredging from marine mining are also addressed later.)

Potential Adverse Impacts

Dredging activities can adversely affect benthic and water-column habitat. The environmental effects of dredging on managed species and their habitat can include (1) direct removal/burial of organisms; (2) turbidity and siltation, including light attenuation from turbidity; (3) contaminant release and uptake, including nutrients, metals, and organics; (4) release of oxygen consuming substances (e.g., chemicals and bacteria); (5) entrainment; (6) noise disturbances; and (7) alteration to hydrodynamic regimes and physical habitat.

Recommended Conservation Measures

The recommended conservation measures for dredging are listed in the following section. They should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Avoid new dredging in sensitive habitat areas to the maximum extent practicable.
- Reduce the area and volume of material to be dredged to the maximum extent practicable.
- Avoid dredging and placement of equipment used in conjunction with dredging operations in special aquatic sites and other high value habitat areas.

- Implement seasonal restrictions to avoid impacts to habitat during species critical life history stages (e.g., spawning season, egg, and larval development period).
- Utilize BMPs to limit and control the amount and extent of turbidity and sedimentation.
- For new dredging projects, undertake multi-season, pre-, and post-dredging biological surveys to assess the cumulative impacts to EFH and allow for implementation of adaptive management techniques.
- Prior to dredging, test sediments for contaminants as per U.S. Environmental Protection Agency (EPA) and U.S. Army Corps of Engineers (USACE) requirements.
- Provide appropriate compensation for significant impacts (short-term, long-term, and cumulative) to benthic environments resulting from dredging.
- Identify excess sedimentation in the watershed that prompts excessive maintenance dredging activities, and implement appropriate management actions, if possible.

5.3.2 Material Disposal and Filling Activities

Material disposal and filling activities can directly remove important habitat and alter the habitat surrounding the developed area. The discharge of dredged materials or the use of fill material in aquatic habitats can result in covering or smothering existing submerged substrates, loss of habitat function, and adverse effects on benthic communities.

5.3.2.1 *Disposal of Dredged Material*

Potential Adverse Impacts (adapted from NMFS 2008)

The disposal of dredged material can reduce the suitability of water bodies for managed species and their prey by (1) reducing floodwater retention in wetlands; (2) reducing nutrients uptake and release; (3) decreasing the amount of detrital input, an important food source for aquatic invertebrates (Mitsch and Gosselink 1993); (4) habitat conversion through alteration of water depth or substrate type; (5) removing aquatic vegetation and preventing natural revegetation; (6) impeding physiological processes to aquatic organisms (e.g., photosynthesis, respiration) caused by increased turbidity and sedimentation (Arruda et al. 1983, Cloern 1987, Dennison 1987, Barr 1993, Benfield and Minello 1996, Nightingale and Simenstad 2001a); (7) directly eliminating sessile or semi-mobile aquatic organisms via entrainment or smothering (Larson and Moehl 1990, McGraw and Armstrong 1990, Barr 1993, Newell et al. 1998); (8) altering water quality parameters (i.e., temperature, oxygen concentration, and turbidity); and (9) releasing contaminants such as petroleum products, metals, and nutrients (USEPA 2000a).

Recommended Conservation Measures

The following recommended conservation measures for dredged material disposal should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Avoid disposing dredged material in wetlands, submerged aquatic vegetation (SAV) and other special aquatic sites whenever possible.
- Test sediment compatibility for open-water disposal per EPA and USACE requirements.

- Ensure that disposal sites are properly managed and monitored to minimize impacts associated with dredge material.
- Where long-term maintenance dredging is anticipated, acquire and maintain disposal sites for the entire project life.
- Encourage beneficial uses of dredged materials.

5.3.2.2 Fill Material

Like the discharge of dredged material, the discharge of fill material to create upland areas can remove productive habitat and eliminate important habitat functions.

Potential Adverse Impacts

Adverse impacts to EFH from the introduction of fill material include (1) loss of habitat function and (2) changes in hydrologic patterns.

Recommended Conservation Measures

The following recommended conservation measures for the discharge of fill material should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Federal, state, and local resource management and permitting agencies should address the cumulative impacts of fill operations on EFH.
- Minimize the areal extent of any fill in EFH, or avoid it entirely.
- Consider alternatives to the placement of fill into areas that support managed species.
- Fill should be sloped to maintain shallow water, photic zone productivity; allow for unrestricted fish migration; and provide refugia for juvenile fish.
- In marine areas of kelp and other aquatic vegetation, fill (including artificial structure fill reefs) should be designed to maximize kelp colonization and provide areas for juvenile fish to find shelter from higher currents and exposure to predators.
- Fill materials should be tested and be within the neutral range of 7.5 to 8.4 pH.

5.3.3 Vessel Operations, Transportation, and Navigation

In Alaska, the growth in coastal communities is putting demands on port districts to increase infrastructure to accommodate additional vessel operations for cargo handling and marine transportation. Port expansion has become an almost continuous process due to economic growth, competition between ports, and significant increases in vessel size. In addition, increasing boat sales have put more pressure on improving and building new harbors, an important factor in Alaska because of the limited number of roads.

Potential Adverse Impacts

Activities associated with the expansion of port facilities, vessel/ferry operations, and recreational marinas can directly and indirectly impact EFH. Impacts include (1) loss and conversion of habitat; (2) altered light regimes and loss of submerged aquatic vegetation; (3)

altered temperature regimes; (4) siltation, sedimentation, and turbidity; (5) contaminant releases; and; and (6) altered tidal, current, and hydrologic regimes.

Recommended Conservation Measures

The following recommended conservation measures for vessel operations, transportation infrastructure, and navigation, should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Locate marinas in areas of low biological abundance and diversity.
- Leave riparian buffers in place to help maintain water quality and nutrient input.
- Include low-wake vessel technology, appropriate routes, and BMPs for wave attenuation structures as part of the design and permit process.
- Incorporate BMPs to prevent or minimize contamination from ship bilge waters, antifouling paints, shipboard accidents, shipyard work, maintenance dredging and disposal, and nonpoint source contaminants from upland facilities related to vessel operations and navigation.
- Locate mooring buoys in water deep enough to avoid grounding and to minimize the effects of prop wash.
- Use catchment basins for collecting and storing surface runoff to remove contaminants prior to delivery to any receiving waters.
- Locate facilities in areas with enough water velocity to maintain water quality levels within acceptable ranges.
- Locate marinas where they do not interfere with natural processes so as to affect adjacent habitats.
- To facilitate movement of fish around breakwaters, breach gaps and construct shallow shelves to serve as “fish benches,” as appropriate.
- Harbor facilities should be designed to include practical measures for reducing, containing, and cleaning up petroleum spills.

5.3.4 Invasive Species

Introductions of invasive species into estuarine, riverine, and marine habitats have been well documented (Rosecchi et al. 1993, Kohler and Courtenay 1986, Spence et al. 1996) and can be intentional (e.g., for the purpose of stock or pest control) or unintentional (e.g., fouling organisms). Exotic fish, shellfish, pathogens, and plants can be spread via shipping, recreational boating, aquaculture, biotechnology, and aquariums. The introduction of nonindigenous organisms to new environments can have many severe impacts on habitat (Omori et al. 1994).

Invasive aquatic species that are considered high priority threats to Alaska’s marine waters include Atlantic salmon (*Salmo salar*), green crab (*Carcinus maenas*), Chinese mitten crab (*Eriocheir sinensis*), signal crayfish (*Pacifastacus leniuculus*), zebra mussels (*Dreissena polymorpha*), New Zealand mudsnail (*Potamopyrgus antipodarum*), saltmarsh cordgrass

(*Spartina alterniflora*), purple loosestrife (*Lythrum salicaria*), and tunicates (*Botrylloides violaceus* and *Didemnum vexillum*).¹

Potential Adverse Impacts

Invasive species can create five types of negative effects on EFH: (1) habitat alteration, (2) trophic alteration, (3) gene pool alteration, (4) spatial alteration, and (5) introduction of diseases.

Recommended Conservation Measures

The following recommended conservation measures for invasive species should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Uphold fish and game regulations of the Alaska Board of Fisheries (AS 16.05.251) and Board of Game (AS 16.05.255), which prohibit and regulate the live capture, possession, transport, or release of native or exotic fish or their eggs.
- Adhere to regulations and use best management practices outlined in the State of Alaska Aquatic Nuisance Species Management Plan (Fay 2002).
- Encourage vessels to perform a ballast water exchange in marine waters to minimize the possibility of introducing invasive estuarine species into similar habitats.
- Discourage vessels that have not performed a ballast water exchange from discharging their ballast water into estuarine receiving waters.
- Require vessels brought from other areas over land via trailer to clean any surfaces that may harbor non-native plant or animal species (e.g., propellers, hulls, anchors, fenders).
- Treat effluent from public aquaria displays and laboratories and educational institutes using non-native species before discharge.
- Encourage proper disposal of seaweeds and other plant materials used for packing purposes when shipping fish or other animals.
- Undertake a thorough scientific review and risk assessment before any non-native species are introduced.

5.3.5 Pile Installation and Removal (From NMFS 2005)

Pilings are an integral component of many overwater and in-water structures. They provide support for the decking of piers and docks, function as fenders and dolphins to protect structures, support navigation markers, and help in the construction of breakwaters and bulkheads. Materials used in pilings include steel, concrete, wood (both treated and untreated), plastic, or a combination thereof. Piles are usually driven into the substrate by using either impact or vibratory hammers.

¹ <http://www.adfg.state.ak.us/special/invasive/invasive.ph>

5.3.5.1 *Pile Driving*

Potential Adverse Impacts

Pile driving can generate intense underwater sound pressure waves that may adversely affect EFH. These pressure waves have been shown to injure and kill fish (CalTrans 2001, Longmuir and Lively 2001, Stotz and Colby 2001, Stadler, pers. obs. 2002). Fish injuries associated directly with pile driving are poorly studied, but include rupture of the swim bladder and internal hemorrhaging (CalTrans 2001, Abbott and Bing-Sawyer 2002, Stadler pers. obs. 2002). Sound pressure levels (SPLs) 100 decibels (dB) above the threshold for hearing are thought to be sufficient to damage the auditory system in many fishes (Hastings 2002).

The type and intensity of the sounds produced during pile driving depend on a variety of factors, including the type and size of the pile, the firmness of the substrate into which the pile is being driven, the depth of water, and the type and size of the pile-driving hammer. Driving large hollow steel piles with impact hammers produces intense, sharp spikes of sound that can easily reach levels injurious to fish. Vibratory hammers, on the other hand, produce sounds of lower intensity, with a rapid repetition rate. A key difference between the sounds produced by impact hammers and those produced by vibratory hammers is the responses they evoke in fish. The differential responses to these sounds are due to the differences in the duration and frequency of the sounds.

Systems using air bubbles have been successfully designed to reduce the adverse effects of underwater SPLs on fish. Confined (i.e., metal or fabric sleeve) and unconfined air bubble systems have been shown to attenuate underwater sound pressures (Longmuir and Lively 2001, Christopherson and Wilson 2002, Reyff and Donovan 2003).

5.3.5.2 *Recommended Conservation Measures*

The following recommended conservation measures for pile driving should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Install hollow steel piles with an impact hammer at a time of year when larval and juvenile stages of fish species with designated EFH are not present.

If the first measure is not possible, then the following measures regarding pile driving should be incorporated when practicable to minimize adverse effects:

- Drive piles during low tide when they are located in intertidal and shallow subtidal areas.
- Use a vibratory hammer when driving hollow steel piles.
- Implement measures to attenuate the sound should SPLs exceed the 180 dB (re: 1 μ Pa) threshold.
- Surround the pile with an air bubble curtain system or air-filled coffer dam.
- Use a smaller hammer to reduce sound pressures.
- Use a hydraulic hammer if impact driving cannot be avoided.

- Drive piles when the current is reduced in areas of strong current, to minimize the number of fish exposed to adverse levels of underwater sound.

5.3.5.3 Pile Removal

Potential Adverse Impacts

The primary adverse effect of removing piles is the suspension of sediments, which may result in harmful levels of turbidity and release of contaminants contained in those sediments (see earlier). Vibratory pile removal tends to cause the sediments to slough off at the mudline, resulting in relatively low levels of suspended sediments and contaminants. Breaking or cutting the pile below the mudline may suspend only small amounts of sediment, providing that the stub is left in place, and little digging is required to access the pile. Direct pull or use of a clamshell to remove broken piles may, however, suspend large amounts of sediment and contaminants. When the piling is pulled from the substrate using these two methods, sediments clinging to the piling will slough off as it is raised through the water column, producing a potentially harmful plume of turbidity and/or contaminants. The use of a clamshell may suspend additional sediment if it penetrates the substrate while grabbing the piling.

While there is a potential to adversely affect EFH during the removal of piles, many of the piles removed in Alaska are old creosote-treated timber piles. In some cases, the long-term benefits to EFH obtained by removing a chronic source of contamination may outweigh the temporary adverse effects of turbidity.

Recommended Conservation Measures

The following recommended conservation measures for pile removal should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Remove piles completely rather than cutting or breaking them off, if they are structurally sound.
- Minimize the suspension of sediments and disturbance of the substrate when removing piles. Measures to help accomplish this include, but are not limited to, the following:
 - When practicable, remove piles with a vibratory hammer.
 - Remove the pile slowly to allow sediment to slough off at, or near, the mudline.
 - The operator should first hit or vibrate the pile to break the bond between the sediment and the pile.
 - Encircle the pile, or piles, with a silt curtain that extends from the surface of the water to the substrate.
- Complete each pass of the clamshell to minimize suspension of sediment if pile stubs are removed with a clamshell.
- Place piles on a barge equipped with a basin to contain attached sediment and runoff water after removal.

- Using a pile driver, drive broken/cut stubs far enough below the mudline to prevent release of contaminants into the water column as an alternative to their removal.

5.3.6 Overwater Structures (from NMFS 2005)

Overwater structures include commercial and residential piers and docks, floating breakwaters, barges, rafts, booms, and mooring buoys. These structures typically are located in intertidal areas out to about 49 feet (15 meters) below the area exposed by the mean lower low tide (i.e., the shallow subtidal zone).

Potential Adverse Impacts

Overwater structures and associated developments may adversely affect EFH in a variety of ways, primarily by (1) changes in ambient light conditions, (2) alteration of the wave and current energy regime, (3) introduction of contaminants into the marine environment, and (4) activities associated with the use and operation of the facilities (Nightingale and Simenstad 2001b).

Recommended Conservation Measures

The following recommended conservation measures for overwater structures should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Use upland boat storage whenever possible to minimize need for overwater structures.
- Locate overwater structures in deep enough waters to avoid intertidal and shade impacts, minimize or preclude dredging, minimize groundings, and avoid displacement of submerged aquatic vegetation, as determined by a preconstruction survey.
- Design piers, docks, and floats to be multiuse facilities to reduce the overall number of such structures and to limit impacted nearshore habitat.
- Incorporate measures that increase the ambient light transmission under piers and docks.
 - Maximize the height and minimize the width to decrease the shade footprint.
 - Use reflective materials on the underside of the dock to reflect ambient light.
 - Use the fewest number of pilings necessary to support the structures.
 - Align piers, docks, and floats in a north-south orientation to allow the arc of the sun to cross perpendicular to the structure and to reduce the duration of light limitation.
- Use floating rather than fixed breakwaters whenever possible, and remove them during periods of low dock use. Encourage seasonal use of docks and off-season haul-out.
- Locate floats in deep water to avoid light limitation and grounding impacts to the intertidal or shallow subtidal zone.
- Maintain at least 1 foot (0.30 meter) of water between the substrate and the bottom of the float at extreme low tide.
- Conduct in-water work when managed species and prey species are least likely to be impacted.

- To the extent practicable, avoid the use of treated wood timbers or pilings.
- Mitigate for unavoidable impacts to benthic habitats.

5.3.7 Flood Control/Shoreline Protection (from NMFS 2005)

Structures designed to protect humans from flooding events can result in varying degrees of change in the physical, chemical, and biological characteristics of shoreline and riparian habitat. These structures also can have long-term adverse effects on tidal marsh and estuarine habitats. Tidal marshes are highly variable, but typically have freshwater vegetation at the landward side, saltwater vegetation at the seaward side, and gradients of species in between that are in equilibrium with the prevailing climatic, hydrographic, geological, and biological features of the coast. These systems normally drain through tidal creeks that empty into the bay or estuary. Freshwater entering along the upper edges of the marsh drains across the surface and enters the tidal creeks. Structures placed for coastal shoreline protection may include concrete or wood seawalls, rip-rap revetments (sloping piles of rock placed against the toe of the dune or bluff in danger of erosion from wave action), dynamic cobble revetments (natural cobble placed on an eroding beach to dissipate wave energy and prevent sand loss), vegetative plantings, and sandbags.

Potential Adverse Impacts

Dikes, levees, ditches, or other water controls at the upper end of a tidal marsh can cut off all tributaries feeding the marsh, preventing the flow of freshwater, annual renewal of sediments and nutrients, and the formation of new marshes. Water controls within the marsh can intercept and carry away freshwater drainage, thus blocking freshwater from flowing across seaward portions of the marsh, or conversely increase the speed of runoff of freshwater to the bay or estuary. This can result in lowering the water table, which may permit saltwater intrusion into the marsh, and create migration barriers for aquatic species. In deeper channels where anoxic conditions prevail, large quantities of hydrogen sulfide may be produced that are toxic to marsh grasses and other aquatic life (NMFS 2008). Acid conditions of these channels can also result in release of heavy metals from the sediments.

Long-term effects of shoreline protection structures on tidal marshes include land subsidence (sometimes even submergence), soil compaction, conversion to terrestrial vegetation, greatly reduced invertebrate populations, and general loss of productive wetland characteristics (NMFS 2005). Alteration of the hydrology of coastal salt marshes can reduce estuarine productivity, restrict suitable habitat for aquatic species, and result in salinity extremes during droughts and floods (NMFS 2008). Armoring shorelines to prevent erosion and to maintain or create shoreline real estate can reduce the amount of intertidal habitat, and affects nearshore processes and the ecology of numerous species (Williams and Thom 2001). Hydraulic effects on the shoreline include increased energy seaward of the armoring, reflected wave energy, dry beach narrowing, substrate coarsening, beach steepening, changes in sediment storage capacity, loss of organic debris, and downdrift sediment starvation (Williams and Thom 2001). Installation of breakwaters and jetties can result in community changes from burial or removal of resident biota, changes in cover and preferred prey species, and predator attraction (Williams and Thom 2001). As with armoring, breakwaters and jetties modify hydrology and nearshore sediment transport, as well as movement of larval forms of many species (Williams and Thom 2001).

Recommended Conservation Measures

The following recommended conservation measures for flood and shoreline protection should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Avoid or minimize the loss of coastal wetlands as much as possible.
- Do not dike or drain tidal marshlands or estuaries.
- Wherever possible, use soft in lieu of “hard” shoreline stabilization and modifications.
- Ensure that the hydrodynamics and sedimentation patterns are properly modeled and that the design avoids erosion to adjacent properties when “hard” shoreline stabilization is deemed necessary.
- Include efforts to preserve and enhance fishery habitat to offset impacts.
- Avoid installing new water control structures in tidal marshes and freshwater streams.
- Ensure water control structures are monitored for potential alteration of water temperature, dissolved oxygen concentration, and other parameters.
- Use seasonal restrictions to avoid impacts to habitat during critical life history stages.
- Address the cumulative impacts of development activities in the review process for flood control and shoreline protection projects.
- Use an adaptive management plan with ecological indicators to oversee monitoring and to ensure that mitigation objectives are met. Take corrective action as needed.

5.3.8 Log Transfer Facilities/In-Water Log Storage (from NMFS 2005)

Rivers, estuaries, and bays were historically the primary ways to transport and store logs in the Pacific Northwest, and log storage continues in some tidal areas today. Using estuaries and bays and nearby uplands for storage of logs is common in Alaska, with most log transfer facilities (LTFs) found in Southeast Alaska and a few located in Prince William Sound. LTFs are facilities that are constructed wholly or in part in waterways and used to transfer commercially harvested logs to or from a vessel or log raft, or for consolidating logs for incorporation into log rafts (USEPA 2000b). LTFs may use a crane, A-frame structure, conveyor, slide, or ramp to move logs from land into the water. Logs can also be placed in the water at the site by helicopters.

Potential Adverse Impacts

Log handling and storage in the estuaries and intertidal zones can result in modification of benthic habitat and water quality degradation within the area of bark deposition (Levings and Northcote 2004). EFH may be physically impacted by activities associated with LTFs. LTFs may cause shading and other indirect effects similar in many ways to those of floating docks and other over-water structures (see earlier).

Recommended Conservation Measures

The following recommended conservation measures for log transfer and storage facilities should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

The physical, chemical, and biological impacts of LTF operations can be substantially reduced by adherence to appropriate siting and operational constraints. Adherence to the Alaska Timber Task Force (ATTF) operational and siting guidelines and BMPs in the National Pollutant Discharge Elimination System (NPDES) General Permit will reduce (1) the amount of bark and wood debris that enters the marine and coastal environment, (2) the potential for displacement or harm to aquatic species, and (3) the accumulation of bark and wood debris on the ocean floor. The following conservation measures reflect those guidelines.²

- Restrict or eliminate storage and handling of logs from waters where state and federal water quality standards cannot be met at all times outside of the authorized zone of deposition.
- Minimize potential impacts of log storage by employing effective bark and wood debris control, collection, and disposal methods at log dumps, raft building areas, and mill-side handling zones; avoiding free-fall dumping of logs; using easy let-down devices for placing logs in the water; and bundling logs before water storage (bundles should not be broken except on land and at millside).
- Do not store logs in the water if they will ground at any time or shade sensitive aquatic vegetation such as eelgrass.
- Avoid siting log-storage areas and LTFs in sensitive habitat and areas important for specified species, as required by the ATTF guidelines.
- Site log storage areas and LTFs in areas with good currents and tidal exchanges.
- Use land-based storage sites where possible.

5.3.9 Utility Line, Cables, and Pipeline Installation

With the continued development of coastal regions comes greater demand for the installation of cables, utility lines for power and other services, and pipelines for water, sewage, and other utilities. The installation of pipelines, utility lines, and cables can have direct and indirect impacts on the offshore, nearshore, estuarine, wetland, beach, and rocky shore coastal zone habitats. Many of the direct impacts occur during construction, such as ground disturbance in the clearing of the right-of-way, access roads, and equipment staging areas. Indirect impacts can include increased turbidity, saltwater intrusion, accelerated erosion, and introduction of urban and industrial pollutants due to ground clearing and construction.

Potential Adverse Impacts

Adverse effects on EFH from the installation of pipelines, utility lines, and cables can occur through (1) destruction of organisms and habitat, (2) turbidity impacts, (3) resuspension and

² See also http://www.fs.fed.us/r10/TLMP/F_PLAN/APPEND_G.PDF.

release of contaminants, (4) changes in hydrology, and (5) destruction of vertically complex hard bottom habitat (e.g., hard corals and vegetated rocky reef).

Recommended Conservation Measures

The following recommended conservation measures for cable and utility line installation should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Align crossings along the least environmentally damaging route.
- Use horizontal directional drilling where cables or pipelines would cross anadromous fish streams, salt marsh, vegetated inter-tidal zones, or steep erodible bluff areas adjacent to the intertidal zone.
- Store and contain excavated material on uplands.
- Backfill excavated wetlands with either the same or comparable material capable of supporting similar wetland vegetation, and at original marsh elevations.
- Use existing rights-of-way whenever possible.
- Bury pipelines and submerged cables where possible.
- Remove inactive pipelines and submerged cables unless they are located in sensitive areas (e.g., marsh, reefs, sea grass).
- Use silt curtains or other barriers to reduce turbidity and sedimentation whenever possible.
- Limit access for equipment to the immediate project area. Tracked vehicles are preferred over wheeled vehicles.
- Limit construction equipment to the minimum size necessary to complete the work.
- Conduct construction during the time of year when it will have the least impact on sensitive habitats and species.
- Suspend transmission lines beneath existing bridges or conduct directional boring under streams to reduce the environmental impact.
- For activities on the Continental Shelf, implement the following to the extent practicable:
 - Shunt drill cuttings through a conduit and either discharge the cuttings near the sea floor, or transport them ashore.
 - Locate drilling and production structures, including pipelines, at least 1 mile (1.6 kilometers) from the base of a hard-bottom habitat.
 - Bury pipelines at least 3 feet (0.9 meter) beneath the sea floor whenever possible.
 - Locate alignments along routes that will minimize damage to marine and estuarine habitat.

5.3.10 Mariculture

Productive embayments are often used for commercial culturing and harvesting operations. These locations provide protected waters for geoduck, oyster, and mussel culturing. In 1988, Alaska passed the Alaska Aquatic Farming Act (AAF Act) which is designed to encourage establishment and growth of an aquatic farming industry in the state. The AAF Act establishes four criteria for issuance of an aquatic farm permit, including the requirement that the farm may not significantly affect fisheries, wildlife, or other habitats in an adverse manner. Aquatic farm permits are issued by the Alaska Department of Natural Resources (ADNR).

Potential Adverse Impacts

Shellfish aquaculture tends to have less impact on EFH than finfish aquaculture because the shellfish generally are not fed or treated with chemicals (OSPAR Commission 2009). Adverse impacts to EFH by mariculture operations include (1) risk of introducing undesirable species and disease; (2) physical disturbance of intertidal and subtidal areas; and (3) impacts on estuarine food webs, including disruption of eelgrass habitat (e.g., dumping of shell on eelgrass beds, repeated mechanical raking or trampling, and impacts from predator exclusion netting, though few studies have documented impacts). Hydraulic dredges used to harvest oysters in coastal bays can cause long-term adverse impacts to eelgrass beds by reducing or eliminating the beds (Phillips 1984).

Recommended Conservation Measures

The following recommended conservation measures for mariculture facilities should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Site mariculture operations away from kelp or eelgrass beds.
- Do not enclose or impound tidally influenced wetlands for mariculture.
- Undertake a thorough scientific review and risk assessment before any non-native species are introduced.
- Encourage development of harvesting methods to minimize impacts on plant communities and the loss of food and/or habitat to fish populations during harvesting operations.
- Provide appropriate mitigation for the unavoidable, extensive, or permanent loss of plant communities.
- Ensure that mariculture facilities, spat, and related items transported from other areas are free of nonindigenous species.

5.4 Coastal/Marine Activities

5.4.1 Point-Source Discharges

Point source pollutants are generally introduced via some type of pipe, culvert, or similar outfall structure. These discharge facilities typically are associated with domestic or industrial activities, or in conjunction with collected runoff from roadways and other developed portions of

the coastal landscape. Waste streams from sewage treatment facilities and watershed runoff may be combined in a single discharge. Point source discharges introduce inorganic and organic contaminants into aquatic habitats, where they may become bioavailable to living marine resources.

Potential Adverse Impacts (adopted from NMFS 2008)

The Clean Water Act (CWA) includes important provisions to address acute or chronic water pollution emanating from point source discharges. Under the NPDES program, most point-source discharges are regulated by the state or EPA. While the NPDES program has led to ecological improvements in U.S. waters, point sources continue to introduce pollutants into the aquatic environment, albeit at reduced levels.

Determining the fate and effect of natural and synthetic contaminants in the environment requires an interdisciplinary approach to identify and evaluate all processes sensitive to pollutants. This is critical as adverse effects may be manifested at the biochemical level in organisms (Luoma 1996) in a manner particular to the species or life stage exposed. Exposure to pollutants can inhibit (1) basic detoxification mechanisms, e.g., production of metallothioneins or antioxidant enzymes; (2) disease resistance; (3) the ability of individuals or populations to counteract pollutant-induced metabolic stress; (4) reproductive processes including gamete development and embryonic viability; (5) growth and successful development through early life stages; (6) normal processes including feeding rate, respiration, osmoregulation; and (7) overall Darwinian fitness (Capuzzo and Sassner 1977; Widdows et al. 1990; Nelson et al. 1991; Stiles et al. 1991; Luoma 1996; Thurberg and Gould 2005).

Recommended Conservation Measures

The following recommended conservation measures for point source discharges should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Locate discharge points in coastal waters well away from shellfish beds, sea grass beds, corals, and other similar fragile and productive habitats.
- Reduce potentially high velocities by diffusing effluent to acceptable velocities.
- Determine baseline benthic productivity by sampling before any construction activity.
- Provide for mitigation when degradation or loss of habitat occurs.
- Institute source-control programs that effectively reduce noxious materials.
- Ensure compliance with pollutant discharge permits, which set effluent limitations and/or specify operation procedures, performance standards, or BMPs.
- Treat discharges to the maximum extent practicable.
- Use land-treatment and upland disposal/storage techniques where possible.
- Avoid siting pipelines and treatment facilities in wetlands and streams.

5.4.2 Seafood Processing Waste—Shoreside and Vessel Operation

Seafood processing is conducted throughout much of coastal Alaska. Processing facilities may be vessel-based or located onshore (ADEC 2010a). Seafood processing facilities generally consist of mechanisms to offload the harvest from fishing boats; tanks to hold the seafood until the processing lines are ready to accept them; processing lines, process water, and waste collection systems; treatment and discharge facilities; processed seafood storage areas; and necessary support facilities such as electrical generators, boilers, retorts, water desalinators, offices, and living quarters. In addition, recreational fish cleaning at marinas and small harbors can produce a large quantity of fish waste.

Pollutants of concern from seafood processing wastewater are primarily components of the biological wastes generated by processing raw seafood into a marketable form, chemicals used to maintain sanitary conditions for processing equipment and fish containment structures, and refrigerants (ammonia and freon) that may leak from refrigeration systems used to preserve seafood (ADEC 2010b). Biological wastes include fish parts (e.g., heads, fins, bones, and entrails) and chemicals, which are primarily disinfectants that must be used in accordance with EPA specifications.

Potential Adverse Impacts

Seafood processing operations have the potential to adversely affect EFH through the discharge of nutrients, chemicals, fish byproducts, and “stickwater” (water and entrained organics originating from the draining or pressing of steam-cooked fish products). Seafood processing discharges influence nutrient loading, eutrophication, and anoxic and hypoxic conditions significantly influencing marine species diversity and water quality (Theriault et al. 2006, Roy Consultants 2003, Lotze et al. 2003). Although fish waste is biodegradable, fish parts that are ground to fine particles may remain suspended for some time, thereby overburdening habitats from particle suspension (NMFS 2005). Scum and foam from seafood waste deposits can also occur on the water surface and/or increase turbidity. Turbidity decreases light penetration into the water column, reducing primary production. In addition, stickwater takes the form of a fine gel or slime that can concentrate on surface waters and move onshore to cover intertidal areas.

Recommended Conservation Measures

The following recommended conservation measures for fish processing waste should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- To the maximum extent practicable, base effluent limitations on site-specific water quality concerns.
- Encourage the use of secondary or wastewater treatment systems where possible.
- Do not allow designation of new zones of deposit for fish processing waste and instead seek disposal options that avoid an accumulation of waste.
- Promote sound recreational fish waste management through a combination of fish-cleaning restrictions, public education, and proper disposal of fish waste.
- Encourage alternative uses of fish processing wastes.

- Explore options for additional research.
- Monitor biological and chemical changes to the site of processing waste discharges.

5.4.3 Water Intake Structures/Discharge Plumes

Withdrawals of riverine, estuarine, and marine waters are common for a variety of uses such as to cool power-generating stations and create temporary ice roads and ice ponds. In the case of power plants, the subsequent discharge of heated and/or chemically treated discharge water can also occur.

Potential Adverse Impacts

Water intake structures and effluent discharges can interfere with or disrupt EFH functions in the source or receiving waters by (1) entrainment, (2) impingement, (3) degrading water quality, (4) operation and maintenance, and (5) construction-related impacts.

Recommended Conservation Measures

The following recommended conservation measures for water intakes and discharges should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Locate facilities that rely on surface waters for cooling in areas other than estuaries, inlets, heads of submarine canyons, rock reefs, or small coastal embayments where managed species or their prey concentrate.
- Design intake structures to minimize entrainment or impingement.
- Design power plant cooling structures to meet the best technology available requirements as developed pursuant to section 316(b) of the CWA.
- Regulate discharge temperatures so they do not appreciably alter the ambient temperature to an extent that could cause a change in species assemblages and ecosystem function in the receiving waters.
- Avoid the use of biocides (e.g., chlorine) to prevent fouling where possible.
- Treat all discharge water from outfall structures to meet state water quality standards at the terminus of the pipe.

5.4.4 Oil and Gas Exploration, Development, and Production

Two agencies, the Bureau of Ocean Energy Management and the Bureau of Safety and Environmental Enforcement are responsible for regulating oil and gas operations on the Outer Continental Shelf (OCS). The ADNDR Division of Oil and Gas exercises similar authority over State waters (ADNR1999). Offshore petroleum exploration, development, and production activities have been conducted in Alaska waters or on the Alaska OCS in since the 1960s (Kenai Peninsula Borough 2004). As demand for energy resources grows, the debate over trying to balance the development of oil and gas resources and the protection of the environment will also continue.

Potential Adverse Impacts

Offshore oil and gas operations can be classified into exploration, development, and production activities (which includes transportation). These activities occur at different depths in a variety of habitats, and can cause an assortment of physical, chemical, and biological disturbances (NMFS 2005, Helvey 2002). (Some of these disturbances are listed below; however, not all of the potential disturbances in this list apply to every type of activity.)

Noise from seismic surveys, vessel traffic, and construction of drilling platforms or islands

Physical alterations to habitat from the construction, presence, and eventual decommissioning and removal of facilities such as islands or platforms, storage and production facilities, and pipelines to onshore common carrier pipelines, storage facilities, or refineries

Waste discharges, including well drilling fluids, produced waters, surface runoff and deck drainage, domestic waste waters generated from the offshore facility, solid waste from wells (drilling muds and cuttings), and other trash and debris from human activities associated with the facility

Oil spills

Platform storage and pipeline decommissioning

The potential disturbances and associated adverse impacts on the marine environment have been reduced through operating procedures required by regulatory agencies and, in many cases, self-imposed by facilities operators. Most of the activities associated with oil and gas operations are conducted under permits and regulations that require companies to minimize impacts or avoid construction in sensitive marine habitats. New technological advances in operating procedures also reduce the potential for impacts.

Recommended Conservation Measures

The following recommended conservation measures for oil and gas exploration and development should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH:

- Avoid the discharge of produced waters into marine waters and estuaries.
- Avoid discharge of muds and cuttings into the marine and estuarine environment.
- To the extent practicable, avoid the placement of fill to support construction of causeways or structures in the nearshore marine environment.
- As required by federal and state regulatory agencies, encourage the use of geographic response strategies that identify EFH and environmentally sensitive areas.
- Evaluate potential impacts to EFH that may result from activities carried out during the decommissioning phase of oil and gas facilities.
- Vessel operations and shipping activities should be familiar with Alaska Geographic Response Strategies which detail environmentally sensitive areas of Alaska's coastline.

5.4.5 Habitat Restoration and Enhancement

Habitat loss and degradation are major, long-term threats to the sustainability of fishery resources (NMFS 2002). Viable coastal and estuarine habitats are important to maintaining healthy fish stocks. Good water quality and quantity, appropriate substrate, ample food sources, and adequate shelter from predators are needed to sustain fisheries. Restoration and/or enhancement of coastal and riverine habitat that supports managed fisheries and their prey will assist in sustaining and rebuilding fish stocks by increasing or improving ecological structure and functions. Habitat restoration and enhancement may include, but is not limited to, improvement of coastal wetland tidal exchange or reestablishment of natural hydrology; dam or berm removal; fish passage barrier removal or modification; road-related sediment source reduction; natural or artificial reef, substrate, or habitat creation; establishment or repair of riparian buffer zones; improvement of freshwater habitats that support anadromous fishes; planting of native coastal wetland and submerged aquatic vegetation; and improvements to feeding, shade or refuge, spawning, and rearing areas that are essential to fisheries.

Potential Adverse Impacts

The implementation of restoration and enhancement activities may have localized and temporary adverse impacts on EFH. Possible impacts can include (1) localized nonpoint source pollution such as influx of sediment or nutrients, (2) interference with spawning and migration periods, (3) temporary removal feeding opportunities, (4) indirect effects from construction phase of the activity, (5) direct disturbance or removal of native species, and (6) temporary or permanent habitat disturbance.

Recommended Conservation Measures

The following recommended conservation measures for habitat restoration and enhancement should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Use BMPs to minimize and avoid potential impacts to EFH during restoration activities.
 - Use turbidity curtains, hay bales, and erosion mats.
 - Plan staging areas in advance, and keep them to a minimum size.
 - Establish buffer areas around sensitive resources.
 - Remove invasive plant and animal species from the proposed action area before starting work. Plant only native plant species.
 - Establish temporary access pathways before restoration activities.
- Avoid restoration work during critical life stages for fish such as spawning, nursery, and migration.
- Provide adequate training and education for volunteers and project contractors to ensure minimal impact to the restoration site.
- Conduct monitoring before, during, and after project implementation.
- To the extent practicable, mitigate any unavoidable damage to EFH.

- Remove and, if necessary, restore any temporary access pathways and staging areas used.
- Determine benthic productivity by sampling before any construction activity in the case of subtidal enhancement (e.g., artificial reefs). Avoid areas of high productivity to the maximum extent possible.

5.4.6 Marine Mining

Mining activities, which are also described in Sections 3.1.1 and 3.1.2 of the EFH EIS (NMFS 2005), can lead to the direct loss or degradation of EFH for certain species. Offshore mining, such as the extraction of gravel and gold in the Bering Sea, can increase turbidity, and resuspension of organic materials could impact eggs and recently hatched larvae in the area. Mining large quantities of beach gravel can also impact turbidity, and may significantly affect the transport and deposition of sand and gravel along the shore, both at the mining site and down-current (NMFS 2005).

Potential Adverse Impacts

Impacts from mining on EFH include both physical impacts (i.e., intertidal dredging) and chemical impacts (i.e., additives such as flocculants) (NMFS 2005). Physical impacts may include the removal of substrates that serve as habitat for fish and invertebrates; habitat creation or conversion in less productive or uninhabitable sites, such as anoxic holes or silt bottom; burial of productive habitats, such as in near-shore disposal sites (as in beach nourishment); release of harmful or toxic materials either in association with actual mining, or in connection with machinery and materials used for mining; creation of harmful turbidity levels; and adverse modification of hydrologic conditions so as to cause erosion of desirable habitats. Submarine disposal of mine tailings can also alter the behavior of marine organisms.

Recommended Conservation Measures

The following recommended conservation measures for marine mining should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- To the extent practicable, avoid mining in waters containing sensitive marine benthic habitat, including EFH (e.g., spawning, migrating, and feeding sites).
- Minimize the areal extent and depth of extraction to reduce recolonization times.
- Monitor turbidity during operations, and cease operations if turbidity exceeds predetermined threshold levels.
- Monitor individual mining operations to avoid and minimize cumulative impacts.
- Use seasonal restrictions as appropriate; to avoid and minimize impacts to EFH during critical life history stages of managed species (e.g., migration and spawning).
- Deposit tailings within as small an area as possible.

5.5 References

- Abbe, T.B. and D.R. Montgomery. 1996. "Large woody debris jams, channel hydraulics, and habitat formation in large rivers." *Regulated Rivers: Research and Management*. 12:201-221.
<http://www.cems.uvm.edu/ce361/papers/abbe1996.pdf>
- Abbott, R. and E. Bing-Sawyer. 2002. Assessment of pile driving impacts on the Sacramento blackfish (*Othodon microlepidotus*). Draft report prepared for Caltrans District 4. October 10, 2002.
- Alaska Department of Environmental Conservation (ADEC). 2010a. Ocean Discharge Criteria Evaluation Alaska Offshore Seafood Processors APDES General Permit AKG523000. Prepared by Tetra Tech, 10306 Eaton Place Suite 340, Fairfax, VA 22030. 152 pp.
- ADEC. 2010b. Wastewater Discharge Authorization Program, 555 Cordova Street, Anchorage, AK 99501. Fact Sheet Alaska Offshore Seafood Processors General Permit AKG523000. 43 pp.
- Alaska Department of Natural Resources (ADNR). 1999. Cook Inlet Areawide 1999 Oil and Gas Lease Sale, Final Finding of the Director. Volume II. Appendix B: "Laws and Regulations Pertaining to Oil and Gas Exploration, Development, Production, and Transportation."
- American Fisheries Society (AFS). 2000. AFS Policy Statement #13: Effects of Surface Mining on Aquatic Resources in North America (Revised). (Abbreviated) http://www.fisheries.org/afs/docs/policy_13f.pdf
- Arruda, J.A., G.R. Marzolf, R.T. Faulk. 1983. The role of suspended sediments in the nutrition of zooplankton in turbid reservoirs. *Ecology* 64(5):1225-35.
- Atlantic States Marine Fisheries Commission. 1992. Fishery management plan for inshore stocks of winter flounder. Washington (DC): ASMFC. FMR No. 21. 138 p.
- Barr BW. 1993. Environmental impacts of small boat navigation: vessel/sediment interactions and management implications. In: Magoon OT, editor. Coastal Zone '93: proceedings of the eighth Symposium on Coastal and Ocean Management; 1993 Jul 19-23; New Orleans, LA. American Shore and Beach Preservation Association. p 1756-70.
- Benfield, M.C. and T. J. Minello. 1996. "Relative effects of turbidity and light intensity on reactive distance and feeding of an estuarine fish." *Environmental Biology of Fishes*. 46:211-216.
- Brix, K.V., D.K. DeForest, and W.J. Adams 2001. Assessing acute and chronic copper risks to freshwater aquatic life using species sensitivity distributions for different taxonomic groups. *Environmental Toxicology and Chemistry*. 20(8): 1846-1856.
- Caltrans. 2001. Fisheries Impact Assessment, Pile Installation Demonstration Project for the San Francisco - Oakland Bay Bridge, East Span Seismic Safety Project, August 2001. 59 pp.
- Capuzzo J.M., and J.J. Sassner Jr. 1977. The effect of chromium on filtration rates and metabolic activity of *Mytilus edulis* L. and *Mya arenaria* L. In: Vernberg FJ, and others, editors. Physiological responses of marine biota to pollutants. San Diego (CA): Academic Press. p 225-37.
- Center for Watershed Protection (CWP). 2003. Impacts of Impervious Cover on Aquatic Systems. Elliott City, MD, www.cwp.org. 141 pp.
- Christopherson, A. and J. Wilson. 2002. Technical Letter Report Regarding the San Francisco-Oakland Bay Bridge East Span Project Noise Energy Attenuation Mitigation. Peratrovich, Nottingham & Drage, Inc. Anchorage, Alaska. 27 pp.

- Cloern, J.E. 1987. "Turbidity as a control on phytoplankton biomass and productivity in estuaries." *Continental Shelf Research*. 7:1367-1381.
- Conner, Billy, Director Alaska University Transportation Center. University of Alaska, Fairbanks PO Box 755900. 2007 Interview in Building Alaska. http://www.buildingalaskamovie.com/interviews_billy.html
- Deegan, L.A. and R.N. Buchsbaum. 2005. The effect of habitat loss and degradation on fisheries. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline on fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 67-96.
- Dennison, W.C. 1987. "Effect of light on seagrass photosynthesis, growth and depth distribution." *Aquatic Botany*. 27:15-26.
- Dugan, J.E., D.M. Hubbard, D.L. Martin, J.M. Engle, D.M. Richards, G.E. Davis, K.D. Lafferty, and R.F. Ambrose. 2000. Macrofauna communities of exposed sandy beaches on the Southern California mainland and Channel Islands. pp 339-346. In Brown, D.R., K.L. Mitchell, and H.W. Chang, eds. Proceedings of the Fifth California Islands Symposium. Minerals Management Service Publication # 99-0038.
- Frag, A.M., D.A. Skaar, E. Nimick, C. MacConnell, and C. Hogstrand. 2003. Characterizing aquatic health using salmonids mortality, physiology, and biomass estimates in streams with elevated concentrations of arsenic, cadmium, copper, lead, and zinc in the Boulder River Watershed, Montana. Transaction of the American Fisheries Society 132(3): 450-457.
- Fay, V. 2002. Alaska Aquatic Nuisance Species Management Plan. Alaska Department of Fish and Game Publication. Juneau, AK. http://www.adfg.state.ak.us/special/invasive/ak_ansmp.pdf.
- Goldstein, J.N., D.F. Woodward, and A.M. Frag. 1999. Movement of adult Chinook salmon during spawning migration in a metals-contaminated system, Coeur d'Alene River, Idaho. Transactions of the American Fisheries Society 128:121-129.
- Gregory, S.V. and P.A. Bisson. 1997. Degradation and loss of anadromous salmonid habitat in the Pacific Northwest. In Stouder, J.D., P.A. Bisson, and R.J. Naiman, eds. Pacific Salmon and Their Ecosystems: Status and Future Options, pp. 277-314. Chapman and Hall, New York.
- Groundwater Protection Council. 2010. State Groundwater Fact Sheets. http://www.gwpc.org/e-library/documents/state_fact_sheets/alaska.pdf. Ground Water Protection Council, 13308 N. MacArthur Blvd., Oklahoma City, OK 73142.
- Hansen, J.A., Lipton J., and Welsh P.G. 2002. Environmental toxicology and chemistry. 21 (3): 633-639
- Hastings, M.C. 2002. Clarification of the meaning of sound pressure levels and the known effects of sound on fish. Document in support of Biological Assessment for San Francisco-Oakland Bay Bridge East Span Seismic Safety Project. August 26, 2002. Revised August 27, 2002. 8 pp.
- Helvey, M. 2002. "Are southern California oil and gas platforms essential fish habitat?" *ICES Journal of Marine Science*. 59:S266-S271.
- Kenai Peninsula Borough. 2004. Cook Inlet Oil and Gas, Kenai Peninsula Borough Oil and Gas History. <http://www.cookinletoilandgas.org/kpb/history.htm>
- Kohler, C.C. and W.R. Courtenay, Jr. 1986. "Introduction of aquatic species." *Fisheries*. 11(2):39-42. Proceedings of the Seventh International Zebra Mussel and Aquatic Nuisance Species Conference. 1997.

- Koski, K.V. 1992. Restoring stream habitats affected by logging activities. Pages 343-404 in G. W. Thayer (editor) Restoring the nation's marine environment. Publication UM-SG-TS-92-06. Maryland Sea Grant College, College Park, MD.
- Larson, K. and C. Moehl. 1990. Entrainment of anadromous fish by hopper dredge at the mouth of the Columbia River. In C.A. Simenstad, ed. Effects of dredging on anadromous Pacific coast fishes. University of Washington Sea Grant. pp. 102-112.
- Levings, C.D. and T. G. Northcote. 2004. Effects of forestry on estuarine ecosystems supporting fishes. In T.G. Northcote and G.F. Hartman, editors, Fishes and Forestry Worldwide Watershed Interactions and Management, Blackwell Publishing, pp 320 -335.
- Longmuir, C. and T. Lively. 2001. Bubble curtain systems for use during marine pile driving. Report by Fraser River Pile & Dredge Ltd., New Westminster, British Columbia. 9 pp.
- Lotze, H., I. Milewski, B. Worm, and Z. Koller. 2003 Nutrient Pollution: A Eutrophication Survey of Eelgrass Beds in Estuaries and Coastal Bays in Northern and Eastern New Brunswick. Conservation Council of New Brunswick Inc.
- Luce, A. and M. Crowe. 2001. "Invertebrate terrestrial diversity along a gravel road on Barrie Island, Ontario, Canada." *Great Lakes Entomologist*. 34(1):55-60 SPR-SUM.
- Luoma, S.N. 1996. The developing framework of marine ecotoxicology: pollutants as a variable in marine ecosystems. *Journal of Experimental Marine Biology and Ecology* 200:29-55.
- Maser, C. and J.R. Sedell. 1994. From the Forest to the Sea: the Ecology of Wood in Streams, Estuaries and Oceans. St. Lucie Press, Delray Beach, FL. 200 pp.
- McGraw, K. and D. Armstrong. 1990. Fish entrainment by dredges in Grays Harbor, Washington. In C.A. Simenstad, ed. Effects of dredging on anadromous Pacific coast fishes. University of Washington Sea Grant. pp. 113-131.
- Mitsch WJ, Gosselink JG. 1993. Wetlands. 2nd ed. New York (NY): Van Nostrand Reinhold. 722 pp.
- Montgomery, D.R., R.D. Smith, K.M. Schmidt, and G.R. Pess. 1995. "Pool Spacing in Forest Channels." *Water Resources Research*. 31:1097-1105.
- NMFS. 2011. Impacts to Essential Fish Habitat from Non-fishing Activities in Alaska. National Marine Fisheries Service, Alaska Region. Juneau, Alaska. November, 2011.
- NMFS. 2008. Impacts to Marine Fisheries Habitat from Nonfishing Activities in the Northeastern United States. Northeast Regional Office Gloucester, Massachusetts NOAA Technical Memorandum NMFS-NE-209.
- NMFS. 2005. Final Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska, Appendix G Non-fishing Impacts to Essential Fish Habitat and Recommended Conservation Measures.
- NMFS. 2004. Draft National Gravel Extraction Policy. 1335 East-West Highway, Silver Spring, MD 20910. <http://www.nmfs.noaa.gov/habitat/habitatprotection/pdf/gravelguidance.pdf>
- NMFS. 2002. Environmental Assessment, NMFS' Restoration Plan for the Community-Based Restoration Program. Prepared by the NOAA Restoration Center, Office of Habitat Conservation. Silver Spring, MD.
- NMFS. 1998a. Draft document - Non-fishing threats and water quality: A reference for EFH consultation

- NMFS. 1998b. Final recommendations: Essential Fish Habitat for Pacific Coast Groundfish. Prepared by: The Core Team for EFH for Pacific Coast Groundfish June 3, 1998. 2725 Montlake Blvd. E. Seattle, WA 98112. http://www.psmfc.org/efh/groundfish_desc.pdf.
- National Oceanic and Atmospheric Agency (NOAA). 2010. Office of Ocean and Coastal Resource Management. Ocean and Coastal Management in Alaska. <http://coastalmanagement.noaa.gov/mystate/ak.html>.
- National Research Council. 1999. Committee on Hardrock Mining. Hardrock Mining on Federal Lands. Appendix B. Potential Environmental Impacts of Hardrock Mining. (http://www.nap.edu/html/hardrock_fed_lands/appB.html).
- Nelson D, Miller J, Rusanowsky D, Greig R, Sennefelder G, Mercaldo-Allen R, Kuropat C, Gould E, Thurberg F, Calabrese A. 1991. Comparative reproductive success of winter flounder in Long Island Sound: a three-year study (biology, biochemistry, and chemistry). *Estuaries* 14(3):318-31.
- Newell, R.C., L.J. Seiderer, and D.R. Hitchcock. 1998. "The impact of dredging on biological resources of the sea bed." *Oceanography and Marine Biology Annual Review*. 36:127-178.
- Nightingale, B. and C.A. Simenstad. 2001a. Dredging activities: Marine issues. Washington State Transportation Center, University of Washington, Seattle, WA 98105. (Document available through the National Technical Information Service, Springfield, VA 22616).
- Nightingale, B. and C.A. Simenstad. 2001b. Overwater Structures: Marine Issues. White paper submitted to Washington Department of Fish and Wildlife, Washington Department of Ecology and Washington Department of Transportation. www.wa.gov/wdfw/hab. 133 pp.
- North Pacific Fishery Management Council and NMFS. 2010. Essential Fish Habitat (EFH) 5-year Review for 2010 Summary Report: Final. April 2010. <http://alaskafisheries.noaa.gov/habitat/efh/review.htm>.
- Northcote, T.G. and G.F. Hartman. 2004. Fishes and Forestry - Worldwide Watershed Interactions and Management, Blackwell Publishing, Oxford, UK, 789 pp.
- Omori, M., S. Van der Spoel, C.P. Norman. 1994. Impact of human activities on pelagic biogeography. *Progress in Oceanography* 34 (2-3):211-219.
- Oregon Water Resource Research Institute (OWRRI). 1995. Gravel disturbance impacts on salmon habitat and stream health, volume 1. Summary report. Oregon State University, Corvallis, Oregon. (Also available Vol. II: Technical background report). Available from Oregon Division of State Lands, Salem, Oregon, 503-378-3805.
- OSPAR Commission. 2009. Assessment of Impacts of Mariculture . Publication Number: 442/2009. London, UK
- Pacific Fishery Management Council. 1999. Appendix A: Identification and description of essential fish habitat, adverse impacts, and recommended conservation measures for salmon. Amendment 14 to the Pacific Coast Salmon Plan. Portland, OR. 146 pp.
- Packer, D.B., Griffin K., McGlynn K.E. 2005. National Marine Fisheries Service national gravel extraction guidance. Washington (DC): US Department of Commerce. NOAA Technical Memorandum NMFS-F/SPO-70. [cited 2008 Jul 15]. 27 p. Available from: <http://www.nmfs.noaa.gov/habitat/habitatprotection/anadfish/gravel.htm>.
- Phillips, R.C. 1984. The ecology of eelgrass meadows in the Pacific Northwest: a community profile. U.S. Fish and Wildlife Service. FWS/OBS-84/24. 85 pp.

- Ralph, S., G. Poole, L. Conquest, and R. Naiman. 1994. "Stream channel morphology and woody debris in logged and unlogged basins in western Washington." *Can. J. Fish. Aquatic Sciences*. 51:37-51.
- Reyff, J.A and P. Donovan. 2003. Benicia-Martinez Bridge Bubble Curtain Test - Underwater Sound Measurement Data. Memo to Caltrans dated January 31, 2003. 3 pp.
- Robinson W.E., and Pederson J. 2005. Contamination, habitat degradation, overfishing - An "either-or" debate? In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 1-10.
- Rosecchi, E., A.J. Crivelli, G. Catsadorakis. 1993. The establishment and impact of *Pseudorabara parva*, an exotic fish species introduced into lake Mikri Prespa (northwestern Greece). *Aquatic Conservation: Marine and Freshwater Ecosystems* 3:223-231.
- Roy Consultants Ltd., NATECH Environmental Services Inc. and OCL Group. Environmental Management Consultants. 2003. Lamèque Bay environmental management study. Report No. 133-01.
- Scott G.I., M.H. Fulton, D.W. Moore, E.F. Wirth, G.T. Chandler, P.B. Key, J.W. Daugomah, E.D. Strozier, J. Devane, J.R. Clark, M.A. Lewis, D.B. Finley, W. Ellenberg, and K.J. Karnaky. 1999. "Assessment of risk reduction strategies for the management of agricultural nonpoint source pesticide runoff in estuarine ecosystems." *Toxicology and Industrial Health*. 15:200-213.
- Sedell, J.R., and K.J. Luchessa. 1982. Using the historical record as an aid to salmonid habitat enhancement. In Armantrout, N.B. (ed.), Acquisition and utilization of aquatic habitat inventory information, p. 210-222. American Fisheries Society, Western Division, Bethesda, MD.
- Sengupta, M. 1993. Environmental Impacts of Mining: Monitoring, Restoration, and Control. CRC Press, Inc. 2000 Corporate Blvd., N.W. Boca Raton, FL. 33431. p.1.
- Spence, B.C., G.A. Lomnický, R.M. Hughes, and R.P. Novitzki. 1996. An ecosystem approach to salmonid conservation. TR-4501-96-6057. ManTech Environmental Research Services Corp., Corvallis, OR. 356 pp. (Available from the NMFS Habitat Branch, Portland, OR).
- Stadler, J.H. 2002. Personal observation of fish-kill occurring during pile driving activity at the Winslow Ferry Terminal, Winslow, WA. October 7, 2002. Fish Biologist, DOC/NOAA/National Marine Fisheries Service/HCD, Lacey, WA.
- Stiles, S., J. Choromanski, D. Nelson, J. Miller, R. Grieg, and G. Sennefelder. 1991. Early reproductive success of the hard clam (*Mercenaria mercenaria*) from five sites in Long Island Sound. *Estuaries* 14(3):332-42.
- Stotz, T. and J. Colby. 2001. January 2001 dive report for Mukilteo wingwall replacement project. Washington State Ferries Memorandum. 5 pp. + appendices.
- Theriault, M.H., S.C. Courtenay, C. Godin and W.B. Ritchie. 2006. Evaluation of the Community Aquatic Monitoring Program (CAMP) to assess the health of four coastal areas within the southern Gulf of St. Lawrence with special reference to the impacts of effluent from seafood processing plants. *Can. Tech. Rep. Fish. Aquat. Sci.* 2649: vii + 60 p.
- Thurberg, F.P., and E. Gould. 2005. Pollutant effects upon cod, haddock, pollock, and flounder of the inshore fisheries of Massachusetts and Cape Cod Bays. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 43-66.

- Trombulak, S.C. and C.A. Frissell. 2000. "Review of ecological effects of roads on terrestrial and aquatic communities." *Conservation Biology*. 14(10):18-30. February.
- USDA Forest Service. 2008. Tongass Monitoring and Evaluation Report – Appendix B
http://www.fs.fed.us/r10/tongass/projects/tlmp/2008_monitoring_report/index2008.shtml
- USEPA. 2000a. Environmental Screening Checklist and Workbook for the Water Transportation Industry. August 2000.
- USEPA, Region 10. 2000b. Authorization to discharge under the National Pollutant Discharge Elimination System (NPDES) for Section 402 modifications of Section 404 permits for log Transfer Facilities which received a Section 404 permit prior to October 22, 1985. NPDES Permit Number AK-G70-0000. March 2000. 1200 Sixth Avenue, OW-130 Seattle, Washington 98101.
- USEPA. 1993. Guidance for specifying management measures for sources of nonpoint pollution in coastal waters. EPA Office of Water. 840-B-92-002. 500+ pp.
- Washington Department of Fish and Wildlife. 2009. Gold and fish. Rules for mineral prospecting and placer mining. 2nd edition. April 2009. Olympia, WA.
- Widdows J, Burns KA, Menon NR, Page D, Soria S. 1990. Measurement of physiological energetics (scope for growth) and chemical contaminants in mussel (*Arca zebra*) 220 transplanted along a contamination gradient in Bermuda. *Journal of Experimental Marine Biology and Ecology* 138:99-117.
- Williams, G.D. and R.M. Thom. 2001. Marine and estuarine shoreline modification issues. White paper submitted to Washington Department of Fish and Wildlife, Washington Department of Ecology and Washington Department of Transportation. www.wa.gov/wdfw/hab/ahg. 99 pp.

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Appendix 5 Arctic FMP Amendment 1 - amendment text for updating non-fishing activity EFH conservation recommendations, changing HAPC timeline (EFH Omnibus Amendment)

1. Insert a new Section E.S. 1.4, titled “Amendments to the FMP”, with the following content (update to indicate the effective date of the approved amendment):

Amendment 1, implemented on _____ (insert effective date)_____:

1. Update description of EFH impacts from non-fishing activities, and EFH conservation recommendations for non-fishing activities.
2. Revise the timeline associated with the HAPC process to a 5-year timeline.

2. In Section 3.20.2, Schedule for Review, revise the second paragraph under the subheading “Essential Fish Habitat Components” as follows (note, delete text indicated with ~~strikeout~~, insert text that is underlined):

Additionally, the Council may ~~use the FMP amendment cycle every three years to~~ solicit proposals for HAPCs and/or conservation and enhancement measures to minimize the potential adverse effects of fishing. Any proposal endorsed by the Council would be implemented by FMP amendments. HAPC proposals may be solicited every 5 years, coinciding with the EFH 5-year review, or may be initiated at any time by the Council.

3. In Section 4.1.3.4, HAPC Process, revise the fourth paragraph, as follows (note, delete text with ~~strikeout~~, insert text that is underlined):

The Council will initiate the HAPC process by setting priorities and issuing a request for HAPC proposals. Any member of the public may submit a HAPC proposal. HAPC proposals may be solicited every ~~3 years or on a schedule established by the Council 5 years, to coincide with the EFH 5-year review, or may be initiated at any time by the Council.~~ The Council may periodically review existing HAPCs for efficacy and considerations based on new scientific research.

4. Replace Appendix C, Non-fishing Effects on EFH in the Arctic, with the revised Appendix C in the attached file.

5. Update table of contents.

Appendix C: Non-fishing Effects on EFH in the Arctic

The Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act), the federal law that governs U.S. marine fisheries management, contains provisions to identify Essential Fish Habitat (EFH) for federally managed species and consider measures to conserve and enhance the habitat necessary for these species throughout their life cycles. The Magnuson-Stevens Act requires NMFS to recommend conservation measures to those federal and state agencies whose actions may adversely affect EFH. EFH conservation recommendations are advisory, not mandatory, and may include measures to avoid, minimize, mitigate, or otherwise offset the adverse effects to EFH.

Non-fishing activities that may adversely affect EFH are diverse.¹ Example activities include oil and gas exploration and production facilities, harbor construction, exotic species introduction, fill for nearshore development, shoreline stabilization, and point source discharges. The most recent evaluation of the various non-fishing activities that may adversely affect EFH in Alaska is “Impacts to Essential Fish Habitat from Non-fishing Activities in Alaska” (NMFS 2011), which is incorporated in the fishery management plan (FMP) by reference. It is a comprehensive document that evaluates the impacts of non-fishing activities on EFH and identifies EFH conservation and enhancement recommendations for each of these activities. An abbreviated version the larger document is included in this appendix to the FMP, along with EFH conservation recommendations to avoid, minimize, or compensate for adverse effects on EFH caused by each activity other than fishing.

While the sections below cover a broad range of non-fishing activities, not all of them may be immediately relevant to the Arctic. The non-fishing activities included in the report are those that could conceivably occur now or in the future in the Arctic; not all of these actions are expected to occur soon, and some may not occur at all. This discussion is intended to be representative of a broad range of possible scenarios, rather than predictive of what is actually expected to occur; however, the actions listed are not necessarily all-inclusive. The intent is to provide an accurate description of those non-fishing activities and offer general recommendations to conserve and protect EFH. Those activities of immediate importance in the Arctic are the following:

- Dredging (Section 1.4.1)
- Material Disposal and Fill Material (Section 1.4.2)
- Vessel Operations, Transportation, and Navigation (Section 1.4.3)
- Introduction of Invasive Species (Section 1.4.4)
- Utility Lines, Cables, and Pipeline Installation (section 1.4.9)
- Point-source Discharges (Section 1.5.1)
- Water Intake Structures/Discharge Plumes (Section 1.5.3)

¹ Non-fishing activities (or developmental activities) information is compiled by NOAA, other federal agencies, academia, and environmental consulting firms. The amount of this type of information as compared to information used to address fishing effects on fish habitat is extensive. The evaluation addresses those activities most likely to reduce the quantity and/or quality of EFH. It is not meant to provide a conclusive review and analysis of the impacts of all potentially detrimental activities; rather it highlights notable threats and provides information to determine if further examination of a proposed activity is necessary. Subject-specific EFH Conservation Recommendations are advisory and serve as proactive conservation measures that would help minimize and avoid adverse effects of these fishing activities on EFH. Site-specific EFH Conservation Recommendations will be prepared per activity and as necessary during EFH Consultation [see: CFR 50 Part 600 Subpart K].

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- Oil and Gas Exploration, Development and Production (Section 1.5.4)

1.1 Non-fishing Activities that may Adversely Affect Essential Fish Habitat

The waters and substrates that comprise EFH are susceptible to a wide array of human activities unrelated to fishing. Broad categories of such activities include, but are not limited to, mining, dredging, fill, impoundment, discharges, water diversions, thermal additions, actions that contribute to nonpoint source pollution and sedimentation, introduction of potentially hazardous materials, introduction of exotic species, and the conversion of aquatic habitat that may eliminate, diminish, or disrupt the functions of EFH. Non-fishing activities discussed in this document are subject to a variety of regulations and restrictions designed to limit environmental impacts under federal, state, and local laws. Listing all applicable environmental laws and management practices is beyond the scope of the document. Moreover, the coordination and consultation required by section 305(b) of the Magnuson-Stevens Act does not supersede the regulations, rights, interests, or jurisdictions of other federal or state agencies. NMFS may use the information in this document as a source when developing conservation recommendations for specific actions under section 305(b)(4)(A) of the Magnuson-Stevens Act. NMFS will not recommend that state or federal agencies take actions beyond their statutory authority, and NMFS' EFH conservation recommendations are not binding.

Ideally, actions that are not water-dependent should not be located in EFH if such actions may have adverse impacts on EFH. Activities that may result in significant adverse effects on EFH should be avoided where less environmentally harmful alternatives are available. If there are no alternatives, the impacts of these actions should be minimized. Environmentally sound engineering and management practices should be employed for all actions that may adversely affect EFH. If avoidance or minimization is not practicable, or will not adequately protect EFH, compensatory mitigation, as defined for section 404 of the Clean Water Act (CWA), should be considered to conserve and enhance EFH.

The potential for effects from larger, less readily managed processes associated with human activity also exists, such as climate change and ocean acidification. Climate change may lead to habitat changes that prompt shifts in the distribution of managed species. Likewise, should ocean conditions warm to allow for new shipping routes, new vectors may emerge for introducing invasive species in cargo and ballast waters. Ocean acidification could also alter species distributions and complicated food web dynamics. These larger ecosystem-level effects are discussed in this document where applicable, within each activity type.

This section of the FMP synthesizes a comprehensive review of the "Impacts to Essential Fish Habitat from Non-fishing Activities in Alaska" (NMFS 2011), which is incorporated in the FMP by reference. The general purpose of that document is to identify non-fishing activities that may adversely impact EFH and provide conservation recommendations that can be implemented for specific types of activities to avoid or minimize adverse impacts to EFH. This information is required to be included in FMPs under section 303(a)(7) of the Magnuson-Stevens Act. It is also useful to NMFS biologists reviewing proposed actions that may adversely affect EFH, and the comprehensive document (NMFS 2011) will be utilized by federal action agencies undertaking EFH consultations with NMFS, especially in preparing EFH assessments.

The conservation recommendations for each activity category are suggestions the action agency or others can undertake to avoid, offset, or mitigate impacts to EFH. NMFS develops EFH conservation recommendations for specific activities case-by-case based on the circumstances; therefore, the recommendations in this document may or may not apply to any particular project. Because many non-fishing activities have similar adverse effects on living marine resources, some redundancy in the descriptions of impacts and the accompanying conservation recommendations between sections in this report is unavoidable.

The comprehensive non-fishing activities document (NMFS 2011) updates and builds upon a collaborative evaluation of non-fishing effects to EFH completed in 2004 by the NMFS Alaska Region, Northwest Region, and Southwest Region, and the respective Fisheries Science Centers. In April 2005, NMFS completed the Final Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska (EFH EIS; NMFS 2005) and the North Pacific Fishery Management Council (Council) amended its FMPs to address the EFH requirements of the Magnuson-Stevens Act. The EFH EIS contained an appendix (Appendix G) that addressed non-fishing impacts to EFH. A 5-year review of the Council's EFH provisions, including those addressing non-fishing impacts to EFH, was completed by the Council in April 2010 (NPFMC and NMFS 2010), on the basis of which this section has been updated.

The remainder of this section addresses non-fishing activities that may adversely affect EFH. These activities are grouped into the four different systems in which they usually occur: upland, river or riverine, estuary or estuarine, and coastal or marine.

1.2 Upland Activities

Upland activities can impact EFH through both point source and nonpoint source pollution. Nonpoint source impacts are discussed here. Technically, the term "nonpoint source" means anything that does not meet the legal definition of point source in section 502(14) of the CWA, which refers to discernible, confined, and discrete conveyance from which pollutants are or may be discharged. Land runoff, precipitation, atmospheric deposition, seepage, and hydrologic modification, generally driven by anthropogenic development, are the major contributors to nonpoint source pollution.

Nonpoint source pollution is usually lower in intensity than an acute point source event, but may be more damaging to fish habitat in the long term. It may affect sensitive life stages and processes, is often difficult to detect, and its impacts may go unnoticed for a long time. When population impacts are detected, they may not be tied to any one event or source, and may be difficult to correct, clean up, or mitigate.

The impacts of nonpoint source pollution on EFH may not necessarily represent a serious, widespread threat to all species and life history stages. The severity of the threat of any specific pollutant to aquatic organisms depends upon the type and concentration of the pollutant and the length of exposure for a particular species and its life history stage. For example, species that spawn in areas that are relatively deep with strong currents and well-mixed water may not be as susceptible to pollution as species that inhabit shallow, inshore areas near or within enclosed bays and estuaries. Similarly, species whose egg, larval, and juvenile life history stages utilize shallow, inshore waters and rivers may be more prone to coastal pollution than are species whose early life history stages develop in offshore, pelagic waters.

1.2.1 Silviculture/Timber Harvest

Recent revisions to federal and state timber harvest regulations in Alaska and best management practices (BMPs) have resulted in increased protection of EFH on federal, state, and private timber lands (USDA 2008; <http://www.fs.fed.us/r10/tongass/projects/tlmp/>).

These revised regulations include forest management practices, which when fully implemented and effective, could avoid or minimize adverse effects to EFH. However, if these management practices are ineffective or not fully implemented, timber harvest could have both short and long term impacts on EFH throughout many coastal watersheds and estuaries. Historically, timber harvest in Alaska was not conducted under the current protective standards, and these past practices may have degraded EFH in some watersheds.

Potential Adverse Impacts

In both small and large watersheds there are many complex and important interactions between fish and forests (Northcote and Hartman 2004). Five major categories of silvicultural activities can adversely affect EFH if appropriate forestry practices are not followed: (1) construction of logging roads, (2) creation of fish migration barriers, (3) removal of streamside vegetation, (4) hydrologic changes and sedimentation, and (5) disturbance associated with log transfer facilities (LTFs). Possible effects to EFH include the following (Northcote and Hartman 2004):

- Removal of the dominant vegetation and conversion of mature and old-growth upland and riparian forests to tree stands or forests of early seral stage;
- Reduction of soil permeability and increase in the area of impervious surfaces;
- Increase in erosion and sedimentation due to surface runoff and mass wasting processes, also potentially affecting riparian areas;
- Impaired fish passage because of inadequate design, construction, and/or maintenance of stream crossings;
- Altered hydrologic regimes resulting in inadequate or excessive surface and stream flows, increased streambank and streambed erosion, loss of complex instream habitats;
- Changes in benthic macroinvertebrate populations;
- Loss of instream and riparian cover;
- Increased surface runoff with associated contaminants (e.g., herbicides, fertilizers, and fine sediments) and higher temperatures;
- Alterations in the supply of large woody debris (LWD) and sediment, which can have negative effects on the formation and persistence of instream habitat features; and
- Excess debris in the form of small pieces of wood and silt, which can cover benthic habitat and reduce dissolved oxygen levels.

Recommended Conservation Measures

The following recommended conservation measures for silviculture/timber harvest should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH. Additionally, management standards, guidelines, and BMPs are available from the Forest Service Region 10, the State of Alaska Division of Forestry, and forest plans for the Tongass and Chugach National Forests.

- **Stream Buffers:** For timber operations in watersheds with EFH, adhere to modern forest management practices and BMPs, including the maintenance of vegetated buffers along all streams to the extent practicable in order to reduce sedimentation and supply large wood.
- **Estuary and Beach Fringe:** For timber operations adjacent to estuaries or beaches, maintain vegetated buffers as needed to protect EFH.
- **Watershed Analysis:** A watershed analysis should be incorporated into timber and silviculture projects whenever practicable.
- **Forest Roads:** Forest roads can be a major cause of sediment into streams and road culverts can block or inhibit upstream fish passage. Roads need to be designed to minimize sediment transport problems and to avoid fish passage problems.

1.2.2 Pesticides

Pesticides are substances intended to prevent, destroy, control, repel, kill, or regulate the growth of undesirable biological organisms. Pesticides include the following: insecticides, herbicides, fungicides, rodenticides, repellents, bactericides, sanitizers, disinfectants, and growth regulators. More than 900 different active pesticide ingredients are currently registered for use in the United States and are formulated with a variety of other inert ingredients that may also be toxic to aquatic life. Legal mandates covering pesticides are the CWA and the Federal Insecticide, Fungicide, and Rodenticide Act. Water quality criteria for the protection of aquatic life have only been developed for a few of the currently used ingredients (EPA, Office of Pesticide Programs). While agricultural run-off is a major source of pesticide pollution in the lower 48 states, in Alaska, other human activities, such as fire suppression on forested lands, forest site preparation, noxious weed control, right-of-way maintenance (e.g., roads, railroads, power lines), algae control in lakes and irrigation canals, riparian habitat restoration, and urban and residential pest control, are the most common sources of these substances.

Pesticides are frequently detected in freshwater and estuarine systems that provide EFH. Pesticides can enter the aquatic environment as single chemicals or as complex mixtures. Direct applications, surface runoff, spray drift, agricultural return flows, and groundwater intrusions are all examples of transport processes that deliver pesticides to aquatic ecosystems. Habitat alteration from pesticides is different from more conventional water quality parameters because, unlike temperature or dissolved oxygen, the presence of pesticides can be difficult to detect due to limitations in proven methodologies. This monitoring may also be expensive. As analytical methodologies have improved in recent years, the number of pesticides documented in fish and their habitats has increased. In addition, pesticides may bioaccumulate in the ecosystem by retention in sediments and detritus, which are then ingested by macroinvertebrates, and which, in turn, are eaten by larger invertebrates and fish (Atlantic States Marine Fisheries Commission 1992).

Potential Adverse Impacts

There are three basic ways that pesticides can adversely affect EFH. These are (1) a direct, lethal or sublethal, toxicological impact on the health or performance of exposed fish; (2) an indirect impairment of aquatic ecosystem structure and function; and (3) a loss of aquatic

macroinvertebrates that are prey for fish and aquatic vegetation that provides physical shelter for fish.

Recommended Conservation Measures

The following recommended conservation measures regarding pesticides (including insecticides, herbicides, fungicides, rodenticides, repellents, bactericides, sanitizers, disinfectants, and growth regulators) should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Incorporate integrated pest management and BMPs as part of the authorization or permitting process (Scott et al. 1999). If pesticides must be applied, consider area, terrain, weather, droplet size, pesticide characteristics, and other conditions to avoid or reduce effects to EFH.
- Carefully review labels and ensure that application is consistent with the product's directions.
- Avoid the use of pesticides within 500 linear feet and/or 1,000 aerial feet of anadromous fish bearing streams.
- For forestry vegetation management projects, establish a 35-foot pesticide-free buffer area from any surface or marine water body and require that pesticides not be applied within 200 feet of a public water source (Alaska Department of Environmental Conservation guidelines).
- Consider current and recent meteorological conditions. Rain events may increase pesticide runoff into adjacent water bodies. Saturated soils may inhibit pesticide penetration.
- Do not apply pesticides when wind speeds exceed 10 mph.
- Begin application of pesticide products nearest to the aquatic habitat boundary and proceed away from the aquatic habitat; do not apply towards a water body.

1.2.3 Urban and Suburban Development

Urban and suburban development is most likely the greatest non-fishing threat to EFH (NMFS 1998a, 1998b). Urban and suburban development and the corresponding infrastructure result in four broad categories of impacts to aquatic ecosystems: hydrological, physical, water quality and biological (CWP 2003).

Potential Adverse Impacts

Potential impacts to EFH most directly related to general urban and suburban development discussed below are the watershed effects of land development, including stormwater runoff. Other development-related impacts are discussed in later sections of this document, including dredging, wetland fill, and shoreline construction.

Development activities within watersheds and in coastal marine areas can impact EFH on both long and short timeframes. The Center for Watershed Protection (CWP) made a comprehensive review of the impacts associated with impervious cover and urban development and found a negative relationship between watershed development and 26 stream quality indicators (CWP

2003). The primary impacts include (1) the loss of hyporheic zones (the region beneath and next to streams where surface and groundwater mix), and riparian and shoreline habitat and vegetation; and (2) runoff. Removal of riparian and upland vegetation has been shown to increase stream water temperatures, reduce supplies of LWD, and reduce sources of prey and nutrients to the water system. An increase in impervious surfaces in a watershed, such as the addition of new roads, buildings, bridges, and parking facilities, results in a decreased infiltration to groundwater and increased runoff volumes. This also has the potential to adversely affect water quality and the shape of the hydrograph in downstream water bodies (i.e., estuaries and coastal waters).

Recommended Conservation Measures

The following recommended conservation measures should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH where threats of impacts from urban and suburban development exist.

- Implement BMPs for sediment control during construction and maintenance operations (USEPA 1993).
- Avoid using hard engineering structures for shoreline stabilization and channelization when possible.
- Encourage comprehensive planning for watershed protection, and avoid or minimize filling and building in coastal and riparian areas affecting EFH.
- Where feasible, remove obsolete impervious surfaces from riparian and shoreline areas, and reestablish water regime, wetlands, and native vegetation.
- Protect and restore vegetated buffer zones of appropriate width along streams, lakes, and wetlands that include or influence EFH.
- Manage stormwater to replicate the natural hydrologic cycle, maintaining natural infiltration and runoff rates to the maximum extent practicable.
- Where instream flows are insufficient to maintain water quality and quantity needed for EFH, establish conservation guidelines for water use permits, and encourage the purchase or lease of water rights and the use of water to conserve or augment instream flows.
- Use the best available technologies in upgrading wastewater systems to avoid combined sewer overflow problems and chlorinated sewage discharges into rivers, estuaries, and the ocean.
- Design and install proper wastewater treatment systems.
- Where vegetated swales are not feasible, install and maintain oil/water separators to treat runoff from impervious surfaces in areas adjacent to marine or anadromous waters.

1.2.4 Road Building and Maintenance

Roads and trails have always been part of man's impact on his environment (Luce and Crowe 2001). Federal, state, and local transportation departments devote huge budgets to construction and upgrading of roads. As in other places, roads play an important part in access and thus are vital to the economy of Alaska (Connor 2007).

Potential Adverse Impacts

Today's road design construction and management practices have improved from the past. Roads however, still have a negative effect on the biotic integrity of both terrestrial and aquatic ecosystems (Trombulak and Frissell 2000), and the effects of roads on aquatic habitat can be profound. Potential adverse impacts to aquatic habitats resulting from existence of roads in watersheds include (1) increased surface erosion, including mass wasting events, and deposition of fine sediments; (2) changes in water temperature; (3) elimination or introduction of migration barriers such as culverts; (4) changes in streamflow; (5) introduction of invasive species; and (6) changes in channel configuration; and (7) the concentration and introduction of polycyclic aromatic hydrocarbons (PAH), heavy metals and other pollutants.

Recommended Conservation Measures

The following conservation measures should be viewed as options to avoid and minimize adverse impacts from road building and maintenance and promote the conservation, enhancement, and proper functioning of EFH.

- Roads should be sited to avoid sensitive areas such as streams, wetlands, and steep slopes to the extent practicable.
- Build bridges rather than culverts for stream crossings when possible. If culverts are to be used, they should be sized, constructed, and maintained to match the gradient and width of the stream, so as to accommodate design flood flows; they should be large enough to provide for migratory passage of adult and juvenile fishes.
- Design bridge abutments to minimize disturbances to stream banks, and place abutments outside of the floodplain whenever possible.
- Specify erosion control measures in road construction plans.
- Avoid side casting of road materials on native surfaces and into streams.
- Use only native vegetation in stabilization plantings.
- Use seasonal restrictions to avoid impacts to habitat during species critical life history stages (e.g., spawning and egg development periods).
- Properly Maintain roadway and associated stormwater collection systems.
- Limit roadway sanding and the use of deicing chemicals during the winter to minimize sedimentation and introduction of contaminants into nearby aquatic habitats.

1.3 Riverine Activities

1.3.1 Mining

Mining within riverine habitats may result in direct and indirect chemical, biological, and physical impacts to habitats within the mining site and surrounding areas during all stages of operations. On site mining activities include exploration, site preparation, mining and milling, waste management, decommissioning or reclamation, and abandonment (NMFS 2004, American Fisheries Society [AFS] 2000). Mining and its associated activities have the potential to cause adverse effects to EFH from exploration through post-closure. The operation of metal, coal, rock quarries, and gravel pit mines in upland and riverine areas has caused varying degrees of

environmental damage in urban, suburban, and rural areas. Some of the most severe damage, however, occurs in remote areas, where some of the most productive fish habitat is often located (Sengupta 1993). In Alaska, existing regulations, promulgated and enforced by other federal and state agencies, are designed to control and manage these changes to the landscape to avoid and minimize impacts. However, while environmental regulations may avoid, limit, control, or offset many potential impacts, mining will, to some degree, always alter landscapes and environmental resources (National Research Council [NRC] 1999). (Additional information on mining impacts in the marine environment is covered later in this synthesis.)

1.3.1.1 Mineral Mining

Mining and mineral extraction activities take many forms, such as commercial and recreational suction dredging, placer, open pit and surface mining, and contour operations. The process for mineral extraction involves exploration, mine development, mining (extraction), processing, and reclamation.

Potential Adverse Impacts

The potential adverse effects of mineral mining on fish populations and EFH are well documented (Farag et al. 2003, Hansen et al. 2002, Brix et al. 2001, Goldstein et al. 1999) and depend on the type, extent, and location of the activities. Impacts associated with the extraction of material from within or near a stream or river bed may include (1) alteration in channel morphology, hydraulics, lateral migration and natural channel meander; (2) increases in channel incision and bed degradation; (3) disruption in pre-existing balance of suspended sediment transport and turbidity; (4) direct impacts to fish spawning and nesting habitats (redds), juveniles, and prey items; (5) simplification of in-channel fluvial processes and LWD deposition; (6) altered surface and ground water regimes and hydro-geomorphic and hyporheic processes; and (7) destruction of the riparian zone during extraction operations. Additional impacts may include mining-related pollution, acid mine drainage, habitat fragmentation and conversion, altered temperature regimes, reduction in oxygen concentration, the release of toxic materials (NMFS 2008), and additional impacts to wetland and riverine habitats. Many of these types of impacts have been previously introduced in the document. The additional discussion that follows is intended to round out the discussion of impacts that have not been previously introduced.

Recommended Conservation Measures

The following measures are adapted from recommendations in Spence et al. (1996), NMFS (2004), and Washington Department of Fish and Wildlife (2009). These conservation recommendations for mineral mining should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- To the extent practicable, avoid mineral mining in waters, water sources and watersheds, riparian areas, hyporheic zones, and floodplains providing habitat for federally managed species.
- Schedule necessary in-water activities when the fewest species/least vulnerable life stages of federally managed species will be present.
- Minimize spillage of dirt, fuel, oil, toxic materials, and other contaminants into EFH. Prepare a spill prevention plan if appropriate.

- Treat and test wastewater (acid neutralization, sulfide precipitation, reverse osmosis, electrochemical, or biological treatments) and recycle on site to minimize discharge to streams.
- Minimize the effects of sedimentation on fish habitat, using methods such as contouring, mulching, construction of settling ponds, and sediment curtains. Monitor turbidity during operations, and cease operations if turbidity exceeds predetermined threshold levels.
- If possible, reclaim, rather than bury, mine waste that contains heavy metals, acid materials, or other toxic compounds to limit the possibility of leachate entering groundwater.
- Restore natural contours and use native vegetation to stabilize and restore habitat function to the extent practicable. Monitor the site to evaluate performance.
- Minimize the aerial extent of ground disturbance and stabilize disturbed lands to reduce erosion.
- For large scale mining operations, stochastic models should be employed to make predictions of ground and surface hydrologic impacts and acid generating potential in mine pits and tailing impoundments.

1.3.1.2 Sand and Gravel Mining

In Alaska, riverine sand and gravel mining is extensive and can involve several methods: wet-pit mining (i.e., removal of material from below the water table); dry-pit mining on beaches, exposed bars, and ephemeral streambeds; and subtidal mining.

Potential Adverse Impacts

Primary impacts associated with riverine sand and gravel mining activities include (1) turbidity plumes and re-suspension of sediment and nutrients, (2) removal of spawning habitat, and (3) alteration of channel morphology. These often lead to secondary impacts including alteration of migration patterns, physical and thermal barriers to upstream and downstream migration, increased fluctuation in water temperature, decrease in dissolved oxygen, high mortality of early life stages, increased susceptibility to predation, loss of suitable habitat (Packer et al. 2005), decreased nutrients (from loss of floodplain connection and riparian vegetation), and decreased food production (loss of invertebrates) (Spence et al. 1996).

Recommended Conservation Measures

The following recommended conservation measures for sand and gravel mining are adapted from NMFS (2004) and OWRRI (1995). They should be viewed as options to avoid and minimize adverse impacts to EFH due to sand and gravel mining and promote the conservation, enhancement, and proper functioning of EFH.

- To the extent practicable, avoid sand/gravel mining in waters, water sources and watersheds, riparian areas, hyporheic zones, and floodplains providing habitat for federally managed species.
- Identify upland or off-channel (where the channel will not be captured) gravel extraction sites as alternatives to gravel mining in or adjacent to EFH, if possible.

- If operations in EFH cannot be avoided, design, manage, and monitor sand and gravel mining operations to minimize potential direct and indirect impacts to living marine resources and habitat. For example, minimize the areal extent and depth of extraction.
- Include restoration, mitigation, and monitoring plans, as appropriate, in sand/gravel extraction plans.
- Implement seasonal restrictions to avoid impacts to habitat during species critical life history stages.

1.3.2 Organic and Inorganic Debris

Organic and inorganic debris, and its impacts to EFH, extend beyond riverine systems into estuarine coastal and marine systems. To reduce duplication, impacts to other systems are also addressed here.

Natural occurring flotsam, such as LWD and macrophyte wrack (i.e., kelp), plays an important role in aquatic ecosystems, including EFH. LWD and wrack promote habitat complexity and provide structure to various aquatic and shoreline habitats.

The natural deposition of LWD creates habitat complexity by altering local hydrologic conditions, nutrient availability, sediment deposition, turbidity, and other structural habitat conditions. In riverine systems, the physical structure of LWD provides cover for managed species, creates habitats and microhabitats (e.g., pools, riffles, undercut banks, and side channels), retains gravels, and helps maintain underlying channel structure (Abbe and Montgomery 1996, Montgomery et al. 1995, Ralph et al. 1994, Spence et al. 1996). LWD also plays similar role in salt marsh habitats (Maser and Sedell 1994). In benthic ocean habitats, LWD enriches local nutrient availability as deep-sea wood borers convert the wood to fecal matter, providing terrestrially-based carbon to the ocean food chain (Maser and Sedell 1994). When deposited on coastal shorelines, macrophyte wrack creates microhabitats and provides a food source for aquatic and terrestrial organisms such as isopods and amphipods, which play an important role in marine food webs.

Conversely, inorganic flotsam and jetsam debris can negatively impact EFH. Inorganic marine debris is a problem along much of the coastal United States, where it litters shorelines, fouls estuaries, entangles fish and wildlife, and creates hazards in the open ocean. Marine debris consists of a wide variety of man-made materials, including general litter, plastics, hazardous wastes, and discarded or lost fishing gear. The debris enters waterbodies indirectly through rivers and storm water outfalls, as well as directly via ocean dumping and accidental release. Although laws and regulatory programs exist to prevent or control the problem, marine debris continues to affect aquatic resources.

1.3.2.1 *Organic Debris Removal*

Natural occurring flotsam, such as LWD and macrophyte wrack (i.e., kelp), is sometimes intentionally removed from streams, estuaries, and coastal shores. This debris is removed for a variety of reasons, including dam operations, aesthetic concerns, and commercial and recreational purposes (e.g., active beach log harvests, garden mulch, and fertilizer). However, the presence of organic debris is important for maintaining aquatic habitat structure and function.

Potential Adverse Impacts

The removal of organic debris from natural systems can reduce habitat function, adversely impacting habitat quality. Reductions in LWD inputs to estuaries may also affect the ecological balance of estuarine systems by altering rates and patterns of nutrient transport, sediment deposition, and availability of in-water cover for larval and juvenile fish. In rivers and streams of the Pacific Northwest, the historic practice of removing LWD to improve navigability and facilitate log transport has altered channel morphology and reduced habitat complexity, thereby negatively affecting habitat quality for spawning and rearing salmonids (Koski 1992, Sedell and Luchessa 1982).

Beach grooming and wrack removal can substantially alter the macrofaunal community structure of exposed sand beaches (Dugan et al. 2000). Species richness, abundance, and biomass of macrofauna associated with beach wrack (e.g., sand crabs, isopods, amphipods, and polychaetes) are higher on ungroomed beaches than on those that are groomed (Dugan et al. 2000). The input and maintenance of wrack can strongly influence the structure of macrofauna communities, including the abundance of sand crabs (*Emerita analoga*) (Dugan et al. 2000), an important prey species for some managed species of fish.

Recommended Conservation Measures

The recommended conservation measures for organic debris removal are listed below. They should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Encourage the preservation of LWD whenever possible, removing it only when it presents a threat to life or property.
- Encourage appropriate federal, state, and local agencies to aid in the downstream movement of LWD around dams, culverts, and bridges wherever possible, rather than removing it from the system.
- Educate landowners and recreationalists about the benefits of maintaining LWD.
- Localize beach grooming practices, and minimize them whenever possible.
- Advise gardeners to only harvest dislodged, dead kelp and leave live, growing kelp (whether dislodged or not).

1.3.2.2 Inorganic Debris

Inorganic debris in the marine environment is a chronic problem along much of the U.S. coast, resulting in littered shorelines and estuaries with varying degrees of negative effects to coastal ecosystems. Nationally, land-based sources of marine debris account for about 80 percent of the marine debris on beaches and in U.S. waters. Debris can originate from combined sewer overflows and storm drains, stormwater runoff, landfills, solid waste disposal, poorly maintained garbage bins, floating structures, and general littering of beaches, rivers, and open waters. It generally enters waterways indirectly through rivers and storm drains or by direct ocean dumping. Ocean-based sources of debris also create problems for managed species. These include discarded or lost fishing gear (NMFS 2008), and galley waste and trash from commercial merchant, fishing, military, and other vessels.

Potential Adverse Impacts

Land and ocean sourced inorganic marine debris is a very diverse problem, and adverse effects to EFH are likewise varied. Floating or suspended trash can directly affect managed species that consume or are entangled in it. Toxic substances in plastics can kill or impair fish and invertebrates that use habitat polluted by these materials. The chemicals that leach from plastics can persist in the environment and can bioaccumulate through the food web.

Once floatable debris settles to the bottom of estuaries, coastal and open ocean areas, it can continue to cause environmental problems. Plastics and other materials with a large surface area can cover and suffocate immobile animals and plants, creating large spaces devoid of life. Currents can carry suspended debris to underwater reef habitats where the debris can become snagged, damaging these sensitive habitats. The typical floatable debris from combined sewer overflows includes street litter, sewage containing viral and bacterial pathogens, pharmaceutical by-products from human excretion, and pet wastes. Pathogens can also contaminate shellfish beds and reefs.

Recommended Conservation Measures

Pollution prevention and improved waste management can occur through regulatory controls and BMPs. The recommended conservation measures for minimizing inorganic debris listed in the section below should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Encourage proper trash disposal, particularly in coastal and ocean settings, and participate in coastal cleanup activities.
- Advocate for local, state, and national legislation that rewards proper disposal of debris.
- Encourage enforcement of regulations addressing marine debris pollution and proper disposal.
- Provide resources and technical guidance for development of studies and solutions addressing the problem of marine debris.
- Educate the public on the impact of marine debris and provide guidance on how to reduce or eliminate the problem.
- Implement structural controls that collect and remove trash before it enters nearby waterways.
- Consider the use of centrifugal separation to physically separate solids and floatables from water in combined sewer outflows.
- Encourage the development of incentives and funding mechanisms to recover lost fishing gear.
- Require all existing and new commercial construction projects near the coast to develop and implement refuse disposal plans.

1.3.3 Dam Operation

Dams provide sources of hydropower, water storage, and flood control. Construction and operation of dams can affect basic hydrologic and geomorphic function including the alteration

of physical, biological, and chemical processes that, in turn, can have effects on water quality, timing, quantity, and alter sediment transport.

Potential Adverse Impacts (adapted from NMFS 2008)

The effects of dam construction and operation on fish and aquatic habitat include (1) complete or partial upstream and downstream migratory impediment; (2) water quality and flow pattern alteration; (3) alteration to distribution and function of ice, sediment and nutrient budgets; (4) alterations to the floodplain, including riparian and coastal wetland systems and associated functions and values; and (5) thermal impacts. Dam construction and operations can impede or block anadromous fish passage and other aquatic species migration in streams and rivers. Unless proper fish passage structures or devices are operational, dams can either prevent access to productive upstream spawning and rearing habitat or can alter downstream juvenile migration. Turbines, spillways, bypass systems, and fish ladders also affect the quality and quantity of EFH available for salmon passage in streams and rivers (Pacific Fishery Management Council [PFMC] 1999). The construction of a dam can fragment habitat, resulting in alterations to both upstream and downstream biogeochemical processes.

Recommended Conservation Measures (adapted from NMFS 2008)

The following conservation recommendations regarding dams should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Avoid construction of new dam facilities, where possible.
- Construct and design facilities with efficient and functional upstream and downstream adult and juvenile fish passage which ensures safe, effective, and timely passage.
- Operate dams within the natural flow fluctuations rates and timing and, when possible, mimic the natural hydrograph, allow for sediment and wood transport, and consider and allow for natural ice function. Monitor water flow and reservoir flow fluctuation.
- Understand longer term climatic and hydrologic patterns and how they affect habitat; plan project design and operation to minimize or mitigate for these changes.
- Use seasonal restrictions for construction, maintenance, and operation of dams to avoid impacts to habitat during species' critical life history stages.
- Develop and implement monitoring protocols for fish passage.
- Retrofit existing dams with efficient and functional upstream and downstream fish passage structures.
- Construct dam facilities with the lowest hydraulic head practicable for the project purpose. Site the project at a location where dam height can be reduced.
- Downstream passage should prevent adults and juveniles from passing through the turbines and provide sufficient water downstream for safe passage.
- Coordinate maintenance and operations that require drawdown of the impoundment with state and federal resource agencies to minimize impacts to aquatic resources.
- Develop water and energy conservation guidelines for integration into dam operation plans and into regional and watershed-based water resource plans.
- Encourage the preservation of LWD, whenever possible.

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- Develop a sediment transport and geomorphic maintenance plan to allow for peak flow mimicking that will result in sediment pulses through the reservoir/dam system and allow high flow geomorphic processes.

1.3.4 Commercial and Domestic Water Use

An increasing demand for potable water, combined with inefficient use of freshwater resources and natural events (e.g., droughts) have led to serious ecological damage worldwide (Deegan and Buchsbaum 2005). Because human populations are expected to continue increasing in Alaska, it is reasonable to assume that water uses, including water impoundments and diversion, will similarly increase (Gregory and Bisson 1997). Groundwater supplies 87 percent of Alaska's 3,500 public drinking water systems. Ninety percent of the private drinking water supplies are groundwater. Each day, roughly 275 million gallons of water derived from aquifers, which directly support riverine systems, are used for domestic, commercial, industrial, and agricultural purposes in Alaska (Groundwater Protection Council 2010). Surface water sources serve a large number of people from a small number of public water systems (e.g., Anchorage and several southeastern communities).

Potential Adverse Impacts

The diversion of freshwater for domestic and commercial uses can affect EFH by (1) altering natural flows and the process associated with flow rates, (2) altering riparian habitats by removing water or by submersion of riparian areas, (3) removing the amount and altering the distribution of prey bases, (4) affecting water quality, and (5) entrapping fishes. Water diversions can involve either withdrawals (reduced flow) or discharges (increased flow).

Recommended Conservation Measures

These conservation measures for commercial and domestic water use should be viewed as options to avoid and minimize adverse impacts from commercial and domestic water use and promote the conservation, enhancement, and proper functioning of EFH.

- Design water diversion and impoundment projects to create flow conditions that provide for adequate fish passage, particularly during critical life history stages. Avoid low water levels that strand juveniles and dewater redds. Incorporate juvenile and adult fish passage facilities on all water diversion projects (e.g., fish bypass systems). Install screens at water diversions on fish-bearing streams, as needed.
- Maintain water quality necessary to support fish populations by monitoring and adjusting water temperature, sediment loads, and pollution levels.
- Maintain appropriate flow velocity and water levels to support continued stream functions. Maintain and restore channel, floodplain, riparian, and estuarine conditions.
- Where practicable, ensure that mitigation is provided for unavoidable impacts to fish and their habitat.

1.4 Estuarine Activities

A large portion of Alaska's population resides near the state's 33,904-mile coastline (NOAA 2010). The dredging and filling of coastal wetlands for commercial, residential, port, and harbor development directly removes important wetland habitat and alters the habitat surrounding the

developed area. Physical changes from shoreline construction can result in secondary impacts such as increased suspended sediment loading, shading from piers and wharves, as well as introduction of chemical contamination from land-based human activities (Robinson and Pederson 2005). Even development projects that appear to have minimal individual impacts can have significant cumulative effects on the aquatic ecosystem (NMFS 2008).

1.4.1 Dredging

The construction of ports, marinas, and harbors typically involves dredging sediments from intertidal and subtidal habitats to create navigational channels, turning basins, anchorages, and berthing docks. Additionally, periodic dredging is used to maintain the required depths after sediment is deposited into these facilities. Dredging is also used to create deepwater navigable channels or to maintain existing channels that periodically fill with sediments. (Impacts from dredging from marine mining are also addressed later.)

Potential Adverse Impacts

Dredging activities can adversely affect benthic and water-column habitat. The environmental effects of dredging on managed species and their habitat can include (1) direct removal/burial of organisms; (2) turbidity and siltation, including light attenuation from turbidity; (3) contaminant release and uptake, including nutrients, metals, and organics; (4) release of oxygen consuming substances (e.g., chemicals and bacteria); (5) entrainment; (6) noise disturbances; and (7) alteration to hydrodynamic regimes and physical habitat.

Recommended Conservation Measures

The recommended conservation measures for dredging are listed in the following section. They should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Avoid new dredging in sensitive habitat areas to the maximum extent practicable.
- Reduce the area and volume of material to be dredged to the maximum extent practicable.
- Avoid dredging and placement of equipment used in conjunction with dredging operations in special aquatic sites and other high value habitat areas.
- Implement seasonal restrictions to avoid impacts to habitat during species critical life history stages (e.g., spawning season, egg, and larval development period).
- Utilize BMPs to limit and control the amount and extent of turbidity and sedimentation.
- For new dredging projects, undertake multi-season, pre-, and post-dredging biological surveys to assess the cumulative impacts to EFH and allow for implementation of adaptive management techniques.
- Prior to dredging, test sediments for contaminants as per U.S. Environmental Protection Agency (EPA) and U.S. Army Corps of Engineers (USACE) requirements.
- Provide appropriate compensation for significant impacts (short-term, long-term, and cumulative) to benthic environments resulting from dredging.

- Identify excess sedimentation in the watershed that prompts excessive maintenance dredging activities, and implement appropriate management actions, if possible.

1.4.2 Material Disposal and Filling Activities

Material disposal and filling activities can directly remove important habitat and alter the habitat surrounding the developed area. The discharge of dredged materials or the use of fill material in aquatic habitats can result in covering or smothering existing submerged substrates, loss of habitat function, and adverse effects on benthic communities.

1.4.2.1 Disposal of Dredged Material

Potential Adverse Impacts (adapted from NMFS 2008)

The disposal of dredged material can reduce the suitability of water bodies for managed species and their prey by (1) reducing floodwater retention in wetlands; (2) reducing nutrients uptake and release; (3) decreasing the amount of detrital input, an important food source for aquatic invertebrates (Mitsch and Gosselink 1993); (4) habitat conversion through alteration of water depth or substrate type; (5) removing aquatic vegetation and preventing natural revegetation; (6) impeding physiological processes to aquatic organisms (e.g., photosynthesis, respiration) caused by increased turbidity and sedimentation (Arruda et al. 1983, Cloern 1987, Dennison 1987, Barr 1993, Benfield and Minello 1996, Nightingale and Simenstad 2001a); (7) directly eliminating sessile or semi-mobile aquatic organisms via entrainment or smothering (Larson and Moehl 1990, McGraw and Armstrong 1990, Barr 1993, Newell et al. 1998); (8) altering water quality parameters (i.e., temperature, oxygen concentration, and turbidity); and (9) releasing contaminants such as petroleum products, metals, and nutrients (USEPA 2000a).

Recommended Conservation Measures

The following recommended conservation measures for dredged material disposal should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Avoid disposing dredged material in wetlands, submerged aquatic vegetation and other special aquatic sites whenever possible.
- Test sediment compatibility for open-water disposal per EPA and USACE requirements.
- Ensure that disposal sites are properly managed and monitored to minimize impacts associated with dredge material.
- Where long-term maintenance dredging is anticipated, acquire and maintain disposal sites for the entire project life.
- Encourage beneficial uses of dredged materials.

1.4.2.2 Fill Material

Like the discharge of dredged material, the discharge of fill material to create upland areas can remove productive habitat and eliminate important habitat functions.

Potential Adverse Impacts

Adverse impacts to EFH from the introduction of fill material include (1) loss of habitat function and (2) changes in hydrologic patterns.

Recommended Conservation Measures

The following recommended conservation measures for the discharge of fill material should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Federal, state, and local resource management and permitting agencies should address the cumulative impacts of fill operations on EFH.
- Minimize the areal extent of any fill in EFH, or avoid it entirely.
- Consider alternatives to the placement of fill into areas that support managed species.
- Fill should be sloped to maintain shallow water, photic zone productivity; allow for unrestricted fish migration; and provide refugia for juvenile fish.
- In marine areas of kelp and other aquatic vegetation, fill (including artificial structure fill reefs) should be designed to maximize kelp colonization and provide areas for juvenile fish to find shelter from higher currents and exposure to predators.
- Fill materials should be tested and be within the neutral range of 7.5 to 8.4 pH.

1.4.3 Vessel Operations, Transportation, and Navigation

In Alaska, the growth in coastal communities is putting demands on port districts to increase infrastructure to accommodate additional vessel operations for cargo handling and marine transportation. Port expansion has become an almost continuous process due to economic growth, competition between ports, and significant increases in vessel size. In addition, increasing boat sales have put more pressure on improving and building new harbors, an important factor in Alaska because of the limited number of roads.

Potential Adverse Impacts

Activities associated with the expansion of port facilities, vessel/ferry operations, and recreational marinas can directly and indirectly impact EFH. Impacts include (1) loss and conversion of habitat; (2) altered light regimes and loss of submerged aquatic vegetation; (3) altered temperature regimes; (4) siltation, sedimentation, and turbidity; (5) contaminant releases; and (6) altered tidal, current, and hydrologic regimes.

Recommended Conservation Measures

The following recommended conservation measures for vessel operations, transportation infrastructure, and navigation, should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Locate marinas in areas of low biological abundance and diversity.
- Leave riparian buffers in place to help maintain water quality and nutrient input.

- Include low-wake vessel technology, appropriate routes, and BMPs for wave attenuation structures as part of the design and permit process.
- Incorporate BMPs to prevent or minimize contamination from ship bilge waters, antifouling paints, shipboard accidents, shipyard work, maintenance dredging and disposal, and nonpoint source contaminants from upland facilities related to vessel operations and navigation.
- Locate mooring buoys in water deep enough to avoid grounding and to minimize the effects of prop wash.
- Use catchment basins for collecting and storing surface runoff to remove contaminants prior to delivery to any receiving waters.
- Locate facilities in areas with enough water velocity to maintain water quality levels within acceptable ranges.
- Locate marinas where they do not interfere with natural processes so as to affect adjacent habitats.
- To facilitate movement of fish around breakwaters, breach gaps and construct shallow shelves to serve as “fish benches,” as appropriate.
- Harbor facilities should be designed to include practical measures for reducing, containing, and cleaning up petroleum spills.

1.4.4 Invasive Species

Introductions of invasive species into estuarine, riverine, and marine habitats have been well documented (Rosecchi et al. 1993, Kohler and Courtenay 1986, Spence et al. 1996) and can be intentional (e.g., for the purpose of stock or pest control) or unintentional (e.g., fouling organisms). Exotic fish, shellfish, pathogens, and plants can be spread via shipping, recreational boating, aquaculture, biotechnology, and aquariums. The introduction of nonindigenous organisms to new environments can have many severe impacts on habitat (Omori et al. 1994).

Invasive aquatic species that are considered high priority threats to Alaska’s marine waters include: Atlantic salmon (*Salmo salar*), green crab (*Carcinus maenas*), Chinese mitten crab (*Eriocheir sinensis*), signal crayfish (*Pacifastacus leniunculus*), zebra mussels (*Dreissena polymorpha*), New Zealand mudsnail (*Potamopyrgus antipodarum*), saltmarsh cordgrass (*Spartina alterniflora*), purple loosestrife (*Lythrum salicaria*), and tunicates (*Botrylloides violaceus* and *Didemnum vexillum*).²

Potential Adverse Impacts

Invasive species can create five types of negative effects on EFH: (1) habitat alteration, (2) trophic alteration, (3) gene pool alteration, (4) spatial alteration, and (5) introduction of diseases.

² <http://www.adfg.state.ak.us/special/invasive/invasive.ph>

Recommended Conservation Measures

The following recommended conservation measures for invasive species should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Uphold fish and game regulations of the Alaska Board of Fisheries (AS 16.05.251) and Board of Game (AS 16.05.255), which prohibit and regulate the live capture, possession, transport, or release of native or exotic fish or their eggs.
- Adhere to regulations and use best management practices outlined in the State of Alaska Aquatic Nuisance Species Management Plan (Fay 2002).
- Encourage vessels to perform a ballast water exchange in marine waters to minimize the possibility of introducing invasive estuarine species into similar habitats.
- Discourage vessels that have not performed a ballast water exchange from discharging their ballast water into estuarine receiving waters.
- Require vessels brought from other areas over land via trailer to clean any surfaces that may harbor non-native plant or animal species (e.g., propellers, hulls, anchors, fenders).
- Treat effluent from public aquaria displays and laboratories and educational institutes using non-native species before discharge.
- Encourage proper disposal of seaweeds and other plant materials used for packing purposes when shipping fish or other animals.
- Undertake a thorough scientific review and risk assessment before any non-native species are introduced.

1.4.5 Pile Installation and Removal (From NMFS 2005)

Pilings are an integral component of many overwater and in-water structures. They provide support for the decking of piers and docks, function as fenders and dolphins to protect structures, support navigation markers, and help in the construction of breakwaters and bulkheads. Materials used in pilings include steel, concrete, wood (both treated and untreated), plastic, or a combination thereof. Piles are usually driven into the substrate by using either impact or vibratory hammers.

1.4.5.1 Pile Driving

Potential Adverse Impacts

Pile driving can generate intense underwater sound pressure waves that may adversely affect EFH. These pressure waves have been shown to injure and kill fish (CalTrans 2001, Longmuir and Lively 2001, Stotz and Colby 2001, Stadler, pers. obs. 2002). Fish injuries associated directly with pile driving are poorly studied, but include rupture of the swim bladder and internal hemorrhaging (CalTrans 2001, Abbott and Bing-Sawyer 2002, Stadler pers. obs. 2002). Sound pressure levels (SPLs) 100 decibels (dB) above the threshold for hearing are thought to be sufficient to damage the auditory system in many fishes (Hastings 2002).

The type and intensity of the sounds produced during pile driving depend on a variety of factors, including the type and size of the pile, the firmness of the substrate into which the pile is being driven, the depth of water, and the type and size of the pile-driving hammer. Driving large hollow steel piles with impact hammers produces intense, sharp spikes of sound that can easily reach levels injurious to fish. Vibratory hammers, on the other hand, produce sounds of lower intensity, with a rapid repetition rate. A key difference between the sounds produced by impact hammers and those produced by vibratory hammers is the responses they evoke in fish. The differential responses to these sounds are due to the differences in the duration and frequency of the sounds.

Systems using air bubbles have been successfully designed to reduce the adverse effects of underwater SPLs on fish. Confined (i.e., metal or fabric sleeve) and unconfined air bubble systems have been shown to attenuate underwater sound pressures (Longmuir and Lively 2001, Christopherson and Wilson 2002, Reyff and Donovan 2003).

1.4.5.2 Recommended Conservation Measures

The following recommended conservation measures for pile driving should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Install hollow steel piles with an impact hammer at a time of year when larval and juvenile stages of fish species with designated EFH are not present.

If the first measure is not possible, then the following measures regarding pile driving should be incorporated when practicable to minimize adverse effects:

- Drive piles during low tide when they are located in intertidal and shallow subtidal areas.
- Use a vibratory hammer when driving hollow steel piles.
- Implement measures to attenuate the sound should SPLs exceed the 180 dB (re: 1 μ Pa) threshold.
- Surround the pile with an air bubble curtain system or air-filled coffer dam.
- Use a smaller hammer to reduce sound pressures.
- Use a hydraulic hammer if impact driving cannot be avoided.
- Drive piles when the current is reduced in areas of strong current, to minimize the number of fish exposed to adverse levels of underwater sound.

1.4.5.3 Pile Removal

Potential Adverse Impacts

The primary adverse effect of removing piles is the suspension of sediments, which may result in harmful levels of turbidity and release of contaminants contained in those sediments (see earlier). Vibratory pile removal tends to cause the sediments to slough off at the mudline, resulting in relatively low levels of suspended sediments and contaminants. Breaking or cutting the pile below the mudline may suspend only small amounts of sediment, providing that the stub is left in place, and little digging is required to access the pile. Direct pull or use of a clamshell to remove

broken piles may, however, suspend large amounts of sediment and contaminants. When the piling is pulled from the substrate using these two methods, sediments clinging to the piling will slough off as it is raised through the water column, producing a potentially harmful plume of turbidity and/or contaminants. The use of a clamshell may suspend additional sediment if it penetrates the substrate while grabbing the piling.

While there is a potential to adversely affect EFH during the removal of piles, many of the piles removed in Alaska are old creosote-treated timber piles. In some cases, the long-term benefits to EFH obtained by removing a chronic source of contamination may outweigh the temporary adverse effects of turbidity.

Recommended Conservation Measures

The following recommended conservation measures for pile removal should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Remove piles completely rather than cutting or breaking them off, if they are structurally sound.
- Minimize the suspension of sediments and disturbance of the substrate when removing piles. Measures to help accomplish this include, but are not limited to, the following:
 - When practicable, remove piles with a vibratory hammer.
 - Remove the pile slowly to allow sediment to slough off at, or near, the mudline.
 - The operator should first hit or vibrate the pile to break the bond between the sediment and the pile.
 - Encircle the pile, or piles, with a silt curtain that extends from the surface of the water to the substrate.
- Complete each pass of the clamshell to minimize suspension of sediment if pile stubs are removed with a clamshell.
- Place piles on a barge equipped with a basin to contain attached sediment and runoff water after removal.
- Using a pile driver, drive broken/cut stubs far enough below the mudline to prevent release of contaminants into the water column as an alternative to their removal.

1.4.6 Overwater Structures (from NMFS 2005)

Overwater structures include commercial and residential piers and docks, floating breakwaters, barges, rafts, booms, and mooring buoys. These structures typically are located in intertidal areas out to about 49 feet (15 meters) below the area exposed by the mean lower low tide (i.e., the shallow subtidal zone).

Potential Adverse Impacts

Overwater structures and associated developments may adversely affect EFH in a variety of ways, primarily by (1) changes in ambient light conditions, (2) alteration of the wave and current

energy regime, (3) introduction of contaminants into the marine environment, and (4) activities associated with the use and operation of the facilities (Nightingale and Simenstad 2001b).

Recommended Conservation Measures

The following recommended conservation measures for overwater structures should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Use upland boat storage whenever possible to minimize need for overwater structures.
- Locate overwater structures in deep enough waters to avoid intertidal and shade impacts, minimize or preclude dredging, minimize groundings, and avoid displacement of submerged aquatic vegetation, as determined by a preconstruction survey.
- Design piers, docks, and floats to be multiuse facilities to reduce the overall number of such structures and to limit impacted nearshore habitat.
- Incorporate measures that increase the ambient light transmission under piers and docks.
 - Maximize the height and minimize the width to decrease the shade footprint.
 - Use reflective materials on the underside of the dock to reflect ambient light.
 - Use the fewest number of pilings necessary to support the structures.
 - Align piers, docks, and floats in a north-south orientation to allow the arc of the sun to cross perpendicular to the structure and to reduce the duration of light limitation.
- Use floating rather than fixed breakwaters whenever possible, and remove them during periods of low dock use. Encourage seasonal use of docks and off-season haul-out.
- Locate floats in deep water to avoid light limitation and grounding impacts to the intertidal or shallow subtidal zone.
- Maintain at least 1 foot (0.30 meter) of water between the substrate and the bottom of the float at extreme low tide.
- Conduct in-water work when managed species and prey species are least likely to be impacted.
- To the extent practicable, avoid the use of treated wood timbers or pilings.
- Mitigate for unavoidable impacts to benthic habitats.

1.4.7 Flood Control/Shoreline Protection (from NMFS 2005)

Structures designed to protect humans from flooding events can result in varying degrees of change in the physical, chemical, and biological characteristics of shoreline and riparian habitat. These structures also can have long-term adverse effects on tidal marsh and estuarine habitats. Tidal marshes are highly variable, but typically have freshwater vegetation at the landward side, saltwater vegetation at the seaward side, and gradients of species in between that are in equilibrium with the prevailing climatic, hydrographic, geological, and biological features of the coast. These systems normally drain through tidal creeks that empty into the bay or estuary. Freshwater entering along the upper edges of the marsh drains across the surface and enters the

tidal creeks. Structures placed for coastal shoreline protection may include concrete or wood seawalls, rip-rap revetments (sloping piles of rock placed against the toe of the dune or bluff in danger of erosion from wave action), dynamic cobble revetments (natural cobble placed on an eroding beach to dissipate wave energy and prevent sand loss), vegetative plantings, and sandbags.

Potential Adverse Impacts

Dikes, levees, ditches, or other water controls at the upper end of a tidal marsh can cut off all tributaries feeding the marsh, preventing the flow of freshwater, annual renewal of sediments and nutrients, and the formation of new marshes. Water controls within the marsh can intercept and carry away freshwater drainage, thus blocking freshwater from flowing across seaward portions of the marsh, or conversely increase the speed of runoff of freshwater to the bay or estuary. This can result in lowering the water table, which may permit saltwater intrusion into the marsh, and create migration barriers for aquatic species. In deeper channels where anoxic conditions prevail, large quantities of hydrogen sulfide may be produced that are toxic to marsh grasses and other aquatic life (NMFS 2008). Acid conditions of these channels can also result in release of heavy metals from the sediments.

Long-term effects of shoreline protection structures on tidal marshes include land subsidence (sometimes even submergence), soil compaction, conversion to terrestrial vegetation, greatly reduced invertebrate populations, and general loss of productive wetland characteristics (NMFS 2005). Alteration of the hydrology of coastal salt marshes can reduce estuarine productivity, restrict suitable habitat for aquatic species, and result in salinity extremes during droughts and floods (NMFS 2008). Armoring shorelines to prevent erosion and to maintain or create shoreline real estate can reduce the amount of intertidal habitat, and affects nearshore processes and the ecology of numerous species (Williams and Thom 2001). Hydraulic effects on the shoreline include increased energy seaward of the armoring, reflected wave energy, dry beach narrowing, substrate coarsening, beach steepening, changes in sediment storage capacity, loss of organic debris, and downdrift sediment starvation (Williams and Thom 2001). Installation of breakwaters and jetties can result in community changes from burial or removal of resident biota, changes in cover and preferred prey species, and predator attraction (Williams and Thom 2001). As with armoring, breakwaters and jetties modify hydrology and nearshore sediment transport, as well as movement of larval forms of many species (Williams and Thom 2001).

Recommended Conservation Measures

The following recommended conservation measures for flood and shoreline protection should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Avoid or minimize the loss of coastal wetlands as much as possible.
- Do not dike or drain tidal marshlands or estuaries.
- Wherever possible, use soft in lieu of “hard” shoreline stabilization and modifications.
- Ensure that the hydrodynamics and sedimentation patterns are properly modeled and that the design avoids erosion to adjacent properties when “hard” shoreline stabilization is deemed necessary.

- Include efforts to preserve and enhance fishery habitat to offset impacts.
- Avoid installing new water control structures in tidal marshes and freshwater streams.
- Ensure water control structures are monitored for potential alteration of water temperature, dissolved oxygen concentration, and other parameters.
- Use seasonal restrictions to avoid impacts to habitat during critical life history stages.
- Address the cumulative impacts of development activities in the review process for flood control and shoreline protection projects.
- Use an adaptive management plan with ecological indicators to oversee monitoring and to ensure that mitigation objectives are met. Take corrective action as needed.

1.4.8 Log Transfer Facilities/In-Water Log Storage (from NMFS 2005)

Rivers, estuaries, and bays were historically the primary ways to transport and store logs in the Pacific Northwest, and log storage continues in some tidal areas today. Using estuaries and bays and nearby uplands for storage of logs is common in Alaska, with most log transfer facilities (LTFs) found in Southeast Alaska and a few located in Prince William Sound. LTFs are facilities that are constructed wholly or in part in waterways and used to transfer commercially harvested logs to or from a vessel or log raft, or for consolidating logs for incorporation into log rafts (USEPA 2000b). LTFs may use a crane, A-frame structure, conveyor, slide, or ramp to move logs from land into the water. Logs can also be placed in the water at the site by helicopters.

Potential Adverse Impacts

Log handling and storage in the estuaries and intertidal zones can result in modification of benthic habitat and water quality degradation within the area of bark deposition (Levings and Northcote 2004). EFH may be physically impacted by activities associated with LTFs. LTFs may cause shading and other indirect effects similar in many ways to those of floating docks and other over-water structures (see earlier).

Recommended Conservation Measures

The following recommended conservation measures for log transfer and storage facilities should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

The physical, chemical, and biological impacts of LTF operations can be substantially reduced by adherence to appropriate siting and operational constraints. Adherence to the Alaska Timber Task Force (ATTF) operational and siting guidelines and BMPs in the National Pollutant Discharge Elimination System (NPDES) General Permit will reduce (1) the amount of bark and wood debris that enters the marine and coastal environment, (2) the potential for displacement or harm to aquatic species, and (3) the accumulation of bark and wood debris on the ocean floor. The following conservation measures reflect those guidelines.³

³ See also http://www.fs.fed.us/r10/TLMP/F_PLAN/APPEND_G.PDF.

- Restrict or eliminate storage and handling of logs from waters where state and federal water quality standards cannot be met at all times outside of the authorized zone of deposition.
- Minimize potential impacts of log storage by employing effective bark and wood debris control, collection, and disposal methods at log dumps, raft building areas, and mill-side handling zones; avoiding free-fall dumping of logs; using easy let-down devices for placing logs in the water; and bundling logs before water storage (bundles should not be broken except on land and at millside).
- Do not store logs in the water if they will ground at any time or shade sensitive aquatic vegetation such as eelgrass.
- Avoid siting log-storage areas and LTFs in sensitive habitat and areas important for specified species, as required by the ATTF guidelines.
- Site log storage areas and LTFs in areas with good currents and tidal exchanges.
- Use land-based storage sites where possible.

1.4.9 Utility Line, Cables, and Pipeline Installation

With the continued development of coastal regions comes greater demand for the installation of cables, utility lines for power and other services, and pipelines for water, sewage, and other utilities. The installation of pipelines, utility lines, and cables can have direct and indirect impacts on the offshore, nearshore, estuarine, wetland, beach, and rocky shore coastal zone habitats. Many of the direct impacts occur during construction, such as ground disturbance in the clearing of the right-of-way, access roads, and equipment staging areas. Indirect impacts can include increased turbidity, saltwater intrusion, accelerated erosion, and introduction of urban and industrial pollutants due to ground clearing and construction.

Potential Adverse Impacts

Adverse effects on EFH from the installation of pipelines, utility lines, and cables can occur through (1) destruction of organisms and habitat, (2) turbidity impacts, (3) resuspension and release of contaminants, (4) changes in hydrology, and (5) destruction of vertically complex hard bottom habitat (e.g., hard corals and vegetated rocky reef).

Recommended Conservation Measures

The following recommended conservation measures for cable and utility line installation should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Align crossings along the least environmentally damaging route.
- Use horizontal directional drilling where cables or pipelines would cross anadromous fish streams, salt marsh, vegetated inter-tidal zones, or steep erodible bluff areas adjacent to the intertidal zone.
- Store and contain excavated material on uplands.

- Backfill excavated wetlands with either the same or comparable material capable of supporting similar wetland vegetation, and at original marsh elevations.
- Use existing rights-of-way whenever possible.
- Bury pipelines and submerged cables where possible.
- Remove inactive pipelines and submerged cables unless they are located in sensitive areas (e.g., marsh, reefs, sea grass).
- Use silt curtains or other barriers to reduce turbidity and sedimentation whenever possible.
- Limit access for equipment to the immediate project area. Tracked vehicles are preferred over wheeled vehicles.
- Limit construction equipment to the minimum size necessary to complete the work.
- Conduct construction during the time of year when it will have the least impact on sensitive habitats and species.
- Suspend transmission lines beneath existing bridges or conduct directional boring under streams to reduce the environmental impact.
- For activities on the Continental Shelf, implement the following to the extent practicable:
 - Shunt drill cuttings through a conduit and either discharge the cuttings near the sea floor, or transport them ashore.
 - Locate drilling and production structures, including pipelines, at least 1 mile (1.6 kilometers) from the base of a hard-bottom habitat.
 - Bury pipelines at least 3 feet (0.9 meter) beneath the sea floor whenever possible.
 - Locate alignments along routes that will minimize damage to marine and estuarine habitat.

1.4.10 Mariculture

Productive embayments are often used for commercial culturing and harvesting operations. These locations provide protected waters for geoduck, oyster, and mussel culturing. In 1988, Alaska passed the Alaska Aquatic Farming Act (AAF Act), which is designed to encourage establishment and growth of an aquatic farming industry in the state. The AAF Act establishes four criteria for issuance of an aquatic farm permit, including the requirement that the farm may not significantly affect fisheries, wildlife, or other habitats in an adverse manner. Aquatic farm permits are issued by the Alaska Department of Natural Resources (ADNR).

Potential Adverse Impacts

Shellfish aquaculture tends to have less impact on EFH than finfish aquaculture because the shellfish generally are not fed or treated with chemicals (OSPAR Commission 2009). Adverse impacts to EFH by mariculture operations include (1) risk of introducing undesirable species and disease; (2) physical disturbance of intertidal and subtidal areas; and (3) impacts on estuarine food webs, including disruption of eelgrass habitat (e.g., dumping of shell on eelgrass beds, repeated mechanical raking or trampling, and impacts from predator exclusion netting, though

few studies have documented impacts). Hydraulic dredges used to harvest oysters in coastal bays can cause long-term adverse impacts to eelgrass beds by reducing or eliminating the beds (Phillips 1984).

Recommended Conservation Measures

The following recommended conservation measures for mariculture facilities should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Site mariculture operations away from kelp or eelgrass beds.
- Do not enclose or impound tidally influenced wetlands for mariculture.
- Undertake a thorough scientific review and risk assessment before any non-native species are introduced.
- Encourage development of harvesting methods to minimize impacts on plant communities and the loss of food and/or habitat to fish populations during harvesting operations.
- Provide appropriate mitigation for the unavoidable, extensive, or permanent loss of plant communities.
- Ensure that mariculture facilities, spat, and related items transported from other areas are free of nonindigenous species.

1.5 Coastal/Marine Activities

1.5.1 Point-Source Discharges

Point source pollutants are generally introduced via some type of pipe, culvert, or similar outfall structure. These discharge facilities typically are associated with domestic or industrial activities, or in conjunction with collected runoff from roadways and other developed portions of the coastal landscape. Waste streams from sewage treatment facilities and watershed runoff may be combined in a single discharge. Point source discharges introduce inorganic and organic contaminants into aquatic habitats, where they may become bioavailable to living marine resources.

Potential Adverse Impacts (adopted from NMFS 2008)

The Clean Water Act (CWA) includes important provisions to address acute or chronic water pollution emanating from point source discharges. Under the NPDES program, most point-source discharges are regulated by the state or EPA. While the NPDES program has led to ecological improvements in U.S. waters, point sources continue to introduce pollutants into the aquatic environment, albeit at reduced levels.

Determining the fate and effect of natural and synthetic contaminants in the environment requires an interdisciplinary approach to identify and evaluate all processes sensitive to pollutants. This is critical as adverse effects may be manifested at the biochemical level in organisms (Luoma 1996) in a manner particular to the species or life stage exposed. Exposure to

pollutants can inhibit (1) basic detoxification mechanisms, e.g., production of metallothioneins or antioxidant enzymes; (2) disease resistance; (3) the ability of individuals or populations to counteract pollutant-induced metabolic stress; (4) reproductive processes including gamete development and embryonic viability; (5) growth and successful development through early life stages; (6) normal processes including feeding rate, respiration, osmoregulation; and (7) overall Darwinian fitness (Capuzzo and Sassner 1977; Widdows et al. 1990; Nelson et al. 1991; Stiles et al. 1991; Luoma 1996; Thurberg and Gould 2005).

Recommended Conservation Measures

The following recommended conservation measures for point source discharges should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Locate discharge points in coastal waters well away from shellfish beds, sea grass beds, corals, and other similar fragile and productive habitats.
- Reduce potentially high velocities by diffusing effluent to acceptable velocities.
- Determine baseline benthic productivity by sampling before any construction activity.
- Provide for mitigation when degradation or loss of habitat occurs.
- Institute source-control programs that effectively reduce noxious materials.
- Ensure compliance with pollutant discharge permits, which set effluent limitations and/or specify operation procedures, performance standards, or BMPs.
- Treat discharges to the maximum extent practicable.
- Use land-treatment and upland disposal/storage techniques where possible.
- Avoid siting pipelines and treatment facilities in wetlands and streams.

1.5.2 Seafood Processing Waste—Shoreside and Vessel Operation

Seafood processing is conducted throughout much of coastal Alaska. Processing facilities may be vessel-based or located onshore (ADEC 2010a). Seafood processing facilities generally consist of mechanisms to offload the harvest from fishing boats; tanks to hold the seafood until the processing lines are ready to accept them; processing lines, process water, and waste collection systems; treatment and discharge facilities; processed seafood storage areas; and necessary support facilities such as electrical generators, boilers, retorts, water desalinators, offices, and living quarters. In addition, recreational fish cleaning at marinas and small harbors can produce a large quantity of fish waste.

Pollutants of concern from seafood processing wastewater are primarily components of the biological wastes generated by processing raw seafood into a marketable form, chemicals used to maintain sanitary conditions for processing equipment and fish containment structures, and refrigerants (ammonia and freon) that may leak from refrigeration systems used to preserve seafood (ADEC 2010b). Biological wastes include fish parts (e.g., heads, fins, bones, and entrails) and chemicals, which are primarily disinfectants that must be used in accordance with EPA specifications.

Potential Adverse Impacts

Seafood processing operations have the potential to adversely affect EFH through the discharge of nutrients, chemicals, fish byproducts, and “stickwater” (water and entrained organics originating from the draining or pressing of steam-cooked fish products). Seafood processing discharges influence nutrient loading, eutrophication, and anoxic and hypoxic conditions significantly influencing marine species diversity and water quality (Theriault et al. 2006, Roy Consultants 2003, Lotze et al. 2003). Although fish waste is biodegradable, fish parts that are ground to fine particles may remain suspended for some time, thereby overburdening habitats from particle suspension (NMFS 2005). Scum and foam from seafood waste deposits can also occur on the water surface and/or increase turbidity. Turbidity decreases light penetration into the water column, reducing primary production. In addition, stickwater takes the form of a fine gel or slime that can concentrate on surface waters and move onshore to cover intertidal areas.

Recommended Conservation Measures

The following recommended conservation measures for fish processing waste should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- To the maximum extent practicable, base effluent limitations on site-specific water quality concerns.
- Encourage the use of secondary or wastewater treatment systems where possible.
- Do not allow designation of new zones of deposit for fish processing waste and instead seek disposal options that avoid an accumulation of waste.
- Promote sound recreational fish waste management through a combination of fish-cleaning restrictions, public education, and proper disposal of fish waste.
- Encourage alternative uses of fish processing wastes.
- Explore options for additional research.
- Monitor biological and chemical changes to the site of processing waste discharges.

1.5.3 Water Intake Structures/Discharge Plumes

Withdrawals of riverine, estuarine, and marine waters are common for a variety of uses such as to cool power-generating stations and create temporary ice roads and ice ponds. In the case of power plants, the subsequent discharge of heated and/or chemically treated discharge water can also occur.

Potential Adverse Impacts

Water intake structures and effluent discharges can interfere with or disrupt EFH functions in the source or receiving waters by (1) entrainment, (2) impingement, (3) degrading water quality, (4) operation and maintenance, and (5) construction-related impacts.

Recommended Conservation Measures

The following recommended conservation measures for water intakes and discharges should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Locate facilities that rely on surface waters for cooling in areas other than estuaries, inlets, heads of submarine canyons, rock reefs, or small coastal embayments where managed species or their prey concentrate.
- Design intake structures to minimize entrainment or impingement.
- Design power plant cooling structures to meet the best technology available requirements as developed pursuant to section 316(b) of the CWA.
- Regulate discharge temperatures so they do not appreciably alter the ambient temperature to an extent that could cause a change in species assemblages and ecosystem function in the receiving waters.
- Avoid the use of biocides (e.g., chlorine) to prevent fouling where possible.
- Treat all discharge water from outfall structures to meet state water quality standards at the terminus of the pipe.

1.5.4 Oil and Gas Exploration, Development, and Production

Two agencies, the Bureau of Ocean Energy Management and the Bureau of Safety and Environmental Enforcement are responsible for regulating oil and gas operations on the Outer Continental Shelf (OCS). The ADNRR Division of Oil and Gas exercises similar authority over state waters (ADNRR1999). Offshore petroleum exploration, development, and production activities have been conducted in Alaska waters or on the Alaska OCS in since the 1960s (Kenai Peninsula Borough 2004). As demand for energy resources grows, the debate over trying to balance the development of oil and gas resources and the protection of the environment will also continue.

Potential Adverse Impacts

Offshore oil and gas operations can be classified into exploration, development, and production activities (which includes transportation). These activities occur at different depths in a variety of habitats, and can cause an assortment of physical, chemical, and biological disturbances (NMFS 2005, Helvey 2002). (Some of these disturbances are listed below; however, not all of the potential disturbances in this list apply to every type of activity.)

- Noise from seismic surveys, vessel traffic, and construction of drilling platforms or islands
- Physical alterations to habitat from the construction, presence, and eventual decommissioning and removal of facilities such as islands or platforms, storage and production facilities, and pipelines to onshore common carrier pipelines, storage facilities, or refineries
- Waste discharges, including well drilling fluids, produced waters, surface runoff and deck drainage, domestic waste waters generated from the offshore facility, solid waste from

wells (drilling muds and cuttings), and other trash and debris from human activities associated with the facility

- Oil spills
- Platform storage and pipeline decommissioning

The potential disturbances and associated adverse impacts on the marine environment have been reduced through operating procedures required by regulatory agencies and, in many cases, self-imposed by facilities operators. Most of the activities associated with oil and gas operations are conducted under permits and regulations that require companies to minimize impacts or avoid construction in sensitive marine habitats. New technological advances in operating procedures also reduce the potential for impacts.

Recommended Conservation Measures

The following recommended conservation measures for oil and gas exploration and development should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH:

- Avoid the discharge of produced waters into marine waters and estuaries.
- Avoid discharge of muds and cuttings into the marine and estuarine environment.
- To the extent practicable, avoid the placement of fill to support construction of causeways or structures in the nearshore marine environment.
- As required by federal and state regulatory agencies, encourage the use of geographic response strategies that identify EFH and environmentally sensitive areas.
- Evaluate potential impacts to EFH that may result from activities carried out during the decommissioning phase of oil and gas facilities.
- Vessel operations and shipping activities should be familiar with Alaska Geographic Response Strategies which detail environmentally sensitive areas of Alaska's coastline.

1.5.5 Habitat Restoration and Enhancement

Habitat loss and degradation are major, long-term threats to the sustainability of fishery resources (NMFS 2002). Viable coastal and estuarine habitats are important to maintaining healthy fish stocks. Good water quality and quantity, appropriate substrate, ample food sources, and adequate shelter from predators are needed to sustain fisheries. Restoration and/or enhancement of coastal and riverine habitat that supports managed fisheries and their prey will assist in sustaining and rebuilding fish stocks by increasing or improving ecological structure and functions. Habitat restoration and enhancement may include, but is not limited to, improvement of coastal wetland tidal exchange or reestablishment of natural hydrology; dam or berm removal; fish passage barrier removal or modification; road-related sediment source reduction; natural or artificial reef, substrate, or habitat creation; establishment or repair of riparian buffer zones; improvement of freshwater habitats that support anadromous fishes; planting of native coastal wetland and submerged aquatic vegetation; and improvements to feeding, shade or refuge, spawning, and rearing areas that are essential to fisheries.

Potential Adverse Impacts

The implementation of restoration and enhancement activities may have localized and temporary adverse impacts on EFH. Possible impacts can include (1) localized nonpoint source pollution such as influx of sediment or nutrients, (2) interference with spawning and migration periods, (3) temporary removal feeding opportunities, (4) indirect effects from construction phase of the activity, (5) direct disturbance or removal of native species, and (6) temporary or permanent habitat disturbance.

Recommended Conservation Measures

The following recommended conservation measures for habitat restoration and enhancement should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Use BMPs to minimize and avoid potential impacts to EFH during restoration activities.
 - Use turbidity curtains, hay bales, and erosion mats.
 - Plan staging areas in advance, and keep them to a minimum size.
 - Establish buffer areas around sensitive resources.
 - Remove invasive plant and animal species from the proposed action area before starting work. Plant only native plant species.
 - Establish temporary access pathways before restoration activities.
- Avoid restoration work during critical life stages for fish such as spawning, nursery, and migration.
- Provide adequate training and education for volunteers and project contractors to ensure minimal impact to the restoration site.
- Conduct monitoring before, during, and after project implementation.
- To the extent practicable, mitigate any unavoidable damage to EFH.
- Remove and, if necessary, restore any temporary access pathways and staging areas used.
- Determine benthic productivity by sampling before any construction activity in the case of subtidal enhancement (e.g., artificial reefs). Avoid areas of high productivity to the maximum extent possible.

1.5.6 Marine Mining

Mining activities, which are also described in Sections 3.1.1 and 3.1.2 of the EFH EIS (NMFS 2005), can lead to the direct loss or degradation of EFH for certain species. Offshore mining, such as the extraction of gravel and gold in the Bering Sea, can increase turbidity, and resuspension of organic materials could impact eggs and recently hatched larvae in the area. Mining large quantities of beach gravel can also impact turbidity, and may significantly affect the transport and deposition of sand and gravel along the shore, both at the mining site and down-current (NMFS 2005).

Potential Adverse Impacts

Impacts from mining on EFH include both physical impacts (i.e., intertidal dredging) and chemical impacts (i.e., additives such as flocculants) (NMFS 2005). Physical impacts may include the removal of substrates that serve as habitat for fish and invertebrates; habitat creation or conversion in less productive or uninhabitable sites, such as anoxic holes or silt bottom; burial of productive habitats, such as in near-shore disposal sites (as in beach nourishment); release of harmful or toxic materials either in association with actual mining, or in connection with machinery and materials used for mining; creation of harmful turbidity levels; and adverse modification of hydrologic conditions so as to cause erosion of desirable habitats. Submarine disposal of mine tailings can also alter the behavior of marine organisms.

Recommended Conservation Measures

The following recommended conservation measures for marine mining should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- To the extent practicable, avoid mining in waters containing sensitive marine benthic habitat, including EFH (e.g., spawning, migrating, and feeding sites).
- Minimize the areal extent and depth of extraction to reduce recolonization times.
- Monitor turbidity during operations, and cease operations if turbidity exceeds predetermined threshold levels.
- Monitor individual mining operations to avoid and minimize cumulative impacts.
- Use seasonal restrictions as appropriate; to avoid and minimize impacts to EFH during critical life history stages of managed species (e.g., migration and spawning).
- Deposit tailings within as small an area as possible.

1.6 References

- Abbe, T.B. and D.R. Montgomery. 1996. "Large woody debris jams, channel hydraulics, and habitat formation in large rivers." *Regulated Rivers: Research and Management*. 12:201-221.
<http://www.cems.uvm.edu/ce361/papers/abbe1996.pdf>
- Abbott, R. and E. Bing-Sawyer. 2002. Assessment of pile driving impacts on the Sacramento blackfish (*Othodon microlepidotus*). Draft report prepared for Caltrans District 4. October 10, 2002.
- Alaska Department of Environmental Conservation (ADEC). 2010a. Ocean Discharge Criteria Evaluation Alaska Offshore Seafood Processors APDES General Permit AKG523000. Prepared by Tetra Tech, 10306 Eaton Place Suite 340, Fairfax, VA 22030. 152 pp.
- ADEC. 2010b. Wastewater Discharge Authorization Program, 555 Cordova Street, Anchorage, AK 99501. Fact Sheet Alaska Offshore Seafood Processors General Permit AKG523000. 43 pp.
- Alaska Department of Natural Resources (ADNR). 1999. Cook Inlet Areawide 1999 Oil and Gas Lease Sale, Final Finding of the Director. Volume II. Appendix B: "Laws and Regulations Pertaining to Oil and Gas Exploration, Development, Production, and Transportation."

- American Fisheries Society (AFS). 2000. AFS Policy Statement #13: Effects of Surface Mining on Aquatic Resources in North America (Revised). (Abbreviated) http://www.fisheries.org/afs/docs/policy_13f.pdf
- Arruda, J.A., G.R. Marzolf, R.T. Faulk. 1983. The role of suspended sediments in the nutrition of zooplankton in turbid reservoirs. *Ecology* 64(5):1225-35.
- Atlantic States Marine Fisheries Commission. 1992. Fishery management plan for inshore stocks of winter flounder. Washington (DC): ASMFC. FMR No. 21. 138 p.
- Barr BW. 1993. Environmental impacts of small boat navigation: vessel/sediment interactions and management implications. In: Magoon OT, editor. Coastal Zone '93: proceedings of the eighth Symposium on Coastal and Ocean Management; 1993 Jul 19-23; New Orleans, LA. American Shore and Beach Preservation Association. p 1756-70.
- Benfield, M.C. and T. J. Minello. 1996. "Relative effects of turbidity and light intensity on reactive distance and feeding of an estuarine fish." *Environmental Biology of Fishes*. 46:211-216.
- Brix, K.V., D.K. DeForest, and W.J. Adams 2001. Assessing acute and chronic copper risks to freshwater aquatic life using species sensitivity distributions for different taxonomic groups. *Environmental Toxicology and Chemistry*. 20(8): 1846-1856.
- CalTrans. 2001. Fisheries Impact Assessment, Pile Installation Demonstration Project for the San Francisco - Oakland Bay Bridge, East Span Seismic Safety Project, August 2001. 59 pp.
- Capuzzo J.M., and J.J. Sassner Jr. 1977. The effect of chromium on filtration rates and metabolic activity of *Mytilus edulis* L. and *Mya arenaria* L. In: Vernberg FJ, and others, editors. Physiological responses of marine biota to pollutants. San Diego (CA): Academic Press. p 225-37.
- Center for Watershed Protection (CWP). 2003. Impacts of Impervious Cover on Aquatic Systems. Elliott City, MD, www.cwp.org. 141 pp.
- Christopherson, A. and J. Wilson. 2002. Technical Letter Report Regarding the San Francisco-Oakland Bay Bridge East Span Project Noise Energy Attenuation Mitigation. Peratrovich, Nottingham & Drage, Inc. Anchorage, Alaska. 27 pp.
- Cloern, J.E. 1987. "Turbidity as a control on phytoplankton biomass and productivity in estuaries." *Continental Shelf Research*. 7:1367-1381.
- Conner, Billy, Director Alaska University Transportation Center. University of Alaska, Fairbanks PO Box 755900. 2007 Interview in Building Alaska. http://www.buildingalaskamovie.com/interviews_billy.html
- Deegan, L.A. and R.N. Buchsbaum. 2005. The effect of habitat loss and degradation on fisheries. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline on fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 67-96.
- Dennison, W.C. 1987. "Effect of light on seagrass photosynthesis, growth and depth distribution." *Aquatic Botany*. 27:15-26.
- Dugan, J.E., D.M. Hubbard, D.L. Martin, J.M. Engle, D.M. Richards, G.E. Davis, K.D. Lafferty, and R.F. Ambrose. 2000. Macrofauna communities of exposed sandy beaches on the Southern California mainland and Channel Islands. pp 339-346. In Brown, D.R., K.L. Mitchell, and H.W. Chang, eds. Proceedings of the Fifth California Islands Symposium. Minerals Management Service Publication # 99-0038.

- Farag, A.M., D.A. Skaar, E. Nimick, C. MacConnell, and C. Hogstrand. 2003. Characterizing aquatic health using salmonids mortality, physiology, and biomass estimates in streams with elevated concentrations of arsenic, cadmium, copper, lead, and zinc in the Boulder River Watershed, Montana. *Transaction of the American Fisheries Society* 132(3): 450-457.
- Fay, V. 2002. Alaska Aquatic Nuisance Species Management Plan. Alaska Department of Fish and Game Publication. Juneau, AK. http://www.adfg.state.ak.us/special/invasive/ak_ansmp.pdf.
- Goldstein, J.N., D.F. Woodward, and A.M. Farag. 1999. Movement of adult Chinook salmon during spawning migration in a metals-contaminated system, Coeur d'Alene River, Idaho. *Transactions of the American Fisheries Society* 128:121-129.
- Gregory, S.V. and P.A. Bisson. 1997. Degradation and loss of anadromous salmonid habitat in the Pacific Northwest. In Stouder, J.D., P.A. Bisson, and R.J. Naiman, eds. *Pacific Salmon and Their Ecosystems: Status and Future Options*, pp. 277-314. Chapman and Hall, New York.
- Groundwater Protection Council. 2010. State Groundwater Fact Sheets. http://www.gwpc.org/e-library/documents/state_fact_sheets/alaska.pdf. Ground Water Protection Council, 13308 N. MacArthur Blvd., Oklahoma City, OK 73142.
- Hansen, J.A., Lipton J., and Welsh P.G. 2002. *Environmental toxicology and chemistry*. 21 (3): 633-639
- Hastings, M.C. 2002. Clarification of the meaning of sound pressure levels and the known effects of sound on fish. Document in support of Biological Assessment for San Francisco-Oakland Bay Bridge East Span Seismic Safety Project. August 26, 2002. Revised August 27, 2002. 8 pp.
- Helvey, M. 2002. "Are southern California oil and gas platforms essential fish habitat?" *ICES Journal of Marine Science*. 59:S266-S271.
- Kenai Peninsula Borough. 2004. Cook Inlet Oil and Gas, Kenai Peninsula Borough Oil and Gas History. <http://www.cookinletoilandgas.org/kpb/history.htm>
- Kohler, C.C. and W.R. Courtenay, Jr. 1986. "Introduction of aquatic species." *Fisheries*. 11(2):39-42. Proceedings of the Seventh International Zebra Mussel and Aquatic Nuisance Species Conference. 1997.
- Koski, K.V. 1992. Restoring stream habitats affected by logging activities. Pages 343-404 in G. W. Thayer (editor) *Restoring the nation's marine environment*. Publication UM-SG-TS-92-06. Maryland Sea Grant College, College Park, MD.
- Larson, K. and C. Moehl. 1990. Entrainment of anadromous fish by hopper dredge at the mouth of the Columbia River. In C.A. Simenstad, ed. *Effects of dredging on anadromous Pacific coast fishes*. University of Washington Sea Grant. pp. 102-112.
- Levings, C.D. and T. G. Northcote. 2004. Effects of forestry on estuarine ecosystems supporting fishes. In T.G. Northcote and G.F. Hartman, editors, *Fishes and Forestry Worldwide Watershed Interactions and Management*, Blackwell Publishing, pp 320 -335.
- Longmuir, C. and T. Lively. 2001. Bubble curtain systems for use during marine pile driving. Report by Fraser River Pile & Dredge Ltd., New Westminster, British Columbia. 9 pp.
- Lotze, H., I. Milewski, B. Worm, and Z. Koller. 2003 *Nutrient Pollution: A Eutrophication Survey of Eelgrass Beds in Estuaries and Coastal Bays in Northern and Eastern New Brunswick*. Conservation Council of New Brunswick Inc.

- Luce, A. and M.Crowe. 2001. "Invertebrate terrestrial diversity along a gravel road on Barrie Island, Ontario, Canada." *Great Lakes Entomologist*. 34(1):55-60 SPR-SUM.
- Luoma, S.N. 1996. The developing framework of marine ecotoxicology: pollutants as a variable in marine ecosystems. *Journal of Experimental Marine Biology and Ecology* 200:29-55.
- Maser, C. and J.R. Sedell. 1994. *From the Forest to the Sea: the Ecology of Wood in Streams, Estuaries and Oceans*. St. Lucie Press, Delray Beach, FL. 200 pp.
- McGraw, K. and D. Armstrong. 1990. Fish entrainment by dredges in Grays Harbor, Washington. In C.A. Simenstad, ed. *Effects of dredging on anadromous Pacific coast fishes*. University of Washington Sea Grant. pp. 113-131.
- Mitsch WJ, Gosselink JG. 1993. *Wetlands*. 2nd ed. New York (NY): Van Nostrand Reinhold. 722 pp.
- Montgomery, D.R., R.D. Smith, K.M. Schmidt, and G.R. Pess. 1995. "Pool Spacing in Forest Channels." *Water Resources Research*. 31:1097-1105.
- NMFS. 2011. Impacts to Essential Fish Habitat from Non-fishing Activities in Alaska. National Marine Fisheries Service, Alaska Region. Juneau, Alaska. November, 2011.
- NMFS. 2008. Impacts to Marine Fisheries Habitat from Nonfishing Activities in the Northeastern United States. Northeast Regional Office Gloucester, Massachusetts NOAA Technical Memorandum NMFS-NE-209.
- NMFS. 2005. Final Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska, Appendix G Non-fishing Impacts to Essential Fish Habitat and Recommended Conservation Measures.
- NMFS. 2004. Draft National Gravel Extraction Policy. 1335 East-West Highway, Silver Spring, MD 20910. <http://www.nmfs.noaa.gov/habitat/habitatprotection/pdf/gravelguidance.pdf>
- NMFS. 2002. Environmental Assessment, NMFS' Restoration Plan for the Community-Based Restoration Program. Prepared by the NOAA Restoration Center, Office of Habitat Conservation. Silver Spring, MD.
- NMFS. 1998a. Draft document - Non-fishing threats and water quality: A reference for EFH consultation
- NMFS. 1998b. Final recommendations: Essential Fish Habitat for Pacific Coast Groundfish. Prepared by: The Core Team for EFH for Pacific Coast Groundfish June 3, 1998. 2725 Montlake Blvd. E. Seattle, WA 98112. http://www.psmfc.org/efh/groundfish_desc.pdf.
- National Oceanic and Atmospheric Agency (NOAA). 2010. Office of Ocean and Coastal Resource Management. Ocean and Coastal Management in Alaska. <http://coastalmanagement.noaa.gov/mystate/ak.html>.
- NRC. 1999. Committee on Hardrock Mining. Hardrock Mining on Federal Lands. Appendix B. Potential Environmental Impacts of Hardrock Mining. (http://www.nap.edu/html/hardrock_fed_land/appB.html).
- Nelson D, Miller J, Rusanowsky D, Greig R, Sennefelder G, Mercaldo-Allen R, Kuropat C, Gould E, Thurberg F, Calabrese A. 1991. Comparative reproductive success of winter flounder in Long Island Sound: a three-year study (biology, biochemistry, and chemistry). *Estuaries* 14(3):318-31.
- Newell, R.C., L.J. Seiderer, and D.R. Hitchcock. 1998. "The impact of dredging on biological resources of the sea bed." *Oceanography and Marine Biology Annual Review*. 36:127-178.

- Nightingale, B. and C.A. Simenstad. 2001a. Dredging activities: Marine issues. Washington State Transportation Center, University of Washington, Seattle, WA 98105. (Document available through the National Technical Information Service, Springfield, VA 22616).
- Nightingale, B. and C.A. Simenstad. 2001b. Overwater Structures: Marine Issues. White paper submitted to Washington Department of Fish and Wildlife, Washington Department of Ecology and Washington Department of Transportation. www.wa.gov/wdfw/hab. 133 pp.
- North Pacific Fishery Management Council and NMFS. 2010. Essential Fish Habitat (EFH) 5-year Review for 2010 Summary Report: Final. April 2010. <http://www.alaskafisheries.noaa.gov/habitat/efh/review.htm>.
- Northcote, T.G. and G.F. Hartman. 2004. Fishes and Forestry - Worldwide Watershed Interactions and Management, Blackwell Publishing, Oxford, UK, 789 pp.
- Omori, M., S. Van der Spoel, C.P. Norman. 1994. Impact of human activities on pelagic biogeography. *Progress in Oceanography* 34 (2-3):211-219.
- Oregon Water Resource Research Institute (OWRRI). 1995. Gravel disturbance impacts on salmon habitat and stream health, volume 1. Summary report. Oregon State University, Corvallis, Oregon. (Also available Vol. II: Technical background report). Available from Oregon Division of State Lands, Salem, Oregon, 503-378-3805.
- OSPAR Commission. 2009. Assessment of Impacts of Mariculture . Publication Number: 442/2009. London, UK
- Pacific Fishery Management Council (PFMC). 1999. Appendix A: Identification and description of essential fish habitat, adverse impacts, and recommended conservation measures for salmon. Amendment 14 to the Pacific Coast Salmon Plan. Portland, OR. 146 pp.
- Packer, D.B., Griffin K., McGlynn K.E. 2005. National Marine Fisheries Service national gravel extraction guidance. Washington (DC): US Department of Commerce. NOAA Technical Memorandum NMFS-F/SPO-70. [cited 2008 Jul 15]. 27 p. Available from: <http://www.nmfs.noaa.gov/habitat/habitatprotection/anadfish/gravel.htm>.
- Phillips, R.C. 1984. The ecology of eelgrass meadows in the Pacific Northwest: a community profile. U.S. Fish and Wildlife Service. FWS/OBS-84/24. 85 pp.
- Ralph, S., G. Poole, L. Conquest, and R. Naiman. 1994. "Stream channel morphology and woody debris in logged and unlogged basins in western Washington." *Can. J. Fish. Aquatic Sciences*. 51:37-51.
- Reyff, J.A and P. Donovan. 2003. Benicia-Martinez Bridge Bubble Curtain Test - Underwater Sound Measurement Data. Memo to Caltrans dated January 31, 2003. 3 pp.
- Robinson W.E., and Pederson J. 2005. Contamination, habitat degradation, overfishing - An "either-or" debate? In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 1-10.
- Rosecchi, E., A.J. Crivelli, G. Catsadorakis. 1993. The establishment and impact of *Pseudorasbora parva*, an exotic fish species introduced into lake Mikri Prespa (northwestern Greece). *Aquatic Conservation: Marine and Freshwater Ecosystems* 3:223-231.
- Roy Consultants Ltd., NATECH Environmental Services Inc. and OCL Group. Environmental Management Consultants. 2003. Lamèque Bay environmental management study. Report No. 133-01.

- Scott G.I., M.H. Fulton, D.W. Moore, E.F. Wirth, G.T. Chandler, P.B. Key, J.W. Daugomah, E.D. Strozier, J. Devane, J.R. Clark, M.A. Lewis, D.B. Finley, W. Ellenberg, and K.J. Karnaky. 1999. "Assessment of risk reduction strategies for the management of agricultural nonpoint source pesticide runoff in estuarine ecosystems." *Toxicology and Industrial Health*. 15:200-213.
- Sedell, J.R., and K.J. Luchessa. 1982. Using the historical record as an aid to salmonid habitat enhancement. In Armantrout, N.B. (ed.), *Acquisition and utilization of aquatic habitat inventory information*, p. 210-222. American Fisheries Society, Western Division, Bethesda, MD.
- Sengupta, M. 1993. *Environmental Impacts of Mining: Monitoring, Restoration, and Control*. CRC Press, Inc. 2000 Corporate Blvd., N.W. Boca Raton, FL. 33431. p.1.
- Spence, B.C., G.A. Lomnický, R.M. Hughes, and R.P. Novitzki. 1996. An ecosystem approach to salmonid conservation. TR-4501-96-6057. ManTech Environmental Research Services Corp., Corvallis, OR. 356 pp. (Available from the NMFS Habitat Branch, Portland, OR).
- Stadler, J.H. 2002. Personal observation of fish-kill occurring during pile driving activity at the Winslow Ferry Terminal, Winslow, WA. October 7, 2002. Fish Biologist, DOC/NOAA/National Marine Fisheries Service/HCD, Lacey, WA.
- Stiles, S., J. Choromanski, D. Nelson, J. Miller, R. Grieg, and G. Sennefelder. 1991. Early reproductive success of the hard clam (*Mercentaria mercenaria*) from five sites in Long Island Sound. *Estuaries* 14(3):332-42.
- Stotz, T. and J. Colby. 2001. January 2001 dive report for Mukilteo wingwall replacement project. Washington State Ferries Memorandum. 5 pp. + appendices.
- Theriault, M.H., S.C. Courtenay, C. Godin and W.B. Ritchie. 2006. Evaluation of the Community Aquatic Monitoring Program (CAMP) to assess the health of four coastal areas within the southern Gulf of St. Lawrence with special reference to the impacts of effluent from seafood processing plants. *Can. Tech. Rep. Fish. Aquat. Sci.* 2649: vii + 60 p.
- Thurberg, F.P., and E. Gould. 2005. Pollutant effects upon cod, haddock, pollock, and flounder of the inshore fisheries of Massachusetts and Cape Cod Bays. In: Buchsbaum R, Pederson J, Robinson WE, editors. *The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation*. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 43-66.
- Trombulak, S.C. and C.A. Frissell. 2000. "Review of ecological effects of roads on terrestrial and aquatic communities." *Conservation Biology*. 14(10):18-30. February.
- USDA Forest Service. 2008. Tongass Monitoring and Evaluation Report – Appendix B http://www.fs.fed.us/r10/tongass/projects/tlmp/2008_monitoring_report/index2008.shtml
- USEPA. 2000a. Environmental Screening Checklist and Workbook for the Water Transportation Industry. August 2000.
- USEPA, Region 10. 2000b. Authorization to discharge under the National Pollutant Discharge Elimination System (NPDES) for Section 402 modifications of Section 404 permits for log Transfer Facilities which received a Section 404 permit prior to October 22, 1985. NPDES Permit Number AK-G70-0000. March 2000. 1200 Sixth Avenue, OW-130 Seattle, Washington 98101.
- USEPA. 1993. Guidance for specifying management measures for sources of nonpoint pollution in coastal waters. EPA Office of Water. 840-B-92-002. 500+ pp.

- Washington Department of Fish and Wildlife. 2009. Gold and fish. Rules for mineral prospecting and placer mining. 2nd edition. April 2009. Olympia, WA.
- Widdows J, Burns KA, Menon NR, Page D, Soria S. 1990. Measurement of physiological energetics (scope for growth) and chemical contaminants in mussel (*Arca zebra*) 220 transplanted along a contamination gradient in Bermuda. *Journal of Experimental Marine Biology and Ecology* 138:99-117.
- Williams, G.D. and R.M. Thom. 2001. Marine and estuarine shoreline modification issues. White paper submitted to Washington Department of Fish and Wildlife, Washington Department of Ecology and Washington Department of Transportation. www.wa.gov/wdfw/hab/ahg. 99 pp.

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Impacts to Essential Fish Habitat from Non-fishing Activities in Alaska

November 2011

Prepared by
National Marine Fisheries Service, Alaska Region

This document is the update to Appendix G of the 2005 Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska. The following people contributed to this update (listed in alphabetical order): Erika Ammann, Chiska Derr, Matthew Eagleton, Jeanne Hanson, Cindy Hartmann Moore, Brian Lance, Doug Limpinsel, Katharine Miller, Linda Shaw, and Susan Walker.



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Chapter 6 **6-1**

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Acronyms and Abbreviations

AAF Act	Alaska Aquatic Farming Act
ADEC	Alaska Department of Environmental Conservation
ADF&G	Alaska Department of Fish and Game
ADNR	Alaska Department of Natural Resources
ADOT&PF	Alaska Department of Transportation and Public Facilities
AISWG	Alaska Invasive Species Working Group
AMD	Acid Mine Drainage
ATTF	Alaska Timber Task Force
BEACH Act	Beaches Environmental Assessment and Coastal Health Act of 2000
BMP	Best Management Practices
BOEM	Bureau of Ocean Energy Management
BSEE	Bureau of Safety and Environmental Enforcement
CWA	Clean Water Act
CWP	Center for Watershed Protection
dB	decibel
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FL	fork length
FMC	Fisheries Management Council
FMP	Fishery Management Plan
GRS	Geographic Response Strategies
hz	hertz
LTF	log transfer facilities
LWD	large woody debris

mm	millimeter
MMS	Minerals Management Service
MSA	Magnuson-Stevens Fishery Conservation and Management Act
mph	miles per hour
nm	nautical mile
NEPA	National Environmental Policy Act
NMDMP	National Marine Debris Monitoring Program
NMFS	National Marine Fishery Service
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRC	National Research Council
OCS	outer coastal shelf
OWRRI	Oregon Water Resources Research Institute
PAH	polycyclic aromatic hydrocarbon
PFMC	Pacific Fishery Management Council
SPL	sound pressure level
U.S.	United States
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
VGP	Vessel General Permit
WestGold	Western Gold Exploration and Mining Company
ZOD	zone of deposit

Chapter 1

Introduction

1.1 Background on Essential Fish Habitat

In 1996, the U.S. Congress added new habitat conservation provisions to the Magnuson-Stevens Fishery Conservation and Management Act (MSA), the federal law that governs U.S. marine fisheries management. The renamed MSA mandated the identification of Essential Fish Habitat¹ (EFH) for federally managed species and consideration of recommendations to conserve and enhance the habitat necessary for these species to carry out their life cycles.

The MSA requires federal agencies to consult with the National Marine Fisheries Service (NMFS) on all actions or proposed actions permitted, funded, or undertaken by the agency that may adversely affect² EFH. Federal agencies initiate consultation by preparing and submitting to NMFS a written assessment of the effects of the proposed federal action on EFH. If a federal action agency determines that an action will not adversely affect EFH, no consultation is required. To promote efficiency and avoid duplication, EFH consultation is usually integrated into existing environmental review procedures under other laws such as the National Environmental Policy Act (NEPA), Endangered Species Act, or Fish and Wildlife Coordination Act.

The MSA requires NMFS to make conservation recommendations to federal and state agencies regarding actions that would adversely affect EFH. These EFH conservation recommendations are advisory, not mandatory, and may include measures to avoid, minimize, mitigate, or otherwise offset the adverse effects to EFH. Within 30 days of receiving NMFS' conservation recommendations, federal action agencies must provide a detailed response in writing. The response must include measures proposed for avoiding, mitigating, or offsetting the impact of a proposed activity on EFH. State agencies are not required to respond to EFH conservation recommendations. If a federal action agency chooses not to adopt NMFS' conservation recommendations, it must provide an explanation. Examples of federal action agencies that permit or undertake activities that may trigger EFH consultation include, but are not limited to, the U.S. Army Corps of Engineers (USACE), Environmental Protection Agency (EPA), Federal Energy Regulatory Commission, and Department of the Navy. Fishery Management Councils (FMCs) may also choose to comment on proposed actions that may adversely affect EFH.

¹ EFH is defined as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." "Waters" include aquatic areas and their associated physical, chemical, and biological properties. "Substrate" includes sediment underlying the waters. "Necessary" means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem. "Spawning, breeding, feeding, or growth to maturity" covers habitat types utilized by a species throughout its life cycle (50 CFR 600.10).

² An adverse effect is any impact that reduces the quality and/or quantity of EFH. Adverse effects may include direct or indirect physical, chemical, or biological alterations of the waters or substrate and loss of, or injury to, benthic organisms, prey species, and their habitat, as well as other ecosystem components. Adverse effects may be site-specific or habitat-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 CFR 600.910[a]).

1.2 Significance of Essential Fish Habitat

As Congress recognized in section 2(a)(9) of the MSA, “One of the greatest long-term threats to the viability of commercial and recreational fisheries is the continuing loss of marine, estuarine, and other aquatic habitats. Habitat considerations should receive increased attention for the conservation and management of the fishery resources of the United States.” EFH-designated waters and substrate are diverse and widely distributed, and also closely interconnected with other aquatic and terrestrial environments. Designated EFH is under the jurisdiction of the FMCs.

Section 303(a)(7) of the MSA requires fishery management plans (FMPs) to describe and identify EFH, minimize to the extent practicable the adverse effects of fishing on EFH, and identify other actions to encourage the conservation and enhancement of EFH. FMCs undertake detailed analyses to evaluate the potential adverse effects of fishing on EFH, with particular emphasis on mobile fishing gear that contacts sensitive bottom habitat features, and must act to address effects to EFH that are more than minimal and not temporary in nature. FMPs also must identify activities other than fishing that may adversely affect EFH, and for each activity describe known and potential adverse effects to EFH and identify actions to encourage the conservation and enhancement of EFH.

This document addresses non-fishing activities that may adversely affect EFH. These activities are grouped into the four different systems in which they usually occur: upland, river or riverine, estuary or estuarine, and coastal or marine.

1.3 Non-fishing Activities

The waters and substrates that comprise EFH are susceptible to a wide array of human activities unrelated to fishing. Broad categories of such activities include, but are not limited to, mining, dredging, fill, impoundment, discharges, water diversions, thermal additions, actions that contribute to nonpoint source pollution and sedimentation, introduction of potentially hazardous materials, introduction of exotic species, and the conversion of aquatic habitat that may eliminate, diminish, or disrupt the functions of EFH. Non-fishing activities discussed in this document are subject to a variety of regulations and restrictions designed to limit environmental impacts under federal, state, and local laws. Listing all applicable environmental laws and management practices is beyond the scope of the document. Moreover, the coordination and consultation required by section 305(b) of the MSA does not supersede the regulations, rights, interests, or jurisdictions of other federal or state agencies. NMFS may use the information in this document as a source when developing conservation recommendations for specific actions under section 305(b)(4)(A) of the MSA. NMFS will not recommend that state or federal agencies take actions beyond their statutory authority, and NMFS’ EFH conservation recommendations are not binding.

Ideally, actions that are not water-dependent should not be located in EFH if such actions may have adverse impacts on EFH. Activities that may result in significant adverse effects on EFH should be avoided where less environmentally harmful alternatives are available. If there are no alternatives, the impacts of these actions should be minimized. Environmentally sound engineering and management practices should be employed for all actions that may adversely affect EFH. If avoidance or minimization is not practicable, or will not adequately protect EFH,

compensatory mitigation; as defined for Section 404 of the Clean Water Act (CWA) should be considered to conserve and enhance EFH.

The potential for effects from larger, less readily managed processes associated with human activity also exists, such as climate change and ocean acidification. Climate change may lead to habitat changes that prompt shifts in the distribution of managed species. Likewise, should ocean conditions warm to allow for new shipping routes, new vectors may emerge for introducing invasive species in cargo and ballast waters. Ocean acidification also could alter species distributions and complicated food web dynamics. These larger ecosystem level effects are discussed in this document where applicable within each activity type.

1.4 Purpose of the Document

The general purpose of this document is to identify non-fishing activities that may adversely impact EFH and provide conservation recommendations that can be implemented for specific types of activities to avoid or minimize adverse impacts to EFH. This information must be included in FMPs, under section 303(a)(7) of the MSA, and will be useful to NMFS biologists reviewing proposed actions that may adversely affect EFH. This document also is intended to be utilized by federal action agencies undertaking EFH consultations with NMFS, especially in preparing EFH assessments.

The conservation recommendations for each activity category are suggestions the action agency or others can undertake to avoid, offset, or mitigate impacts to EFH. These conservation recommendations represent a short menu of actions that can contribute to the conservation, enhancement, and proper functioning of EFH. These recommendations may or may not be applicable on a site-specific basis. For each site and proposed action, different recommendations may be tailored based on the best and most current scientific information before or during EFH consultations. Because many non-fishing activities have similar adverse effects on living marine resources, some redundancy in the descriptions of impacts and the accompanying conservation recommendations between sections in this report is unavoidable.

1.5 Overall Approach

This document updates and builds upon a collaborative evaluation of non-fishing effects to EFH completed in 2004 by the NMFS Alaska Region, Northwest Region, and Southwest Region and the respective Fisheries Science Centers. In April 2005, NMFS completed the Final Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska (EFH EIS; NMFS 2005) and the North Pacific Fishery Management Council amended its FMPs to address the EFH requirements of the MSA. The EFH EIS contained an appendix (Appendix G) that addressed non-fishing impacts to EFH.

EFH regulations state that FMCs and NMFS should review the EFH provisions of FMPs at least once every 5 years and that the EFH provisions should be revised or amended, as warranted, based on available information (50 CFR 600.815(a)(10)). These regulations also state that the review should evaluate published scientific literature, unpublished scientific reports, information solicited from interested parties, and previously unavailable or inaccessible data. The North Pacific Fishery Management Council completed its most recent 5-year review in April 2010 and

voted to revise the EFH sections of its FMPs. This document will be used to revise the sections of the FMPs dealing with non-fishing impacts to EFH.

1.6 Effect of the Recommendations on Non-fishing Activities

The recommendations contained in this document for non-fishing activities are non-binding. They are intended to convey reasonable steps that could be taken to avoid or minimize adverse effects of categories of non-fishing activities on EFH. Their implementation is entirely at the discretion of the entities responsible for the activities and the agencies with applicable regulatory jurisdiction. NMFS habitat biologists may use these recommendations as a starting point when consulting with federal action agencies on specific activities that may adversely affect EFH. NMFS develops EFH conservation recommendations for specific activities case-by-case based on the circumstances, so the recommendations in this document may or may not apply to any particular project.

Chapter 2

Upland Activities

Upland activities can impact EFH through both point source and nonpoint source pollution. Nonpoint source impacts are discussed here. Technically, the term “nonpoint source” means anything that does not meet the legal definition of point source in section 502(14) of the CWA, which refers to discernible, confined, and discrete conveyance from which pollutants are or may be discharged. Land runoff, precipitation, atmospheric deposition, seepage, and hydrologic modification, generally driven by anthropogenic development, are the major contributors to nonpoint source pollution. Major sources of nonpoint pollution that are discussed in detail in this document include:

- Silviculture/Timber Harvest (Section 2.1)
- Pesticides (Section 2.2)
- Urban and Suburban Development (Section 2.3)
- Road Building and Maintenance (Section 2.4)
- Flood Control/Shoreline Protection, including channelization (Section 4.7)

Nonpoint source pollution is usually lower in intensity than an acute point source event, but may be more damaging to fish habitat in the long term. Deegan and Buchsbaum (2005) place human impacts to marine habitats into three categories: (1) permanent loss; (2) degradation; and (3) periodic disturbance. Nonpoint source pollution may be a periodic disturbance that creates a situation of degradation and leads to permanent loss. It may affect sensitive life stages and processes, is often difficult to detect, and its impacts may go unnoticed for a long time. When population impacts are detected, they may not be tied to any one event or source, and may be difficult to correct, clean up, or mitigate.

The impacts of nonpoint source pollution on EFH may not necessarily represent a serious, widespread threat to all species and life history stages. The severity of the threat of any specific pollutant to aquatic organisms depends upon the type and concentration of the pollutant and the length of exposure for a particular species and its life history stage. For example, species that spawn in areas that are relatively deep with strong currents and well-mixed water may not be as susceptible to pollution as species that inhabit shallow, inshore areas near or within enclosed bays and estuaries. Similarly, species whose egg, larval, and juvenile life history stages utilize shallow, inshore waters and rivers may be more prone to coastal pollution than are species whose early life history stages develop in offshore, pelagic waters.

2.1 Silviculture/Timber Harvest

Recent revisions to federal and state timber harvest regulations in Alaska and best management practices (BMPs) have resulted in increased protection of EFH on federal, state, and private timber lands (USDA 2008b).

These revised regulations include forest management practices, which when fully implemented and effective, could avoid or minimize adverse effects to EFH. However, if these management practices are ineffective or not fully implemented, timber harvest could have both short and long term impacts on EFH throughout many coastal watersheds and estuaries. Historically, timber harvest in Alaska was not conducted under the current protective standards, and these past practices may have degraded EFH in some watersheds.

2.1.1 Potential Adverse Impacts

In both small and large watersheds there are many complex and important interactions between fish and forests (Northcote and Hartman 2004). If appropriate environmental standards are not followed, forest conditions after harvest may result in altered or impaired instream habitat structure and watershed function. However, when followed appropriately, modern forestry practices avoid or minimize most of these potential effects on EFH; potential impacts to EFH have been greatly reduced by the adoption of BMPs designed to protect fish habitat.

Five major categories of silvicultural activities can adversely affect EFH if appropriate forestry practices are not followed: 1) construction of logging roads, 2) creation of fish migration barriers, 3) removal of streamside vegetation, 4) hydrologic changes and sedimentation, and 5) disturbance associated with log transfer facilities (LTFs) (Section 4.8). Possible effects to EFH include the following (Northcote and Hartman 2004):

- Removal of the dominant vegetation and conversion of mature and old-growth upland and riparian forests to tree stands or forests of early seral stage;
- Reduction of soil permeability and increase in the area of impervious surfaces;
- Increase in erosion and sedimentation due to surface runoff and mass wasting processes, also potentially affecting riparian areas;
- Impaired fish passage because of inadequate design, construction, and/or maintenance of stream crossings;
- Altered hydrologic regimes resulting in inadequate or excessive surface and stream flows, increased streambank and streambed erosion, loss of complex instream habitats;
- Changes in benthic macroinvertebrate populations,
- Loss of instream and riparian cover;
- Increased surface runoff with associated contaminants (e.g., herbicides, fertilizers, and fine sediments) and higher temperatures;
- Alterations in the supply of large woody debris (LWD) and sediment, which can have negative effects on the formation and persistence of instream habitat features; and
- Excess debris in the form of small pieces of wood and silt, which can cover benthic habitat and reduce dissolved oxygen levels.

2.1.1.1 Construction of Logging Roads

Improperly engineered, constructed, or maintained logging roads can destabilize slopes and increase erosion and sedimentation (as discussed above). Two major types of erosion may occur: mass wasting and surface erosion. Mass wasting (such as landslides, debris slides, slumps, earthflows, debris avalanches, and debris flows) can be directly or indirectly caused or exacerbated by timber harvest and road building on high-hazard soils and unstable slopes. Accelerated erosion rates from roads because of debris slides range from 30 to 300 times the natural rate in forested areas, but vary with terrain in the Pacific Northwest (Sidle et al. 1985). Erosion from roadways is most severe when construction practices do not include properly located, sized, and installed culverts; proper ditching; and ditch blocker water bars (Furniss et al. 1991). The eroded sediment can reach downslope waterways. BMPs included in current federal and state forest practices require that hazardous slopes be avoided or site-specific hazard management plans must be developed.

2.1.1.2 Creation of Fish Migration Barriers

Stream crossings (bridges and culverts) on forest roads that are inadequately designed, installed, or maintained can result in full or partial barriers to both upstream and downstream fish migration. For example, between 10 percent and 13 percent of the stream crossing structures installed since 1997 on the Tongass National Forest do not meet juvenile fish passage standards for upstream migration (USDA 2004). Forest Plan standards stipulate that juvenile fish will have unrestricted upstream passage within a defined range of stream flows (USDA 2004). Current fish passage standards on the Tongass National Forest stipulate that juvenile fish be able to successfully swim through culverts approximately 98 percent of the year (USDA 2004).

Perched and undersized culverts can accelerate stream flows so that these structures become velocity barriers for migrating fish. However, perched culverts are prohibited under current BMPs, and all culverts are now subject to sizing requirements designed to allow passage of fish and significant flood events.

Blocked culverts result from undersized designs or inadequate maintenance to remove debris. When a culvert is blocked, it can result in displacement of the stream from the downstream channel to the roadway or roadside ditch, resulting in dewatering of the downstream channel and increased erosion of the roadway. Under modern BMPs, however, culverts must be properly sized and maintained.

Culverts and bridges deteriorate structurally over time. Failure to replace or remove them at the end of their useful life may cause partial or total fish passage blockage. Current BMPs require removal of culverts upon road closure unless other measures are warranted. Channel incision can often occur downstream of a culvert and generally moves upstream. An existing culvert can act as a grade control, halting the upstream progression of a head cut and causing further channel regrade (Castro 2003); therefore caution should be used when removing culverts, as the unchecked upstream progression of a head cut can cause further damage to EFH. Additional information on culverts is available in the August 2001 Alaska Department of Fish and Game (ADF&G) and Alaska Department of Transportation and Public Facilities (ADOT&PF) Memorandum of Agreement for the Design, Permitting, and Construction of Culverts for Fish

Passage (ADF&G and ADOT&PF 2001) and the 2008 NMFS Northwest Region's Anadromous Salmonid Passage Facility Design (NMFS 2011).

2.1.1.3 Removal of Watershed and Streamside Vegetation

Removing streamside vegetation increases the amount of solar radiation reaching the stream and can result in warmer water temperatures, especially in small, shallow streams of low velocity. In southeast Alaska, Meehan et al. (1969) found that maximum temperature in logged streams without riparian buffers exceeded that of unlogged streams by up to 2.3 °C, but did not reach lethal temperatures. In cold climates, the removal of riparian vegetation can result in lower water temperatures during winter, increasing the formation of ice, and damaging and delaying the development of incubating fish eggs and alevins. Current BMPs require retention of riparian buffers for shade, which should limit changes in water temperature and dissolved oxygen.

By removing watershed or streamside vegetation, timber harvest reduces transpiration losses from the landscape and decreases the absorptive capability of the groundcover. These changes can result in increased surface runoff during periods of high precipitation and decreased base flows during dry periods (Heifetz et al. 1986; Myren and Ellis 1984). Reduced soil strength can result in destabilized slopes and increased sediment and debris input to streams (Swanston 1974). Sediment deposition in streams can reduce benthic community production (Culp and Davies 1983), cause mortality of incubating salmon eggs and alevins (Koski 1981), and reduce the amount of habitat available for juvenile salmon (Heifetz et al. 1986). Cumulative sedimentation from logging activities can significantly reduce the egg-to-fry survival of coho and chum salmon (Cederholm and Reid 1987). Reductions in the supply of LWD also result when old-growth forests are removed, with resulting loss of habitat complexity that is critically important for successful salmonid spawning and rearing (Bisson et al. 1988; Murphy and Koski 1989). These effects are felt when vegetation is removed within a stream's watershed, but are intensified when streamside vegetation is removed. Current riparian buffer standards and BMPs are being implemented in most instances (USDA 2008a) and long-term effectiveness studies are being conducted to determine if timber harvest has any effect on habitat condition (Martin and Grotefendt 2001; Martin and Shelly 2004).

2.1.1.4 Hydrologic Changes and Sedimentation

According to the Tongass Land Management Plan Revision, forest management activities affect water quality and quantity and the timing of water flows, through alteration of soil and watershed conditions. Most watersheds are in a state of dynamic equilibrium where changes occur naturally because of changes in weather patterns. Because of the overriding influence of climate and basin resiliency, changes in streamflow and sediment delivery resulting from management activities (e.g. timber harvest) are difficult to measure.

Sediment is water-transported earth material. Sediment may be transported as either suspended load or bedload. Suspended load is carried within the water column, while bedload material moves (rolls or bounces) along the bottom of the stream or riverbed. Suspended load causes water to have a turbid or murky appearance. Under natural conditions, the great majority of suspended load and bedload transport occurs during storm runoff events (USDA 2003).

The mass wasting of soil, streams cutting new channels, and bank erosion are the main natural processes creating sediment. Landslides cause large, but temporary, increases in suspended and

bedload sediments. Stream and riverbed or bank erosion may contribute to sedimentation over long periods of time. Steep terrain and large amounts of rainfall make the land sensitive to natural sediment production, and to sediment produced by road construction and timber-harvesting activities.

Forest management activities that have the greatest potential to affect soil erosion, including sheet rill, gully, or mass wasting erosion, are associated with timber-harvest and include road and log-landing construction, rock pit development, and some yarding methods. As discussed in Section 2.1.1.1, road construction increases soil erosion because of the destabilizing effect of cuts, fills, and drainage alteration and the lack of protective vegetation cover on road surfaces and other disturbed areas. The actual amount of erosion caused by roads is not known or reliably quantifiable (USDA 2003).

Sediment that settles on, or penetrates into, the stream bed is of more concern than suspended sediment, and can lead to long-term deleterious changes to fish and invertebrate populations. Soil mass wasting constitutes the most potentially damaging type of erosion, and is thought to be the major cause of accelerated erosion resulting from silvicultural activities. Although mass wasting has the potential positive effect of providing new sources of woody debris and gravel, it also negatively affects aquatic habitats by destroying viable eggs by smothering and bed load overturn, and by destroying habitat elements for fish (pools, riffles, log discharge, etc...) (USDA 2003). Standards and guides, Best Management Practices, and other relevant mitigation measures are applied to minimize potential adverse effects.

2.1.2 Recommended Conservation Measures

The following recommended conservation measures for silviculture/timber harvest should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH. The following references apply to all conservation recommendations.

- For all potential adverse impacts to EFH from silviculture/timber harvest, the current standards and guidelines for the Tongass National Forest in Southeast Alaska can be found at: http://tongass-fpadjust.net/Documents/2008_Forest_Plan.pdf.
- The current standards and guidelines for the Chugach National Forest including soils and fish, water, and riparian areas can be found at: http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsm8_028736.pdf.
- The Forest Service Region 10 Best Management Practices Policy, Soil and Water Conservation Handbook, FSH 2509.22 can be found at: http://www.fs.usda.gov/wps/portal/fsinternet!/ut/p/c4/04_SB8K8xLLM9MSSzPy8xBz9CP0os3gjAwhwtDDw9_AI8zPyhQoY6BdkOyoCAGixyPg!/?ss=1110&navtype=BROWS_EBYSUBJECT&cid=fsbdev2_038796&navid=1600000000000000&pnavid=null&position=Not Yet Determined.Html&ttype=detail&pname=Region 10- Land & Resource Management.
- The State of Alaska Forest Resources & Practices Regulations dated June 2004 can be found at: <http://forestry.alaska.gov/pdfs/forpracregs.pdf>.

- The State of Alaska riparian management standards can be found at:
<http://forestry.alaska.gov/pdfs/fprachrt.pdf>.

2.1.2.1 Stream Buffers

For timber operations in watersheds with EFH, adhere to modern forest management practices and BMPs, including the maintenance of vegetated buffers along all streams to the extent practicable in order to reduce sedimentation and supply large wood. In Alaska, buffer width is site-specific and varies by stream class (Class I, II, III, IV, Non-streams), stream process groups (flood plain, glacial outwash, alluvial fan, low gradient contained, moderate gradient/mixed control, moderate gradient contained, high gradient contained, palustrine, and estuarine), channel type (AF1, AF@, AF8, ES1, ES2, ES3, ES4, ES8, FP0, FP1, FP2, FP3, FP4, FP5, GO1, GO2, GO3, GO4, HC0, HC1, HC2, HC3, HC4, HC5, HC6, HC8, HC9, LC1, LC2, MC1, MC2, MC3, MM0, MM1, MM2, PA0, PA1, PA2, PA3, PA4, and PA5), and stream gradient and is dependent on use by anadromous and resident fish. Riparian management standards differ on public and private lands. Riparian buffers required on federal lands can be found in the Tongass and Chugach National Forests Resource Management Plans. Riparian management on the Tongass National Forest is also done in accordance with the Tongass Timber Reform Act, by which no commercial harvest is allowed within 100 feet horizontal distance either side on Class I streams, and Class II streams that flow directly into a Class I stream. Riparian buffers required on other lands must comply with the Alaska Forest Resources & Practices Regulations. See the links listed above for more details.

2.1.2.2 Estuary and Beach Fringe

For timber operations adjacent to estuaries or beaches, maintain vegetated buffers as needed to protect EFH. Estuaries are ecological systems at the mouths of streams where fresh and salt water mix, and where salt marshes and intertidal mudflats are present. The landward extent of an estuary is the limit of salt-tolerant vegetation (not including the tidally influenced stream or river channel incised into the forested uplands), and the seaward extent is a stream's delta at mean low water. The estuary fringe is an area of approximately 1,000 feet slope distance around all identified estuaries and should be maintained as unmodified forest. The beach fringe is an area of approximately 1,000 feet slope distance inland from mean high tide around all marine coastlines. The beach fringe should be maintained as mostly undisturbed forest that contributes to maintenance of the ecological integrity of the biologically rich tidal and intertidal zone.

2.1.2.3 Watershed Analysis

A watershed analysis is a procedure for assessing important riparian and aquatic values and processes in a watershed context. It is designed to:

- Help set the stage for project-level planning and decisions;
- Strengthen the project NEPA analysis and decision; and
- Focus interdisciplinary discussion on key watershed resources (USDA 2008a).

The scope and intensity of the watershed analysis should be commensurate with the level of risk associated with the NEPA decision, and the information necessary to support the decision. Watershed analysis requires site-specific field-based site evaluations. Watershed analysis includes: field inventory of all affected stream reaches to verify fish presence, stream classes,

and channel types; consideration of cumulative effects of past, present, and future timber sales within the watershed; assessment of current condition; and additional analyses. A watershed analysis should be incorporated into timber and silviculture projects whenever practicable.

2.1.2.4 Forest Roads

Forest roads can be a major cause of sediment into streams, and road culverts can block or inhibit upstream fish passage. Roads need to be designed to minimize sediment transport problems and to avoid fish passage problems. Recommended conservation measures include but are not limited to the following:

- Incorporate erosion control and stabilization measures in project plans for stabilizing all human-caused soil disturbances.
- Avoid construction on highly unstable uplifted marine sediment and on slopes in excess of the soil's internal angle of friction. Avoid locating roads and landings on a slope greater than 67 percent, on an unstable slope, or in a slide-prone area.
- Avoid construction of roads across alluvial floodplains, mass wastage areas, and braided bottom lands.
- Seek road locations that avoid fish streams, crossing streams when other locations are not feasible and fish habitat can be protected. Where roads are located near fish streams, avoid the introduction of sediment during clearing, construction, and operation activities. Excess excavation material must not encroach upon the stream course. Leave as much undisturbed ground cover between the road and the stream as feasible. Require complete end haul of excess excavation where there is the probability of downhill movement of that material into the stream.
- Meet fish passage direction at locations where roads cross fish streams. Specify permissible uses of heavy machinery and the timing of road construction activities.
- Slope drainage ditches along the roadbed to the nearest relief culvert. Discharge from road ditches should be cross drained to filter on natural forest floor, rather than flowing directly into streams.
- Avoid the introduction or spread of invasive species during road construction, reconstruction, and maintenance.

2.2 Pesticides

Pesticides are substances intended to prevent, destroy, control, repel, kill, or regulate the growth of undesirable biological organisms. Pesticides include the following: insecticides, herbicides, fungicides, rodenticides, repellents, bactericides, sanitizers, disinfectants, and growth regulators. More than 900 different active pesticide ingredients are currently registered for use in the United States and are formulated with a variety of other inert ingredients that may also be toxic to aquatic life. Legal mandates covering pesticides are the CWA and the Federal Insecticide, Fungicide, and Rodenticide Act. Water quality criteria for the protection of aquatic life have only been developed for a few of the currently used ingredients (EPA, Office of Pesticide Programs). In Alaska, the pesticide control program is administered by the Alaska Department of Environmental Conservation's (ADEC's) Division of Environmental Health (<http://www.dec.state.ak.us/EH/pest/index.htm>). Nationwide, the most comprehensive

environmental monitoring efforts have been conducted by the U.S. Geological Survey as part of the National Water Quality Assessment Program.

While agricultural run-off is a major source of pesticide pollution in the lower 48 states, in Alaska, other human activities, such as fire suppression on forested lands, forest site preparation, noxious weed control, right-of-way maintenance (e.g., roads, railroads, power lines), algae control in lakes and irrigation canals, riparian habitat restoration, and urban and residential pest control are the most common sources of these substances.

Pesticides are frequently detected in freshwater and estuarine systems that provide EFH. Pesticides can enter the aquatic environment as single chemicals or as complex mixtures. Direct applications, surface runoff, spray drift, agricultural return flows, and groundwater intrusions are all examples of transport processes that deliver pesticides to aquatic ecosystems. Habitat alteration from pesticides is different from more conventional water quality parameters because, unlike temperature or dissolved oxygen, the presence of pesticides can be difficult to detect due to limitations in proven methodologies. This monitoring may also be expensive. As analytical methodologies have improved in recent years, the number of pesticides documented in fish and their habitats has increased. In addition, pesticides may bioaccumulate in the ecosystem by retention in sediments and detritus, which are then ingested by macroinvertebrates, and which, in turn, are eaten by larger invertebrates and fish (Atlantic States Marine Fisheries Commission 1992).

2.2.1 Potential Adverse Impacts

There are three basic ways that pesticides can adversely affect EFH. These are (1) a direct, lethal or sublethal, toxicological impact on the health or performance of exposed fish; (2) an indirect impairment of aquatic ecosystem structure and function; and (3) a loss of aquatic macroinvertebrates that are prey for fish and aquatic vegetation that provides physical shelter for fish.

Fish kills are generally rare when pesticides are used according to their labels. For fish, most effects from pesticide exposures are sublethal. Sublethal effects are a concern if they impair the physiological or behavioral performance of individual animals in ways that will decrease their growth or survival, alter migratory behavior, or reduce reproductive success. In addition to early development and growth, many pesticides have been shown to impair fish's endocrine, immune, nervous, and reproductive systems (Moore and Waring 2001). Historically, sublethal impacts of pesticides on fish health were rarely addressed and therefore are poorly understood. Over the past few years, study of acetylcholinesterase-inhibiting insecticides has shown that sublethal exposures affect fitness of exposed salmonids and ultimately may result in population level consequences (NMFS 2008, 2009; Baldwin et al. 2009). Understanding the consequences of sublethal impacts to fish remains a focus of recent and ongoing National Oceanic and Atmospheric Administration (NOAA) research (Scholz et al. 2000; Sandahl et al. 2005; Laetz et al. 2009).

The effects of pesticides on ecosystem structure and function can be key factors in determining the cascading impacts of those chemicals on fish and other aquatic organisms at higher trophic levels (Preston 2002). This includes impacts on primary producers (Hoagland et al. 1996) and aquatic microorganisms (DeLorenzo et al. 2001), as well as on macroinvertebrates that are prey

species for fish. For example, many pesticides are specifically designed to kill insects. Not surprisingly, these chemicals are toxic to insects and crustaceans that inhabit river systems and estuaries. Overall, pesticides will have an adverse impact on fish habitat if they reduce the productivity of aquatic ecosystems.

Some herbicides are toxic to aquatic plants that provide shelter for various fish species. A loss of aquatic vegetation could damage nursery habitat or other sensitive habitats, such as eelgrass beds and emergent marshes.

2.2.2 Recommended Conservation Measures

The following recommended conservation measures regarding pesticides (including insecticides, herbicides, fungicides, rodenticides, repellents, bactericides, sanitizers, disinfectants, and growth regulators) should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Incorporate integrated pest management and BMPs as part of the authorization or permitting process to ensure the reduction of pesticide contamination in EFH (Scott et al. 1999). If pesticides must be applied, consider area, terrain, weather, droplet size, pesticide characteristics, and other conditions to avoid or reduce effects to EFH.
- Carefully review labels and ensure that application is consistent with the product's directions. Follow local, supplemental instructions such as state-use bulletins where they are available.
- Avoid the use of pesticides within 500 linear feet and/or 1000 aerial feet of anadromous fish bearing streams.
- For forestry vegetation management projects, follow the ADEC measures that establish a 35-foot pesticide-free buffer area from any surface or marine water body and require that pesticides not be applied within 200 feet of a public water source.
<http://www.dec.state.ak.us/regulations/pdfs/18%20AAC%2090.pdf>
- Consider current and recent meteorological conditions. Rain events may increase pesticide runoff into adjacent water bodies. Saturated soils may inhibit pesticide penetration.
- Do not apply pesticides when wind speeds exceed 10 mph.
- Begin application of pesticide products nearest to the aquatic habitat boundary and proceed away from the aquatic habitat; do not apply towards a water body.

2.3 Urban and Suburban Development

Urban and suburban development is most likely the greatest non-fishing threat to EFH (NMFS 1998 a, b). Urban and suburban development and the corresponding infrastructure result in four broad categories of impacts to aquatic ecosystems: hydrological, physical, water quality and biological (CWP 2003).

2.3.1 Potential Adverse Impacts

Potential impacts to EFH most directly related to general urban and suburban development discussed below are the watershed effects of land development, including stormwater runoff. Other development-related impacts are discussed in later sections of this document, including dredging (Section 4.1), wetland fill, and shoreline construction (Section 4.2).

Development activities within watersheds and in coastal marine areas can impact EFH on both long and short timeframes. The Center for Watershed Protection (CWP) made a comprehensive review of the impacts associated with impervious cover and urban development and found a negative relationship between watershed development and 26 stream quality indicators (CWP 2003). The primary impacts include (1) the loss of hyporheic zones (the region beneath and next to streams where surface and groundwater mix), and riparian and shoreline habitat and vegetation; and, (2) runoff. Removal of riparian and upland vegetation has been shown to increase stream water temperatures, reduce supplies of LWD, and reduce sources of prey and nutrients to the water system. An increase in impervious surfaces in a watershed, such as the addition of new roads, buildings, bridges, and parking facilities, results in a decreased infiltration to groundwater and increased runoff volumes. This also has the potential to adversely affect water quality and the shape of the hydrograph in downstream water bodies (i.e., estuaries and coastal waters).

The loss of hyporheic zones and riparian and shoreline habitat and vegetation can increase water temperatures and remove sources of cover. Such impacts can alter the structure of benthic and fish communities. Shoreline stabilization projects (Section 4.7) that alter reflective wave energy can impede or accelerate natural movements of shoreline substrates, thereby affecting intertidal and sub-tidal habitats. Channelization of rivers causes loss of floodplain connectivity and simplification of habitat. The resulting sediment runoff can also restrict tidal flows and elevations, resulting in losses of important fauna and flora (e.g., submerged aquatic vegetation).

Runoff from impervious surfaces is the most widespread source of pollution into the nation's waterways (USEPA 1995). Runoff from urban development is an emerging threat, particularly to ecosystems along all coastal margins of the United States (McCarthy et al. 2008; Weiss et al. 2008), as urban and suburban development in the United States continues to expand in coastal areas at a rate approximately four times greater than in non-coastal areas. Impacts from urban and suburban development are generally difficult to control because of the intermittent nature of rainfall and runoff, the large variety of pollutant source types, and the variable nature of source loadings (Safavi 1996). Such runoff includes pollutants such as construction sediments, oil from vehicles, road salts, bacteria from failing septic systems, and heavy metals. The 2000 National Water Quality Inventory (USEPA 2002) reported that runoff from urban areas is the leading source of impairment in surveyed estuaries and the third largest source of impairment in surveyed lakes. While our understanding of the individual, cumulative, and synergistic effects of all contaminants on the coastal ecosystem are incomplete, pollution discharges may cause organisms to be more susceptible to disease or impair reproductive success (USEPA 2005). Urban areas can have a chronic and insidious pollution potential that one-time events such as oil spills do not.

Salmonids and other anadromous fish appear to be particularly impacted by the proportion of impervious cover in a watershed (CWP 2003). In a study in the Pacific Northwest, coho salmon

were seldom found in watersheds above 10 percent or 15 percent impervious cover (Luchetti and Feurstenburg 1993). Other studies have shown that impacts to stream quality can be expected when a watershed exceeds 10 percent impervious cover (CWP 2003). Key stressors in urban streams, such as higher peak flows and reduction in habitat complexity (e.g., fewer pools, LWD, and hiding places), as well as changes in water quality, are believed to change salmon species composition, favoring cutthroat trout populations over the natural coho populations (Horner et al. 1999; May et al. 1997).

Stormwater management systems are often built to move water quickly away from roads, resulting in increased velocities and higher peak volume of water into streams. Uncontrolled higher velocities and higher peak flow volumes of urban stormwater have a greater erosive capacity than stormwater from a forested watershed. Higher velocities and flow volumes erode streambanks and increase stream sediment loads. In a simulation model comparing an urban watershed with a forested watershed, Corbett et al. (1997) demonstrated that runoff from an urban watershed had volume and sediment yield 5.5 times greater than that from a forested watershed. Additionally reduced canopy cover can often cause higher stream temperatures. Literature reviews and ongoing research illustrate the adverse impacts of urban stormwater discharge and growing communities on fresh water and marine invertebrate, fish and marine mammal populations (Weiss 2008, LaLiberte 2006, Beach 2002, Neff 2002).

Urban stormwater also discharges nonpoint pollutants to soil and water, leading to their eventual bioaccumulation in aquatic species, which is also well documented in these and numerous other reports. Polycyclic aromatic hydrocarbons (PAHs) are among the most toxic to aquatic life and can persist for decades (Short et al. 2003). Waterborne PAH levels are often significantly higher in urbanized than non-urbanized watersheds (Fulton et al. 1993). Petroleum-based contaminants contain PAHs, which when released into the environment through spill, combustion, and atmospheric deposition can cause acute toxicity to managed species and their prey, as some PAHs are known carcinogens and mutagens (Neff 1985).

Sublethal effects of fish exposure to many chemical and metal pollutants often associated with urban stormwater over time may prove more deleterious than concentrations that are immediately lethal. Subtle sublethal effects on the fish may alter their behavior, feeding habits, and reproductive success (Murty 1986). Stormwater contaminants have been shown to negatively alter cellular function and biochemical machinery in many aquatic organisms, giving rise to the incidence of carcinogenesis through oxidized metabolites, interfering with DNA repair mechanisms, and/or initiating teratogenesis (prenatal toxicity that causes structural or functional defects in the developing embryo or fetus), all of which can increase mortality in fish species. Some stormwater contaminants disrupt neurotoxic and olfactory responses that maintain normal homing, predator avoidance, and spawning behavior. They can weaken immune system response, and inadvertently increase susceptibility and mortality from diseases. These conclusions are well documented in a variety of fish species (Sandahl 2007b; Baldwin et al. 2003; Dethloff et al. 1999; Hansen et al. 1999a, 1999b; Muir et al. 1988; Neff 1985).

Failing septic systems and combined sewer overflows are an outgrowth of urban development. EPA estimates that 10 percent to 25 percent of all individual septic systems are failing at any one time, introducing excrement, detergents, chlorine and other chemicals into the environment. Even treated wastewater from urban areas can alter the physiology of intertidal organisms

(Moles and Hale 2003). Sewage discharge is a major source of coastal pollution, contributing 41, 16, 41, and 6 percent of the total pollutant load for nutrients, bacteria, oils, and toxic metals, respectively (Kennish 1998). Nutrients such as phosphorus concentrations, in particular, are indicative of urban stormwater runoff (Holler 1990) and as a limiting nutrient for plant growth may lead to algal blooms, eutrophication, loss of biodiversity, and expansion of invasive species. Sewage wastes may also contain significant amounts of organic matter that exert a biochemical oxygen demand (Kennish 1998). Organic contamination contained within urban runoff can also cause immunosuppression (Arkoosh et al. 2001).

2.3.2 Recommended Conservation Measures

The following recommended conservation measures should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH where threats of impacts from urban and suburban development exist.

- Implement BMPs for sediment control during construction and maintenance operations (USEPA 1993). These can include: avoiding ground-disturbing activities during the wet season; minimizing exposure time of disturbed lands; using erosion prevention and sediment control methods; minimizing the spatial extent of vegetation disturbance; maintaining buffers of vegetation around wetlands, streams, and drainage ways; and avoiding building activities in areas with steep slopes and areas prone to mass wasting events with highly erodible soils. Use of structural BMPs such as sediment ponds, sediment traps, vegetated swales, or other facilities designed to slow water runoff and trap sediment and nutrients is recommended.
- Avoid using hard engineering structures for shoreline stabilization and channelization when possible. Use bioengineering approaches (i.e., approaches with principles of geomorphology, ecology, and hydrology) to protect shorelines and riverbanks, such as using native vegetation for soil stabilization. Naturally stable shorelines and river banks should not be altered.
- Encourage comprehensive planning for watershed protection, and avoid or minimize filling and building in coastal and riparian areas affecting EFH. Development sites should be planned to minimize clearing and grading, cut-and-fill, and new impervious surfaces.
- Where feasible, remove obsolete impervious surfaces such as abandoned parking lots and buildings from riparian and shoreline areas, and reestablish water regime, wetlands, and native vegetation.
- Protect and restore vegetated buffer zones of appropriate width along streams, lakes, and wetlands that include or influence EFH.
- Manage stormwater to replicate the natural hydrologic cycle, maintaining natural infiltration and runoff rates to the maximum extent practicable.
- Where instream flows are insufficient to maintain water quality and quantity needed for EFH, establish conservation guidelines for water use permits, and encourage the purchase or lease of water rights and the use of water to conserve or augment instream flows in accordance with state and federal water laws.

- Use the best available technologies in upgrading wastewater systems to avoid combined sewer overflow problems and chlorinated sewage discharges into rivers, estuaries, and the ocean.
- Design and install proper wastewater treatment systems. Locate them away from open waters, wetlands, and floodplains.
- Where vegetated swales are not feasible, install oil/water separators to treat runoff from impervious surfaces in areas adjacent to marine or anadromous waters. Ensure that oil/water separators are regularly maintained such that they do not become clogged and function properly on a continuing basis.

2.4 Road Building and Maintenance

Roads and trails have always been part of man's impact on his environment (Luce and Crowe 2001). Federal, state, and local transportation departments devote huge budgets to construction and upgrading of roads. As in other places, roads play an important part in access and thus are vital to the economy of Alaska (Connor 2007). Potential impacts to EFH associated with building and maintenance of paved and unpaved roads are discussed in the following section.

2.4.1 Potential Adverse Impacts

Today's road design construction and management practices have improved from the past. Roads, however, still have a negative effect on the biotic integrity of both terrestrial and aquatic ecosystems (Trombulak and Frissell 2000), and the effects of roads on aquatic habitat can be profound. Potential adverse impacts to aquatic habitats resulting from existence of roads in watersheds include (1) increased surface erosion, including mass wasting events and deposition of fine sediments; (2) changes in water temperature; (3) elimination or introduction of migration barriers such as culverts; (4) changes in streamflow; (5) introduction of invasive species; (6) changes in channel configuration; and (7) the concentration and introduction of PAHs, heavy metals, and other pollutants.

Road building and maintenance can affect aquatic habitats by increasing rates of natural disturbances such as landslides and sedimentation, and even properly designed and constructed roads can become sources of landslides and sedimentation if they are not maintained. Streams, wetlands, or other sensitive areas located near roads may experience increased sedimentation from general road maintenance and use, as well as from storm and snowmelt events. Poorly surfaced or unpaved roads can substantially increase surface erosion. The rate of erosion is primarily a function of storm intensity, surfacing material, road slope, and traffic levels. This surface erosion results in an increase in fine sediment deposition (Cederholm and Reid 1987; Bilby et al. 1989; MacDonald et al. 2001). Increased fine sediment deposition in stream gravels has been linked to decreased fry emergence and juvenile densities, loss of winter carrying capacity, and increased predation of fishes. Increased fine sediment can reduce benthic production or alter the composition of the benthic community. For example, embryo-to-emergent fry survival of incubating salmonids is negatively affected by increases in fine sediments in spawning gravels (Chapman 1988; Everest et al. 1987; Koski 1981; Scrivener and Brownlee 1989; Weaver and Fraley 1993; Young et al. 1991). Road crossings also affect benthic communities of stream invertebrates. Additionally, studies show that populations of non-insect invertebrates tend to increase the farther away they are from a road (Luce and Crowe 2001).

Beschta et al. (1987) and Hicks et al. (1991) document some of the negative effects of road construction on fish habitat, including elevation of stream temperatures beyond the range of preferred rearing where vegetation has been removed, inhibition of upstream migrations, increased disease susceptibility, reduced metabolic efficiency, and shifts in species assemblages. Roads built adjacent to streams can result in changes in water temperature due to increased sunlight reaching the stream if vegetation is removed and/or altered in composition.

Roads can also degrade aquatic habitat through improperly placed culverts at road-stream crossings that reduce or eliminate fish passage (Belford and Gould 1989, Clancy and Reichmuth 1990, Evans and Johnston 1980, Furniss et al. 1991).

Roads have three primary effects on hydrologic processes and therefore streamflow. First, they intercept rainfall directly on the road surface, in road cutbanks, and as subsurface water moving down the hillslope. Second, they concentrate flow, either on the road surfaces or in adjacent ditches or channels. Last, they divert or reroute water from flowpaths that would otherwise be taken if the road were not present (Furniss et al. 1991). Another possible consequence of road building is the destabilization of the stream channel by intercepting groundwater flow and channeling water directly into the stream; thus, increasing the frequency and volume of floods as well as erosion and other associated natural processes. Erosion is most severe when poor construction practices are allowed, combined with inadequate attention to proper road drainage and maintenance practices.

Roads can serve as vectors to introduce invasive species to a watershed by creating suitable habitat for invasive species; planting invasive species along roadsides for erosion control; and serving as a vector for accidental introduction from vehicular or other traffic traveling along the road system. (Trombulak and Frissell 2000)

Pavement and many paving compounds used in road construction, surfacing, and resurfacing, such as asphalt, bitumen, and especially pavement sealing and repair products, contain high levels of PAHs, (Mahler et al. 2005; Teaf 2008 Barsh et al. 2007; Grosenheider et al. 2005). The friction between road and tire surfaces erodes and liberates asphalt, rubber material and chemical compounds. Further contributions of automotive fluids, fuel, and brake linings concentrate on or near road surfaces and eventually reach streams and the ocean (Weiss et al. 2008; Simon and Sobieraj 2006; Grosenheider et al. 2005). PAHs and heavy metals are toxic to aquatic species such as fish and invertebrate populations (Logan 2007; Rand 1995), and accumulate in estuarine, near shore and marine fish and invertebrate species (Kennish 2001; Johnson et al. 2002; Kennish 1997).

2.4.2 Recommended Conservation Measures

The following conservation measures should be viewed as options to avoid and minimize adverse impacts from road building and maintenance and promote the conservation, enhancement, and proper functioning of EFH.

- Roads should be sited to avoid sensitive areas such as streams, wetlands, and steep slopes to the extent practicable.

1. Build bridges rather than culverts for stream crossings when possible. If culverts are to be used, they should be sized, constructed, and maintained to match the gradient and width of the stream, so as to accommodate design flood flows, and they should be large enough to provide for migratory passage of adult and juvenile fishes. If appropriate, use the 2011 NMFS Northwest Region's Anadromous Salmonid Passage Facility Design (NMFS 2011) or the culvert guidelines contained in the August 2001 ADF&G and the ADOT&PF Fish Pass Memorandum of Agreement) (ADF&G and ADOT&PF 2001).
 - Design bridge abutments to minimize disturbances to stream banks, and place abutments outside of the floodplain whenever possible.
 - Specify erosion control measures in road construction plans.
 - Avoid side casting of road materials on native surfaces and into streams.
 - Use only native vegetation in stabilization plantings.
 - Use seasonal restrictions to avoid impacts to habitat during species critical life history stages (e.g., spawning and egg development periods). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
 - Maintain roadway and associated stormwater collection systems properly.
 - Limit roadway sanding and the use of deicing chemicals during the winter to minimize sedimentation and introduction of contaminants into nearby aquatic habitats. Snow-melt disposal areas should be silt-fenced and include a collection basin. Roads should be swept after break up to reduce sediment loading in streams and wetlands.

Chapter 3

Riverine Activities

3.1 Mining

Mining within riverine habitats may result in direct and indirect chemical, biological, and physical impacts to habitats within the mining site and surrounding areas during all stages of operations. On site mining activities include exploration, site preparation, mining and milling, waste management, decommissioning or reclamation, and abandonment (NMFS 2004, American Fisheries Society 2000). Mining and its associated activities have the potential to cause adverse effects to EFH from exploration through post-closure. The operation of metal, coal, rock quarries, and gravel pit mining in upland and riverine areas has caused varying degrees of environmental damage in urban, suburban, and rural areas. Some of the most severe damage, however, occurs in remote areas, where some of the most productive fish habitat is often located (Sengupta 1993). In Alaska, existing regulations, promulgated and enforced by other federal and state agencies, are designed to control and manage these changes to the landscape to avoid and minimize impacts. However, while environmental regulations may avoid, limit, control, or offset many potential impacts, mining will, to some degree, always alter landscapes and environmental resources (National Research Council [NRC] 1999). (For additional information on mining impacts in the marine environment please see Section 5.6.)

3.1.1 Mineral Mining

Mining and mineral extraction activities take many forms, such as commercial and recreational suction dredging, placer, open pit and surface mining, and contour operations (Section 5.6). The process for mineral extraction involves exploration, mine development, mining (extraction), processing, and reclamation.

3.1.1.1 *Potential Adverse Impacts*

The potential adverse effects of mineral mining on fish populations and EFH are well documented (Farang et al. 2003; Hansen et al. 2002; Brix et al. 2001; Goldstein et al. 1999) and depend on the type, extent, and location of the activities. Recreational gold mining with such equipment as pans, motorized or nonmotorized sluice boxes, concentrators, rockerboxes, and dredges can adversely affect EFH on a local level. Commercial mining is likely to involve activities at a larger scale with greater disturbance (Oregon Water Resources Research Institute [OWRRI] 1995).

Impacts associated with the extraction of material from within or near a stream or river bed may include (1) alteration in channel morphology, hydraulics, lateral migration and natural channel meander; (2) increases in channel incision and bed degradation; (3) disruption in pre-existing balance of suspended sediment transport and turbidity; (4) direct impacts to fish spawning and nesting habitats (redds), juveniles, and prey items; (5) simplification of in-channel fluvial processes and LWD deposition; (6) altered surface and ground water regimes and hydro-geomorphic and hyporheic processes; and (7) destruction of the riparian zone during extraction

operations. Additional impacts may include mining-related pollution, acid mine drainage, habitat fragmentation and conversion, altered temperature regimes, reduction in oxygen concentration, the release of toxic materials (NMFS 2008), and additional impacts to wetland and riverine habitats. Many of these types of impacts have been previously introduced in the document. The additional discussion that follows is intended to round out the discussion of impacts that have not been previously introduced.

Scientific literature has many examples of spawning substrate selection by salmonid species being influenced by chemical and physical variables such as instream and inter-substrate flow (hyporheic zone), dissolved gases, nutrient exchange, and temperature. Mining activities may disrupt these physical and geochemical systems initiating and promulgating mineral dissolution or precipitation reactions that can alter pre-mining ground water quality and chemistry in ways that may be difficult to predict (Lewis-Russ 1997).

Recent studies suggest that diffuse mining-related pollution in rivers may significantly contribute to the loading of metals, principally because mine water contribution may be influenced by altered water tables (Younger 2000). Minerals and metals liberated from rock and soil substrates interact with atmospheric oxygen and water (Jennings et al. 2000, 2008; Younger et al. 2002). The introduction of this metal and mineral rich runoff or acid mine drainage (AMD) into the aquatic ecosystem can have adverse impacts on the ecology of entire watersheds. AMD has been demonstrated to be toxic to fish and aquatic invertebrate populations at the ecosystem, metabolic and cellular level (Buhl and Hamilton 1991; Saiki et al. 1995; West et al. 1995; Barry et al. 2000; Hansen et al. 2002; Peplow and Edmonds 2004). The hyporheic zone is especially vulnerable since this zone supports salmon spawning and incubating eggs as well as production of aquatic insects and aquatic vegetation. Groundwater may enter the hyporheic zone in an undiluted condition, leading to injury and mortality of aquatic organisms (including fish) prior to benefiting from the dilution effects of the overlying streamflow (Brunke and Gonser 1997; Gandy 2007).

Metal contamination and exposure has been shown to influence simple migratory behavior and avoidance mechanisms in fish populations (Goldstein et al. 1999; Hansen et al. 1999a; Brix et al. 2001; Farag et al. 2003; Sandahl et al. 2007a). Additional studies indicate that salmonids exposed to sub-lethal levels of metals are susceptible to increasing levels of fish pathogens due to stressed immune responses and metabolisms (Spromberg and Meador 2005; Peplow and Edmonds 2004; Jacobson et al. 2003).

The ability to treat or neutralize AMD is very site specific, and often unpredictable. Mine waste will be exposed to the natural elements of weathering for a long time (CSS 2002). Studies on rivers recovering from metal and mineral contamination concluded that, despite efforts to remediate surface water pollution, community recovery in the hyporheic zone may take longer than surface macroinvertebrate recovery due to the continued release of metals by reductive dissolution and exposure to AMD. Depending on the scale of the mining operation and associated topography and hydrogeomorphic processes, active treatment to neutralize AMD may need to last in perpetuity to be effective (Jennings et al. 2008; Kuipers 2000).

In addition, physical changes can be profound. The creation of waste dumps, tailings impoundments, mine pits, and other facilities that become permanent features of the post-mining

landscape can cause fundamental changes in the physical characteristics of a watershed (O'Hearn 1997). Mining and placement of spoils in riparian areas can cause the loss of riparian vegetation and changes in heat exchange, leading to higher summer temperatures and lower winter stream temperatures (Spence et al. 1996). Bank instability can also lead to altered width-to-depth ratios, which further influence temperature (Spence et al. 1996). Mining efforts can also bury productive habitats near mine sites. Although reclamation efforts and mitigation practices may restore topographic land forms to mine sites, these efforts generally fail to restore natural hydrogeomorphic and aquatic function, and associated water quantity and quality within measurable time frames (Mutz 1998, Kilmartin 1989). Additionally, commercial operations may also involve road building (Section 2.4), tailings disposal (Section 4.2), and leaching of extraction chemicals, all of which may affect EFH.

In accessing mineral and ore deposits, many mining methods require withdrawals from groundwater aquifers. These naturally occurring, often saturated, ground water aquifers sustain instream flows. Altered water regimes may change instream channel morphologies, stream gradients, and bank and benthic substrates and disrupt the equilibrium between flow and sediment transport in tributaries (Sophocleous 2002; Johnson et al. 1999). Often these impacts are seen many miles upstream and downstream of the actual mine site, thus impacting EFH and anadromous species by limiting access to migratory corridors and reducing available spawning and rearing habitat.

3.1.1.2 Recommended Conservation Measures

The following measures are adapted from recommendations in Spence et al. (1996), NMFS (2004), and Washington Department of Fish and Wildlife (1998). These conservation recommendations for mineral mining should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- To the extent practicable, avoid mineral mining in waters, water sources and watersheds, riparian areas, hyporheic zones, and floodplains providing habitat for federally managed species.
- Schedule necessary in-water activities when the fewest species/least vulnerable life stages of federally managed species will be present.
- Minimize spillage of dirt, fuel, oil, toxic materials, and other contaminants into EFH. Prepare a spill prevention plan if appropriate.
- Treat wastewater (acid neutralization, sulfide precipitation, reverse osmosis, electrochemical, or biological treatments) and recycle on site to minimize discharge to streams. Test wastewater before discharge for compliance with federal and state clean water standards.
- Minimize the effects of sedimentation on fish habitat. Use methods such as contouring, mulching, and construction of settling ponds to control sediment transport. Additionally, use methods such as sediment curtains to limit the spread of suspended sediments. Monitor turbidity during operations, and cease operations if turbidity exceeds predetermined threshold levels.

- If possible, reclaim, rather than bury, mine waste that contains heavy metals, acid materials, or other toxic compounds to limit the possibility of leachate entering groundwater.
- Restore natural contours and use native vegetation to stabilize and restore habitat function to the extent practicable. Monitor the site for an appropriate time to evaluate performance and implement corrective measures if necessary.
- Minimize the aerial extent of ground disturbance (e.g., through phasing of operations) and stabilize disturbed lands to reduce erosion.
- For large scale mining operations, stochastic models (as tools for estimating probability distributions of potential outcomes) should be employed to make predictions of ground and surface hydrologic impacts and acid generating potential in mine pits and tailing impoundments. The model used should describe how the data was collected and put in the model and include the governing equations and defense of assumptions made with a sensitivity analysis.

3.1.2 Sand and Gravel Mining

In Alaska, riverine sand and gravel mining is extensive and can involve several methods: wet-pit mining (i.e., removal of material from below the water table); dry-pit mining on beaches, exposed bars, and ephemeral streambeds; and subtidal mining.

3.1.2.1 *Potential Adverse Impacts*

Primary impacts associated with riverine sand and gravel mining activities include (1) turbidity plumes and re-suspension of sediment and nutrients, (2) removal of spawning habitat, and (3) alteration of channel morphology. These often lead to secondary impacts including (1) alteration of migration patterns, (2) physical and thermal barriers to upstream and downstream migration, (3) increased fluctuation in water temperature, (4) decrease in dissolved oxygen, (5) high mortality of early life stages, (6) increased susceptibility to predation, (7) loss of suitable habitat (Packer et al. 2005), (8) decreased nutrients (from loss of floodplain connection and riparian vegetation), and (9) decreased food production (loss of invertebrates) (Spence et al. 1996).

Turbidity plumes (Section 4.1) can cause spawning habitat to be moved several kilometers downstream. Sand and gravel mining in riverine, estuarine, and coastal environments can also suspend materials at the sites. Sedimentation may be delayed because gravel removal typically occurs at low flow when the stream has the least capacity to transport fine sediments out of the system. Another delayed sedimentation effect results when freshets inundate extraction areas that are less stable than they were before the activity occurred. In addition, for species such as salmon, gravel operations can interfere with migration past the site if they create physical or thermal changes, either at or downstream from the work site (OWRRI 1995).

Extraction of sand and gravel in riverine ecosystems can reduce or eliminate spawning gravels if the extraction rate exceeds the deposition rate of new gravel in the system, reduces gravel depth, or exposes bedrock (Spence et al. 1996). Gravel excavation also reduces the local supply of gravel to downstream habitats. In addition, mechanical disturbance of spawning habitat by mining equipment can lead to high mortality rates in early life stages.

Mining can alter channel morphology by making the stream channel wider and shallower. Consequently, the suitability of stream reaches as rearing habitat for federally managed species may be decreased, especially during summer low-flow periods when deeper waters are important for survival. Similarly, a reduction in pool frequency may adversely affect migrating adults that require holding pools (Spence et al. 1996). Changes in the frequency and extent of bed load movement and increased erosion and turbidity can also remove spawning substrates, scour redds (resulting in a direct loss of eggs and young), or reduce their quality by deposition of increased amounts of fine sediments. Deep pools created by material removal in streams appear to attract migrating adult salmon for holding. These concentrations of fish may result in high losses as a result of increased predation or recreational fishing pressure. Examples of using gravel removal to improve habitat and water quality are limited and isolated (OWRRI 1995).

3.1.2.2 *Recommended Conservation Measures*

The following recommended conservation measures for sand and gravel mining are adapted from NMFS (2004) and OWRRI (1995). They should be viewed as options to avoid and minimize adverse impacts to EFH due to sand and gravel mining and promote the conservation, enhancement, and proper functioning of EFH.

- To the extent practicable, avoid sand/gravel mining in waters, water sources and watersheds, riparian areas, hyporheic zones and floodplains providing habitat for federally managed species.
- Identify upland or off-channel (where the channel will not be captured) gravel extraction sites as alternatives to gravel mining in or adjacent to EFH, if possible.
- If operations in EFH cannot be avoided, design, manage, and monitor sand and gravel mining operations to minimize potential direct and indirect impacts to living marine resources and habitat. For example, minimize the areal extent and depth of extraction.
- Include restoration, mitigation, and monitoring plans, as appropriate, in sand/gravel extraction plans.
- Implement seasonal restrictions to avoid impacts to habitat during species critical life history stages (e.g., spawning season, egg, and larval development period). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.

3.2 Organic and Inorganic Debris

Organic and inorganic debris, and its impacts to EFH, extend beyond riverine systems into estuarine coastal and marine systems. For ease in organization of this document we have placed this topic where impacts first occur in the document, however impacts to other systems are also addressed here.

Natural occurring flotsam, such as LWD and macrophyte wrack (i.e., kelp), plays an important role in aquatic ecosystems, including EFH. LWD and wrack promote habitat complexity and provide structure to various aquatic and shoreline habitats.

The natural deposition of LWD creates habitat complexity by altering local hydrologic conditions, nutrient availability, sediment deposition, turbidity, and other structural habitat

conditions. In riverine systems, the physical structure of LWD provides cover for managed species, creates habitats and microhabitats (e.g., pools, riffles, undercut banks, and side channels), retains gravels, and helps maintain underlying channel structure (Abbe and Montgomery 1996; Montgomery et al. 1995; Ralph et al. 1994; Spence et al. 1996). LWD also plays similar role in salt marsh habitats (Maser and Sedell 1994). In benthic ocean habitats, LWD enriches local nutrient availability as deep-sea wood borers convert the wood to fecal matter, providing terrestrially-based carbon to the ocean food chain (Maser and Sedell 1994). When deposited on coastal shorelines, macrophyte wrack creates microhabitats and provides a food source for aquatic and terrestrial organisms such as isopods and amphipods, which play an important role in marine food webs.

Conversely, inorganic flotsam and jetsam debris can negatively impact EFH. Inorganic marine debris is a problem along much of the coastal United States, where it litters shorelines, fouls estuaries, entangles fish and wildlife, and creates hazards in the open ocean. Marine debris consists of a wide variety of man-made materials, including general litter, plastics, hazardous wastes, and discarded or lost fishing gear. The debris enters waterbodies indirectly through rivers and storm water outfalls, as well as directly via ocean dumping and accidental release. Although laws and regulatory programs exist to prevent or control the problem, marine debris continues to affect aquatic resources.

3.2.1 Organic Debris Removal

Natural occurring flotsam, such as LWD and macrophyte wrack (i.e., kelp), is sometimes intentionally removed from streams, estuaries, and coastal shores. This debris is removed for a variety of reasons, including dam operations, aesthetic concerns, and commercial and recreational purposes (e.g. active beach log harvests, garden mulch, and fertilizer). However, the presence of organic debris is important for maintaining aquatic habitat structure and function.

3.2.1.1 *Potential Adverse Impacts*

The removal of organic debris from natural systems can reduce habitat function, adversely impacting habitat quality. For example, in parts of the Pacific Northwest, reduction in LWD inputs to estuaries has reduced the number of spatially complex and diverse channel systems that provide productive salmon habitat (NRC 1996). Reductions in LWD inputs to estuaries may also affect the ecological balance of estuarine systems by altering rates and patterns of nutrient transport, sediment deposition, and availability of in-water cover for larval and juvenile fish. In rivers and streams of the Pacific Northwest, the historic practice of removing LWD to improve navigability and facilitate log transport has altered channel morphology and reduced habitat complexity, thereby negatively affecting habitat quality for spawning and rearing salmonids (Koski 1992; Sedell and Luchessa 1982).

Beach grooming and wrack removal can substantially alter the macrofaunal community structure of exposed sand beaches (Dugan et al. 2000). Species richness, abundance, and biomass of macrofauna associated with beach wrack (e.g., sand crabs, isopods, amphipods, and polychaetes) are higher on ungroomed beaches than on those that are groomed (Dugan et al. 2000). The input and maintenance of wrack can strongly influence the structure of macrofauna communities, including the abundance of sand crabs (*Emerita analoga*) (Dugan et al. 2000), an important prey species for some managed species of fish.

3.2.1.2 *Recommended Conservation Measures*

The recommended conservation measures for organic debris removal are listed below. They should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Encourage the preservation of LWD whenever possible, removing it only when it presents a threat to life or property.
- Encourage appropriate federal, state, and local agencies to aid in the downstream movement of LWD around dams, culverts, and bridges wherever possible, rather than removing it from the system.
- Educate landowners and recreationalists about the benefits of maintaining LWD.
- Localize beach grooming practices, and minimize them whenever possible.
- Advise gardeners to only harvest dislodged, dead kelp and leave live, growing kelp (whether dislodged or not). (See ADF&G brochure, “Harvesting Kelp and other Aquatic Plants in Southcentral Alaska, www.sf.adfg.state.ak.us.)

3.2.2 Inorganic Debris

Inorganic debris in the marine environment is a chronic problem along much of the U.S. coast, resulting in littered shorelines and estuaries with varying degrees of negative effects to coastal ecosystems. Nationally, land-based sources of marine debris account for about 80 percent of the marine debris on beaches and in U.S. waters. Debris can originate from combined sewer overflows and storm drains, stormwater runoff, landfills, solid waste disposal, poorly maintained garbage bins, floating structures, and general littering of beaches, rivers, and open waters. It generally enters waterways indirectly through rivers and storm drains or by direct ocean dumping. Ocean-based sources of debris also create problems for managed species. These include discarded or lost fishing gear (NMFS 2008), and galley waste and trash from commercial merchant, fishing, military, and other vessels.

Congress has passed numerous laws intended to prevent the disposal of marine debris in U.S. ocean waters. These include the Marine Protection, Research, and Sanctuaries Act, Titles I and II (also known as the Ocean Dumping Act). The Ocean Dumping Act implements the International Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Dumping Convention), commonly known as the MARPOL Annex V (33 CFR 151) for the U.S. The MARPOL Annex V is intended to protect the marine environment from various types of garbage by preventing ocean dumping if the ship is less than 25 nautical miles (nm) from shore. Dumping of unground food waste and other garbage is prohibited within 12 nm from shore, and ground non-plastic or food waste may not be dumped within 3 nm from shore.

Laws and regulations that address land-based sources of inorganic debris include the Beaches Environmental Assessment and Coastal Health Act of 2000 (BEACH Act), the Shore Protection Act of 1988, and the CWA. The BEACH Act authorizes EPA to fund state, territorial, Tribal, and local government programs that test and monitor coastal recreational waters near public access sites for microbial contaminants and to assess and monitor floatable debris. The Shore Protection Act contains provisions to ensure that municipal and commercial solid wastes are not

deposited in coastal waters during vessel transport from source to the waste receiving station. The CWA regulates discharges of pollutants into U.S. waters. The basis of the CWA was enacted in 1948 and was called the Federal Water Pollution Control Act, but the Act was significantly reorganized and expanded in 1972. "Clean Water Act" became the Act's common name with amendments in 1977. Under the CWA, EPA implements pollution control programs such as setting wastewater standards for industry, and water quality standards for all contaminants in surface waters. Laws and regulatory programs also prevent or control debris disposal from ocean-sources, including commercial merchant vessels (e.g., galley waste and other trash), recreational boaters and fishermen, offshore oil and gas exploration, development and production facilities, military and research vessels, and commercial fishing vessels (NMFS 2008).

Despite these laws and regulations, marine debris continues to adversely impact our waters. The National Marine Debris Monitoring Program (NMDMP) was a 5-year study, conducted from 2001 to 2006, designed to provide statistically valid estimates of marine debris affecting the entire U.S. coastline and to determine the main sources of the debris. Results from the study indicate that marine debris continues to plague the United States, and that certain regions face larger problems than others (Sheavly 2007). Alaska was not included in the results of the study because an insufficient number of surveys were conducted that did not meet the sampling criteria. Hawaii was the only location to demonstrate a significant decrease in all debris. Generally, marine debris from both ocean and land-based activities increased across the United States by more than 5 percent each year over the study period. The most abundant debris items surveyed nationally were straws, plastic beverage bottles, and plastic bags.

3.2.2.1 Potential Adverse Impacts

Land and ocean sourced inorganic marine debris is a very diverse problem, and adverse effects to EFH are likewise varied. Floating or suspended trash can directly affect managed species that consume or are entangled in it. Toxic substances in plastics can kill or impair fish and invertebrates that use habitat polluted by these materials. The chemicals the leach from plastics can persist in the environment and can bioaccumulate through the food web.

Once floatable debris settles to the bottom of estuaries, coastal and open ocean areas, it can continue to cause environmental problems. Plastics and other materials with a large surface area can cover and suffocate immobile animals and plants, creating large spaces devoid of life. Currents can carry suspended debris to underwater reef habitats where the debris can become snagged, damaging these sensitive habitats. The typical floatable debris from combined sewer overflows includes street litter, sewage containing viral and bacterial pathogens, pharmaceutical by-products from human excretion, and pet wastes. Pathogens can also contaminate shellfish beds and reefs.

3.2.2.2 Recommended Conservation Measures

Pollution prevention and improved waste management can occur through regulatory controls and best management practices. The recommended conservation measures for minimizing inorganic debris listed in the section below should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Encourage proper trash disposal, particularly in coastal and ocean settings, and participate in coastal cleanup activities.
- Advocate for local, state, and national legislation that rewards proper disposal of debris (e.g., implementation of a deposit on all plastic bottles).
- Encourage enforcement of regulations addressing marine debris pollution and proper disposal.
- Provide resources and technical guidance for development of studies and solutions addressing the problem of marine debris.
- Educate the public on the impact of marine debris and provide guidance on how to reduce or eliminate the problem.
- Implement structural controls that collect and remove trash before it enters nearby waterways, such as trash racks, mesh nets, bar screens, and trash booms, concentrate floating debris and trash, and prevent it from traveling downstream.
- Consider the use of centrifugal separation to physically separate solids and floatables from water in combined sewer outflows by increasing the settling time of trash and particles.
- Encourage the development of incentives and funding mechanisms to recover lost fishing gear.
- Require all existing and new commercial construction projects near the coast (e.g., marinas and ferry terminals, recreational facilities, boat building and repair facilities) to develop and implement refuse disposal plans.

3.3 Dam Operation

Dams provide sources of hydropower, water storage, and flood control. Construction and operation of dams can affect basic hydrologic and geomorphic function including the alteration of physical, biological, chemical processes that, in turn, can have effects on water quality, timing, quantity, and alter sediment transport.

3.3.1 *Potential Adverse Impacts (adapted from NMFS 2008)*

The effects of dam construction and operation on fish and aquatic habitat include (1) complete or partial upstream and downstream migratory impediment; (2) water quality and flow pattern alteration; (3) alteration to distribution and function of ice, sediment, and nutrient budgets; (4) alterations to the floodplain, including riparian and coastal wetland systems and associated functions and values; and (5) thermal impacts. Dam construction and operations can impede or block anadromous fish passage and other aquatic species migration in streams and rivers. Unless proper fish passage structures or devices are operational, dams can either prevent access to productive upstream spawning and rearing habitat or can alter downstream juvenile migration. Turbines, spillways, bypass systems, and fish ladders also affect the quality and quantity of EFH available for salmon passage in streams and rivers (Pacific Fishery Management Council [PFMC] 1999). The construction of a dam can fragment habitat, resulting in alterations to both upstream and downstream biogeochemical processes.

An understanding of the hydrologic system, including timing and annual variation of flows, as well as longer term trends in hydrology and climate, are necessary to understand how changes could alter habitat, habitat flow needs, and project operations.

Dam operations alter downstream water velocities and change discharge patterns. Water-level fluctuations, altered seasonal and daily flow regimes, and reduced water velocities discharge volumes can affect the migratory behavior of juvenile salmonids and reduce the availability of shelter and foraging habitat (PFMC 1999) and these modifications can increase migration times (Raymond 1979). Dam operation effects include pulse type flows, with sudden changes in flow over short periods of time, most often occurring in regulated rivers associated with hydroelectric operations and water resource needs. Pulse type flows can affect fish communities and benthic macro-invertebrates. The effects on anadromous fish can include stranding and trapping, isolation of habitat features, disruption of spawning, dewatering of redds, scour and flushing of redds, and food chain disruption (Reiser et al. 2005).

Many dams have multiple functions including flood control and water storage. Dams that are used for flood control are designed to decrease peak flows; dams that are designed for water storage use the reservoir capacity to store peak flows to increase water supply during normally low flow periods. The result of flood control and water storage is a reduction in the range of flows in the river, which can result in a loss of hydrologic and geomorphic functions. The width of the active portion of the watershed is reduced and the river channel shrinks (Heinz Center 2002).

The effects on migratory behavior on anadromous species are additionally complicated by development of reservoirs associated with dams. Reservoir affects include impediments to migration such as increased migration times, thermal barriers, increased predation, and loss of riparian habitat due to the large range of water level fluctuation.

Changes to the natural flow regime have effects on sediment and large wood transport as well as to seasonal icing. Ice formation and breakup is important to flood hazards, fluvial morphology, and fish habitat. An understanding of the relationship between the natural flow regime, ice development and function is necessary to assess how dam operations will affect these processes. An understanding of sediment and large wood transport, geomorphic influence, and an overall sediment budget is also important to understand dam effects. Dam operation can limit the natural processes associated with flooding, breakup, and can limit or alter natural sediment and LWD transport processes by impeding the high flows needed to scour fine sediments and move gravel and woody debris downstream. Floods transport sediments like silt, sand, and gravel, as well as aquatic plants and animals, leafy debris, and large woody debris. Curtailing these resources will affect the availability of spawning gravels and simplify channel morphology (Spence et al. 1996).

Changes to the timing and quantity of flow in rivers may result in the loss of riparian wetlands when water levels increase upstream and result in flow alterations downstream of the dam. In general, the greater the storage capacity of a dam, the more extensive downstream geomorphologic and biological impacts (Heinz Center 2002). Lost wetlands result in a loss of floodplain and flood storage capacity, and thus a reduced ability to provide flood control during storm event (NMFS 2008).

Dams can affect the thermal regimes of streams by raising or lowering water temperatures. Reductions in river water temperatures are common below dams if the intake of the water is from lower levels of the reservoir. Stratification of reservoir water not only affects temperature but can create oxygen-poor conditions in deeper areas and, if these waters are released, can degrade the water quality of the downstream areas (NMFS 2008).

3.3.2 Recommended Conservation Measures (adapted from NMFS 2008)

The following conservation recommendations regarding dams should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Avoid the construction of new dam facilities, where possible.
- Construct and design facilities with efficient and functional upstream and downstream adult and juvenile fish passage which ensures safe, effective, and timely passage.
- Operate dams within the natural flow fluctuations rates and timing and when possible to mimic the natural hydrograph, allow for sediment and wood transport, and consider and allow for natural ice function. Run-of-river dam operation is optimal, such that the volume of water entering an impoundment exits the impoundment with minimal change in storage, and is the preferred mode of operation for fishery and aquatic resource interests. Water flow monitoring equipment should be installed upstream and downstream of the facility. Reservoir level fluctuation should also be monitored.
- Understand longer term climatic and hydrologic patterns and how they affect habitat; plan project design and operation to minimize or mitigate for these changes.
- Use seasonal restrictions for construction, maintenance, and operations of dams to avoid impacts to habitat during species' critical life history stages (e.g., spawning and egg development periods). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
- Develop and implement monitoring protocols for fish passage.
- Retrofit existing dams with efficient and functional upstream and downstream fish passage structures.
- Construct dam facilities with the lowest hydraulic head practicable for the project purpose. Site the project at a location where dam height can be reduced.
- Downstream passage should prevent adults and juveniles from passing through the turbines and provide sufficient water downstream for safe passage.
- Coordinate maintenance and operations that require drawdown of the impoundment with state and federal resource agencies to minimize impacts to aquatic resources.
- Develop water and energy conservation guidelines for integration into dam operation plans and into regional and watershed-based water resource plans.
- Encourage the preservation of LWD, whenever possible. If possible, relocate debris as opposed to removing it completely. Remove LWD only to prevent damage to property or threats to human health and safety.

- Develop a sediment transport and geomorphic maintenance plan to allow for peak flow mimicking that will result in sediment pulses through the reservoir/dam system and allow high flow geomorphic processes.

3.4 Commercial and Domestic Water Use

An increasing demand for potable water, combined with inefficient use of freshwater resources and natural events (e.g., droughts) have led to serious ecological damage worldwide (Deegan and Buchsbaum 2005). Because human populations are expected to continue increasing in Alaska, it is reasonable to assume that water uses, including water impoundments and diversion, will similarly increase (Gregory and Bisson 1997). Groundwater supplies 87 percent of Alaska's 3,500 public drinking water systems. Ninety percent of the private drinking water supplies are groundwater. Each day, roughly 275 million gallons of water derived from aquifers, which directly support riverine systems, are used for domestic, commercial, industrial, and agricultural purposes in Alaska (Groundwater Protection Council 2010). Surface water sources serve a large number of people from a small number of public water systems (e.g., Anchorage and several southeastern communities).

3.4.1 Potential Adverse Impacts

The diversion of freshwater for domestic and commercial uses can affect EFH by (1) altering natural flows and the process associated with flow rates; (2) altering riparian habitats by removing water or by submersion of riparian areas; (3) removing the amount and altering the distribution of prey bases; (4) affecting water quality; and (5) entrapping fishes. Water diversions can involve either withdrawals (reduced flow) or discharges (increased flow).

Water withdrawal alters natural flow, stream velocity, and channel depth and width. Water withdrawal can also change sediment and nutrient transport characteristics (Christie et al. 1993; Fajen and Layzer 1993), increase deposition of sediments, reduce water depth, and accentuate diel temperature patterns (Zale et al. 1993). Loss of vegetation along streambanks and coastlines due to fluctuating water levels can decrease the availability of fish cover and food, and reduce bank stability (Christie et al. 1993). Changes in the quantity and timing of stream flow alters the velocity of streams, which, in turn, affects the composition and abundance of both insect and fish populations (Spence et al. 1996). Returning irrigation water to a stream, lake, or estuary can substantially alter and degrade habitat (NRC 1989). Problems associated with return flows include increased water temperature, increased salinity, introduction of pathogens, decreased dissolved oxygen, increased toxic contaminants from pesticides and fertilizers, and increased sedimentation (Northwest Power Planning Council 1986). Diversions can also physically divert or entrap EFH-managed species (Section 5.3).

Responsible water utilization can help reduce domestic and commercial water usage (Flowers 2004), which minimizes the effects to EFH. In 1990, industry and mining was the major commercial water use category in Alaska (Solley 1997). Prudent planning and water usage at the commercial scale also has the advantage of being cost effective.

3.4.2 Recommended Conservation Measures

These conservation measures for commercial and domestic water use should be viewed as options to avoid and minimize adverse impacts from commercial and domestic water use and promote the conservation, enhancement, and proper functioning of EFH.

- Design water diversion and impoundment projects to create flow conditions that provide for adequate fish passage, particularly during critical life history stages. Avoid low water levels that strand juveniles and dewater redds. Incorporate juvenile and adult fish passage facilities on all water diversion projects (e.g., fish bypass systems). Install screens at water diversions on fish-bearing streams, as needed.
- Maintain water quality necessary to support fish populations by monitoring and adjusting water temperature, sediment loads, and pollution levels.
- Maintain appropriate flow velocity and water levels to support continued stream functions. Maintain and restore channel, floodplain, riparian, and estuarine conditions.
- Where practicable, ensure that mitigation is provided for unavoidable impacts to fish and their habitat. Mitigation can include water conservation measures that reduce the volume of water diverted or impounded.

Chapter 4

Estuarine Activities

A large portion of Alaska's population resides near the state's 33,904-mile coastline (NOAA 2010). Historically, coastal features such as estuaries and embayments have been ideal for fishing, farming, or hunting and provided sheltered waters with access to rivers and the ocean for transportation purposes. Nationally, urban development in coastal areas is growing at a rate approximately five times that of other areas of the country and over one-half of all Americans live within 50 miles of the coast (Markham 2006). The expansion of port facilities, urbanization, filling of aquatic habitat and wetlands, and other forms of development surrounding estuaries and other coastal areas can have adverse impacts on fish habitat.

The dredging and filling of coastal wetlands for commercial and residential development, port, and harbor development directly removes important wetland habitat and alters the habitat surrounding the developed area. Physical changes from shoreline construction can result in secondary impacts such as increased suspended sediment loading, shading from piers and wharves, as well as introduction of chemical contamination from land-based human activities (Robinson and Pederson 2005). Even development projects that appear to have minimal individual impacts can have significant cumulative effects on the aquatic ecosystem (NMFS 2008).

4.1 Dredging

The construction of ports, marinas, and harbors typically involves dredging sediments from intertidal and subtidal habitats to create navigational channels, turning basins, anchorages, and berthing docks. Additionally, periodic dredging is used to maintain the required depths after sediment is deposited into these facilities. Dredging is also used to create deepwater navigable channels or to maintain existing channels that periodically fill with sediments. Port expansion has become an almost continuous process due to economic growth, competition between ports, and significant increases in vessel size (Section 4.3). (Impacts from dredging from marine mining are also addressed in Section 5.6.).

4.1.1 Potential Adverse Impacts

Dredging activities can adversely affect benthic and water-column habitat. The environmental effects of dredging on managed species and their habitat can include (1) direct removal/burial of organisms; (2) turbidity and siltation, including light attenuation from turbidity; (3) contaminant release and uptake, including nutrients, metals, and organics; (4) release of oxygen consuming substances (e.g., chemicals and bacteria); (5) entrainment; (6) noise disturbances; and (7) alteration to hydrodynamic regimes and physical habitat.

Many managed species forage on infaunal and bottom-dwelling organisms. Dredging may adversely affect these prey species by directly removing or burying them (Newell et al. 1998; Van der Veer et al. 1985). Similarly, dredging may also force mobile animals such as fish to migrate out of the project area. Recolonization studies suggest that recovery may not be

straightforward. Physical factors, including particle size distribution, currents, and compaction/stabilization processes can limit recovery after dredging events. Rates of recovery listed in the literature range from several months for estuarine muds to up to 2 to 3 years for sands and gravels. Recolonization can take up to 1 to 3 years in areas of strong current, but up to 5 to 10 years in areas of low current. Additionally, post-dredging recovery in cold waters at high latitudes may require additional time because these benthic communities can be composed of large, slow-growing species (Newell et al. 1998). Thus, forage resources for benthic feeders may be substantially reduced in dredged areas.

Certain types of dredging equipment can elevate levels of mineral particles or suspended sediment smaller than silt, and organic matter in the water column. The associated turbidity plumes of suspended particulates may reduce light penetration and lower the rate of photosynthesis for subaquatic vegetation (Dennison 1987) and the primary productivity of an aquatic area if particulates remain suspended for extended periods of times (Cloern 1987). If suspended sediment loads remain high, fish may suffer reduced feeding ability (Benfield and Minello 1996) and be prone to gill injury (Nightingale and Simenstad 2001a).

Sensitive habitats such as submerged aquatic vegetation beds, which provide food and shelter, may also be damaged. Eelgrass beds are critical to nearshore food web dynamics (Wyllie-Echeverria and Phillips 1994; Murphy et al. 2000). Studies have shown seagrass beds to be among the areas of highest primary productivity in the world (Herke and Rogers 1993; Hoss and Thayer 1993). This primary production provides high rates of secondary production in the form of fish (Herke and Rogers 1993; Good 1987; Sogard and Able 1991).

Suspended material from dredging may react with dissolved oxygen in the water and result in short-term oxygen depletion to aquatic resources (Nightingale and Simenstad 2001a). Dredging can also disturb aquatic habitats by resuspending bottom sediments and recirculating toxic metals (e.g., lead, zinc, mercury, cadmium, copper), hydrocarbons (e.g., polyaromatics), hydrophobic organics (e.g., dioxins), pesticides, pathogens, and nutrients into the water column (USEPA 2000a). Toxic metals and organics, pathogens, and viruses may become biologically available to organisms either in the water column or through food chain processes.

Entrainment is the direct uptake of aquatic organisms by the suction field created by hydraulic dredges. Benthic infauna is particularly vulnerable to entrainment by dredging, although some mobile epibenthic and demersal species such as shrimp, crabs, and fish can be susceptible to entrainment as well (Nightingale and Simenstad 2001b).

Fish detect and respond to sounds for many life history requirements (NMFS 2008). The noise generated by pumps, cranes, and the mechanical action of the dredge has the ability to alter the behavior of fish and other aquatic organisms. The noise levels and frequencies produced from dredging depend on the type of dredging equipment being used, the depth and thermal variations in the surrounding water, and the topography and composition of the surrounding sea floor (Nightingale and Simenstad 2001b; Stocker 2002). Dredging activities from both mechanical and hydraulic dredges produce sounds that are strongest at low frequencies. Due to rapid attenuation of low frequencies in shallow water, dredge noise normally is undetectable underwater at ranges beyond 20 km to 25 km (Richardson et al. 1995). While noise levels from large ships may exceed those from dredging, single ships usually do not produce strong noise in

one area for a prolonged period of time (Richardson et al. 1995). Noise from dredging may be continuous impacts for extended time periods (Nightingale and Simenstad 2001b).

Dredging and dredging equipment, such as pipelines, may damage or destroy spawning, nursery, and other sensitive habitats such as emergent marshes and subaquatic vegetation, including eelgrass beds and kelp beds. Dredging may also modify current patterns and water circulation by modifying substrate morphology. This can cause changes in the direction or velocity of water flow, water circulation, or dimensions of the waterbody traditionally used by fish for food, shelter, or reproductive purposes. Altered hydrodynamics can affect estuarine circulation, including short-term (diel) and longer term (seasonal or annual) changes (Deegan and Buchsbaum 2005).

4.1.2 Recommended Conservation Measures

The recommended conservation measures for dredging are listed in the following section. They should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Avoid new dredging in sensitive habitat areas to the maximum extent practicable. Activities that would likely require dredging (e.g., placement of piers, docks, marinas) should instead be located in deep water or designed to alleviate the need for maintenance dredging.
- Reduce the area and volume of material to be dredged to the maximum extent practicable.
- Avoid dredging and placement of equipment used in conjunction with dredging operations in special aquatic sites and other high value habitat areas, (e.g., kelp beds, eelgrass beds, salt marshes).
- Implement seasonal restrictions to avoid impacts to habitat during species critical life history stages (e.g., spawning season, egg, and larval development period). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
- Utilize BMPs to limit and control the amount and extent of turbidity and sedimentation. Standard BMPs may include silt fences, coffer dams, and operational modification (e.g., hydraulic dredge rather than mechanical dredge).
- For new dredging projects, undertake multi-season, pre-, and post-dredging biological surveys to assess the cumulative impacts to EFH and allow for implementation of adaptive management techniques.
- Prior to dredging, test sediments to be dredged for contaminants as per EPA and USACE requirements.
- Provide appropriate compensation for significant impacts (short-term, long-term, and cumulative) to benthic environments resulting from dredging.
- Identify excess sedimentation in the watershed that prompts excessive maintenance dredging activities, and implement appropriate management actions, if possible, to curtail those causes.

4.2 Material Disposal and Filling Activities

Material disposal and filling activities can directly remove important habitat and alter the habitat surrounding the developed area. Expansion of navigable waterways is associated with economic growth and development and generally adversely affects benthic and water-column habitats. The discharge of dredged materials or the use of fill material in aquatic habitats can result in covering or smothering existing submerged substrates, loss of habitat function, and adverse effects on benthic communities.

4.2.1 Disposal of Dredged Material

4.2.1.1 *Potential Adverse Impacts (adapted from NMFS 2008)*

The disposal of dredged material can reduce the suitability of water bodies for managed species and their prey by (1) reducing floodwater retention in wetlands; (2) reducing nutrients uptake and release; (3) decreasing the amount of detrital input, an important food source for aquatic invertebrates (Mitsch and Gosselink 1993); (4) habitat conversion through alteration of water depth or substrate type; (5) removing aquatic vegetation and preventing natural revegetation; (6) impeding physiological processes to aquatic organisms (e.g., photosynthesis, respiration) caused by increased turbidity and sedimentation (Arruda et al. 1983; Cloern 1987; Dennison 1987; Barr 1993; Benfield and Minello 1996; Nightingale and Simenstad 2001a); (7) directly eliminating sessile or semi-mobile aquatic organisms via entrainment or smothering (Larson and Moehl 1990; McGraw and Armstrong 1990; Barr 1993; Newell et al. 1998); (8) altering water quality parameters (i.e., temperature, oxygen concentration, and turbidity); and (9) releasing contaminants such as petroleum products, metals, and nutrients (USEPA 2000a).

4.2.1.2 *Recommended Conservation Measures*

The following recommended conservation measures for dredged material disposal should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Avoid disposing dredged material in wetlands, submerged aquatic vegetation and other special aquatic sites whenever possible. Study all options for disposal of dredged materials, including upland disposal sites, and select disposal sites that minimize adverse effects to EFH.
- Test sediment compatibility for open-water disposal per EPA and USACE requirements for inshore and offshore, unconfined disposal.
- Ensure that disposal sites are properly managed (e.g., disposal site marking buoys, inspectors, the use of sediment capping and dredge sequencing) and monitored (e.g., chemical and toxicity testing, benthic recovery) to minimize impacts associated with dredge material.
- Where long-term maintenance dredging is anticipated, acquire and maintain disposal sites for the entire project life.
- Encourage beneficial uses of dredged materials. Consider using dredging material for beach replenishment and construction where appropriate. When dredging material is placed in open water, consider the possibilities for enhancing marine habitat.

4.2.2 Fill Material

Like the discharge of dredged material, the discharge of fill material to create upland areas can remove productive habitat and eliminate important habitat functions. For example, the loss of wetland habitats reduces the production of detritus, an important food source for aquatic invertebrates; alters the uptake and release of nutrients to and from adjacent aquatic and terrestrial systems; reduces wetland vegetation, an important source of food for fish, invertebrates, and water fowl; hinders physiological processes in aquatic organisms (e.g., photosynthesis, respiration) because of degraded water quality and increased turbidity and sedimentation; alters hydrological dynamics, including flood control and groundwater recharge; reduces filtration and absorption of pollutants from uplands; and alters atmospheric functions, such as nitrogen and oxygen cycles (Mitsch and Gosselink 1993).

4.2.2.1 *Potential Adverse Impacts*

Adverse impacts to EFH from the introduction of fill material include (1) loss of habitat function and (2) changes in hydrologic patterns.

Aquatic habitats sustain remarkably high levels of productivity and support various life stages of fish species and their prey. Many times, these habitats are used for multiple purposes, including habitat necessary for spawning, breeding, feeding, or growth to maturity. The introduction of fill material eliminates those functions and permanently removes the habitat from production.

Fill material can modify current patterns and water circulation by obstructing flow, changing the direction or velocity of water flow and circulation, or otherwise changing the dimensions of a water body. As a result, adverse changes can occur in the location, structure, and dynamics of aquatic communities; shoreline and substrate erosion and deposition rates; the deposition of suspended particulates; the rate and extent of mixing of dissolved and suspended components of the water body; and water stratification (NMFS 1998b).

Fill in coastal waters that causes the loss of low gradient habitat or native substrate will likely have a negative effect on salmon rearing in the area. Nearshore shallow slopes are important to juvenile salmonids for (1) optimal feeding habitat, (2) shelter from high currents, and (3) shelter from predators. Both the abundance and productivity of salmon and salmon food organisms are affected by habitat gradient (Celewycz and Wertheimer 1994). The abundance of food organisms for juvenile salmon appears to be affected by habitat gradient (Sturdevant et al. 1994).

In addition to affecting salmon, juvenile flatfish that rear in nearshore areas have specific depth, slope, and substrate preferences (Moles and Norcross 1995) that limit their distribution and abundance. Nearshore juvenile flatfish habitat preferences vary by species, but for those that rear in nearshore areas, can generally be described as intertidal to shallow subtidal areas with substrate conditions that allow the animal to easily bury itself.

Fill that causes a loss of circulation in the nearshore area may also diminish important food sources for juvenile salmon and other managed species. Pelagic zooplankton is an important food source for juvenile pink and chum salmon (Sturdevant et al. 1996). Zooplankton distribution and abundance depends on currents to transport the zooplankton from offshore areas to nearshore areas.

4.2.2.2 *Recommended Conservation Measures*

The following recommended conservation measures for the discharge of fill material should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Federal, state, and local resource management and permitting agencies should address the cumulative impacts of fill operations on EFH and consider them in the permitting process for individual projects.
- Minimize the areal extent of any fill in EFH, or avoid it entirely. Mitigate all non-avoidable adverse impacts as appropriate.
- Consider alternatives to the placement of fill into areas that support managed species. Identify and characterize EFH habitat functions/services in the project areas, so that appropriate mitigation can be determined if necessary.
- Fill should be sloped to maintain shallow water, photic zone productivity; allow for unrestricted fish migration; and provide refugia for juvenile fish.
- In marine areas of kelp and other aquatic vegetation, fill (including artificial structure fill reefs) should be designed to maximize kelp colonization and provide areas for juvenile fish to find shelter from higher currents and exposure to predators.
- Fill materials should be tested and be within the neutral range of 7.5 to 8.4 pH. This pH range, in marine waters, will maximize colonization of marine organisms. Excessively alkaline or acidic fill material should not be used.

4.3 Vessel Operations, Transportation, and Navigation

The demand for increased capacity of marine transportation vessels, facilities, and infrastructure is a global trend in response to an increase in human population in coastal areas. As coastal areas grow, there are associated increases in vessel operations for cargo handling activities, water transportation services, and recreational opportunities (NMFS 2008). In Alaska, the growth in coastal communities is putting demands on port districts to increase infrastructure to accommodate additional vessel operations for cargo handling and marine transportation. Port expansion has become an almost continuous process due to economic growth, competition between ports, and significant increases in vessel size. In addition, increasing boat sales have put more pressure on improving and building new harbors, an important factor in Alaska because of the limited number of roads.

4.3.1 Potential Adverse Impacts

Activities associated with the expansion of port facilities, vessel/ferry operations, and recreational marinas can directly and indirectly impact EFH. Impacts include (1) loss and conversion of habitat; (2) altered light regimes and loss of submerged aquatic vegetation; (3) altered temperature regimes; (4) siltation, sedimentation, and turbidity; (5) contaminant releases; and (6) altered tidal, current, and hydrologic regimes.

Potential adverse impacts to EFH can occur during both the construction and operation phases. One of the most obvious habitat impacts related to the construction of a port or marina facility is alteration or loss of physical space taken up by the structures required for such a facility (Section

4.5). In Alaska, open cell sheet pile dock faces with backfill (Section 4.2.2) are often used to construct or expand existing facilities. Such designs replace existing areas of shallow slow moving water with deep fast moving water across a sheer sheet pile face. The sheltered areas of slower moving water where juvenile fish tend to be more abundant are eliminated, as are the clearer water microhabitats in the intertidal area that allow for visual feeding.

An increase in the number and size of vessels being operated can generate more wave and surge effects on shorelines. Vessel wakes can cause a significant increase in shoreline erosion, affect wetland habitat, and increase water turbidity. Vessel prop wash can also damage aquatic vegetation and disturb sediments, which may increase turbidity and suspend contaminants (Klein 1997, Warrington 1999). Mooring buoys, when anchored in shallow nearshore waters, can drag the anchor chain across the bottom, destroying submerged vegetation and creating a circular scour hole (Walker et al. 1989 *in* Shafer 2002).

Alteration of the light regimes in coastal waters can affect primary production. Docks and piers block sunlight penetration, alter water flow, introduce chemicals, and restrict access and navigation (Section 4.6). The height, width, construction materials used, and orientation of the structure in relation to the sun can influence how large a shade footprint an overwater structure may produce and how much of an adverse impact that shading effect may have on the localized habitat (Fresh 1997; Burdick and Short 1999; Fresh et al. 2001). Piling density can also affect the amount of light attenuation created by dock structures.

Nearshore temperature regimes and biological communities can be altered through the construction of seawalls and bulkheads. Shorelines that have been modified invariably contain less vegetation than do natural shorelines, which can reduce natural shading in the nearshore intertidal zone and cause increases in water temperatures. Conversely, seawalls and bulkheads constructed along north facing shorelines may unnaturally reduce light levels and reduce water temperatures in the water column adjacent to the structures (NMFS 2008).

Inadequate flushing of marinas also results in water quality problems (USACE 1993; Klein 1997). Poor flushing in marinas can increase temperature and raise phytoplankton populations with nocturnal dissolved oxygen level declines, resulting in organism hypoxia and pollutant inputs (Cardwell et al. 1980). An exchange of at least 30 percent of the water in the marina during a tidal change should minimize temperature increases and dissolved oxygen problems (Cardwell et al. 1980).

Typically, large sections of shoreline associated with a port development are replaced with impervious surfaces such as concrete and asphalt. Thus, stormwater runoff is exacerbated and can increase the siltation and sedimentation loads in estuarine and marine habitats. This increase in hard surfaces close to the marine environment intensifies nonpoint surface discharges (Section 2.3), adds debris, and reduces buffers between land use and the aquatic ecosystem. These include direct, indirect, and cumulative impacts on shallow subtidal, deep subtidal, eelgrass beds, mudflats, sand shoals, rock reefs, and salt marsh habitats. Such impacts would be site-specific, but in general structures interfere with longshore sediment transport processes resulting in altered substrate amalgamation, bathymetry, and geomorphology. Changing the type and distribution of sediment may alter key plant and animal assemblages, starve nearshore detrital-based foodwebs, and disrupt the natural processes that build spits and beaches (Nightingale and Simenstad 2001a;

NMFS 2005). In addition, the protected, low energy nature of marinas and ports may alter fish behavior as juvenile fish show an affinity to structure and may congregate around breakwaters or bulkheads (Nightingale and Simenstad 2001a).

4.3.2 Recommended Conservation Measures

The following recommended conservation measures for vessel operations, transportation infrastructure, and navigation, should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Locate marinas in areas of low biological abundance and diversity; if possible, for example, avoid the disturbance of eelgrass or other submerged aquatic vegetation including macroalgae, mudflats, and wetlands as part of the project design. In situations where such impacts are unavoidable, consider mitigation as appropriate.
- Leave riparian buffers in place to help maintain water quality and nutrient input.
- Include low-wake vessel technology, appropriate routes, and BMPs for wave attenuation structures as part of the design and permit process. Vessels should be operated at sufficiently low speeds to reduce wake energy, and no-wake zones should be designated near sensitive habitats.
- Incorporate BMPs to prevent or minimize contamination from ship bilge waters, antifouling paints, shipboard accidents, shipyard work, maintenance dredging and disposal, and nonpoint source contaminants from upland facilities related to vessel operations and navigation.
- Locate mooring buoys in water deep enough to avoid grounding and to minimize the effects of prop wash. Use subsurface floats or other methods to prevent contact of the anchor line with the substrate.
- Use catchment basins for collecting and storing surface runoff from upland repair facilities, parking lots and other impervious surfaces to remove contaminants prior to delivery to any receiving waters.
- Locate facilities in areas with enough water velocity to maintain water quality levels within acceptable ranges.
- Locate marinas where they do not interfere with natural processes so as to affect adjacent habitats.
- To facilitate movement of fish around breakwaters, breach gaps and construct shallow shelves to serve as “fish benches,” as appropriate. Often benches are expanded shelf features used in common toe-slope stabilization transitions within the breakwater design. Benches need to provide for unrestricted fish movement throughout all tidal stages.
- Harbor facilities should be designed to include practical measures for reducing, containing, and cleaning up petroleum spills.

4.4 Invasive Species

Introductions of invasive species into estuarine, riverine, and marine habitats have been well documented (Rosecchi et al. 1993; Kohler and Courtenay 1986; Spence et al. 1996) and can be

intentional (e.g., for the purpose of stock or pest control) or unintentional (e.g., fouling organisms). Exotic fish, shellfish, pathogens, and plants can be spread via shipping, recreational boating, aquaculture, biotechnology, and aquariums. The introduction of nonindigenous organisms to new environments can have many severe impacts on habitat (Omori et al. 1994).

Ballast water, which is water that is taken in or released by cargo vessels to compensate for changes in a ship's weight as cargo is loaded or unloaded, or as fuel and supplies are consumed, is a major source of non-native species introduction into aquatic ecosystems.³ When a vessel takes in ballast water, it also takes in aquatic organisms that may be carried from one port to another along the vessel's route. When ballast water is released, non-native or invasive species may be introduced into new environments where they can cause environmental harm. EPA has historically exempted ballast water discharges, and other discharges incidental to the normal operation of vessels ("incidental discharges") from CWA National Pollutant Discharge Elimination System (NPDES) permit requirements. However, on December 18, 2008 EPA signed the final Vessel General Permit (VGP) (73 FR 79473, December 29, 2009), with an effective date of February 6, 2009 for Alaska (74 FR 7042, February 12, 2009). Effective February 6, 2009, *all* vessels operating as a means of transportation that discharge ballast water or other incidental discharges into waters of the United States require coverage under the VGP, except for (1) recreational vessels, as defined in CWA § 502(25), and (2) vessels of the armed forces, as defined in 40 CFR § 1700.3. In addition, as required by Pub. L. No. 110-299, commercial fishing vessels and non-recreational vessels that are less than 79 feet in length are not subject to this permit, with the exception of ballast water discharges.

Invasive aquatic species that are considered high priority threats to Alaska's marine waters include: Atlantic salmon (*Salmo salar*), green crab (*Carcinus maenas*), Chinese mitten crab (*Eriocheir sinensis*), signal crayfish (*Pacifastacus leniulus*), zebra mussels (*Dreissena polymorpha*), New Zealand mudsnail (*Potamopyrgus antipodarum*), saltmarsh cordgrass (*Spartina alterniflora*), purple loosestrife (*Lythrum salicaria*), and tunicates (*Botrylloides violaceus* and *Didemnum vexillum*).⁴

Relatively few aquatic invasive species have been documented in Alaska; although a wide diversity of non-native taxonomic groups have colonized coastal ecosystems in other parts of the United States (McGee et al. 2006). Alaska's geographic isolation, harsh climate conditions, limited number of highly disturbed habitat areas, stringent plant and animal transportation laws, and smaller human population may explain the relative lack of invasion compared to more temperate sites in North America (Fay 2002; McGee et al. 2006). As economic activity and population size increase and the climate changes, the likelihood of aquatic invasive species establishing in Alaska will increase (Grebmeier et al. 2006, McGee et al. 2006). "Potential introduction pathways include fish farms, the intentional movement of game or bait fish from one aquatic system to another, the movement of large ships and ballast water from the U.S. West Coast and Asia, fishing vessels docking at Alaska's busy commercial fishing ports, construction equipment, trade of live seafood, aquaculture, and contaminated sport angler gear brought to Alaska's world-renowned fishing sites" (Fay 2002).

³ http://www.epa.gov/owow/invasive_species/factsheet.html

⁴ <http://www.adfg.state.ak.us/special/invasive/invasive.ph>

The Alaska Invasive Species Working Group (AISWG) was formed in 2006 to minimize invasive species impacts in Alaska by facilitating collaboration, cooperation, and communication among AISWG members and the people of Alaska. The AISWG is composed of representatives from state, federal, university, citizen, native, conservation, and military organizations. Current information on invasive species in Alaska can be found at www.uaf.edu/ces/aiswg. The 2008–2012 National Invasive Species Management Plan, developed collaboratively by 13 federal departments and agencies and their partners, is the “road map” for NOAA and its federal partners to focus on five strategic goals: Prevention; Early Detection and Rapid Response; Control and Management; Restoration; and Organizational Collaboration.⁵

Invasive species pose a serious threat to Alaska’s native flora and fauna. Long borders, long coastlines, busy shipping centers, and a large amount of imported goods give invasive species a lot of ways to enter Alaskan waters. Coordination and cooperation among Alaska’s existing organizations and their available resources is critical to successfully control and prevent invasive species in Alaska.⁶

4.4.1 Potential Adverse Impacts

Invasive species can create five types of negative effects on EFH: (1) habitat alteration, (2) trophic alteration, (3) gene pool alteration, (4) spatial alteration, and (5) introduction of diseases.

Habitat alteration includes the excessive colonization by sessile invasive species, which precludes the growth of endemic organisms. Invasive species may alter community structure by predation on native species or by population explosions of the introduced species. Introduced organisms increase competition with indigenous species, or they may forage on indigenous species, which can reduce fish and shellfish populations. For example, in freshwater lakes on Alaska’s Kenai Peninsula, introduced northern pike have depleted local salmonid populations through rampant juvenile predation. Spatial alteration occurs when territorial introduced species compete with and displace native species. Although hybridization is rare, it may occur between native and introduced species and can result in gene pool deterioration.

Non-native plants and algae can degrade coastal and marine habitats by changing natural habitat qualities. Introduced organisms increase competition with indigenous species, or they may forage on indigenous species or their prey, which can reduce indigenous fish and shellfish populations. Over the long-term the introduction of nonindigenous species can change the natural community structure and dynamics, lower the overall fitness and genetic diversity of natural stocks, and pass and/or introduce invasive lethal diseases.

Although hybridization is rare, it may occur between native and introduced species and can result in gene pool deterioration. The introduction of invasive organisms also threatens native biodiversity and could lead to changes in relative abundance of species and individuals that are of ecological and economic importance.

⁵ http://www.invasivespecies.gov/home_documents/2008-2012%20National%20Invasive%20Species%20Management%20Plan.pdf

⁶ <http://www.uaf.edu/ces/aiswg/>

Long-term impacts from the introduction of nonindigenous species can change the natural community structure and dynamics, lower the overall fitness and genetic diversity of natural stocks, and pass and/or introduce invasive lethal diseases. The introduction of bacteria, viruses, and parasites is another severe threat to EFH as it may reduce habitat quality. New pathogens or higher concentrations of disease can be spread throughout the environment, resulting in deleterious habitat conditions.

4.4.2 Recommended Conservation Measures

The following recommended conservation measures for invasive species should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Uphold fish and game regulations of the Alaska Board of Fisheries (AS 16.05.251) and Board of Game (AS 16.05.255), which prohibit and regulate the live capture, possession, transport, or release of native or exotic fish or their eggs.
- Adhere to regulations and use best management practices outlined in the State of Alaska Aquatic Nuisance Species Management Plan (Fay 2002).
- Encourage vessels to perform a ballast water exchange in marine waters (in accordance with the U.S. Coast Guard's voluntary regulations) to minimize the possibility of introducing invasive estuarine species into similar habitats. Ballast water taken on in the open ocean will contain fewer organisms, and these will be less likely to become invasive in estuarine conditions than species transported from other estuaries.
- Discourage vessels that have not performed a ballast water exchange from discharging their ballast water into estuarine receiving waters.
- Require vessels brought from other areas over land via trailer to clean any surfaces that may harbor non-native plant or animal species (e.g., propellers, hulls, anchors, fenders). Bilges should be emptied and cleaned thoroughly by using hot water or a mild bleach solution. These activities should be performed in an upland area to prevent introduction of non-native species during the cleaning process.
- Treat effluent from public aquaria displays and laboratories and educational institutes using non-native species before discharge to prevent the introduction of viable animals, plants, reproductive material, pathogens, or parasites into the environment.
- Encourage proper disposal of seaweeds and other plant materials used for packing purposes when shipping fish or other animals. These materials may harbor invasive species and pathogens and should be treated accordingly.
- Undertake a thorough scientific review and risk assessment before any non-native species are introduced.

4.5 Pile Installation and Removal (From NMFS 2005)

Pilings are an integral component of many overwater and in-water structures. They provide support for the decking of piers and docks, function as fenders and dolphins to protect structures, support navigation markers, and help in the construction of breakwaters and bulkheads.

Materials used in pilings include steel, concrete, wood (both treated and untreated), plastic, or a combination thereof.

Piles are usually driven into the substrate by using either impact or vibratory hammers. Impact hammers consist of a heavy weight that is repeatedly dropped onto the top of the pile, driving it into the substrate. Vibratory hammers use a combination of a stationary, heavy weight and vibration, in the plane perpendicular to the long axis of the pile, to force the pile into the substrate. The type of hammer used depends on a variety of factors, including pile material and substrate type. Impact hammers can be used to drive all types of piles, while vibratory hammers are generally most efficient at driving piles with a cutting edge (e.g., hollow steel pipe) and are less efficient at driving displacement piles (those without a cutting edge that must displace the substrate). Displacement piles include solid concrete, wood, and closed-end steel pipe.

4.5.1 Pile Driving

4.5.1.1 *Potential Adverse Impacts*

Feist et al. (1996) reported that pile-driving operations had an effect on the distribution and behavior of juvenile pink salmon (*Oncorhynchus gorbuscha*) and chum salmon (*Oncorhynchus keta*). Fish may leave an area for more suitable spawning grounds or may avoid a natural migration path because of noise disturbances. Pile driving can generate intense underwater sound pressure waves that may adversely affect EFH. These pressure waves have been shown to injure and kill fish (CalTrans 2001; Longmuir and Lively 2001; Stotz and Colby 2001; Stadler, pers. obs. 2002). Fish injuries associated directly with pile driving are poorly studied, but include rupture of the swim bladder and internal hemorrhaging (CalTrans 2001; Abbott and Bing-Sawyer 2002; Stadler pers. obs. 2002). Sound pressure levels (SPLs) 100 decibels (dB) above the threshold for hearing are thought to be sufficient to damage the auditory system in many fishes (Hastings 2002).

The type and intensity of the sounds produced during pile driving depend on a variety of factors, including the type and size of the pile, the firmness of the substrate into which the pile is being driven, the depth of water, and the type and size of the pile-driving hammer. SPLs are positively correlated with the size of the pile, as more energy is required to drive larger piles. Wood and concrete piles appear to produce lower sound pressures than hollow-steel piles of a similar size, although it is unclear if the sounds produced by wood or concrete piles are harmful to fishes. Hollow steel piles with a diameter of 14 inches (35.5 centimeters) in diameter have been shown to produce SPLs that can injure fish (Reyff 2003). Firmer substrates require more energy to drive piles and produce more intense sound pressures. Sound attenuates more rapidly with distance from the source in shallow water than it does in deep water (Rogers and Cox 1988).

Driving large hollow steel piles with impact hammers produces intense, sharp spikes of sound that can easily reach levels injurious to fish. Vibratory hammers, on the other hand, produce sounds of lower intensity, with a rapid repetition rate. A key difference between the sounds produced by impact hammers and those produced by vibratory hammers is the responses they evoke in fish. When exposed to sounds that are similar to those of a vibratory hammer, fish consistently displayed an avoidance response (Enger et al. 1993; Dolat 1997; Knudsen et al. 1997; Sand et al. 2000), and they did not habituate to the sound, even after repeated exposure (Dolat 1997; Knudsen et al. 1997). Fishes may respond to the first few strikes of an impact

hammer with a startle response. After these initial strikes, the startle response wanes, and the fishes may remain within the field of a potentially harmful sound (Dolat 1997; NMFS 2001). The differential responses to these sounds are due to the differences in the duration and frequency of the sounds.

When compared to impact hammers, the sounds produced by vibratory hammers are of longer duration (minutes versus milliseconds) and have more energy in the lower frequencies (15 to 26 hertz [hz] versus 100 to 800 hz) (Würsig et al. 2000; Carlson et al. 2001). Studies have shown that fish respond to particle acceleration of 0.01 meter per second squared at infrasound frequencies, that the response to infrasound is limited to the nearfield (less than 1 wavelength), and that the fish must be exposed to the sound for several seconds (Enger et al. 1993; Knudsen et al. 1994; Sand et al. 2000). Impact hammers, however, produce such short spikes of sound with little energy in the infrasound range that fish fail to respond to the particle motion (Carlson et al. 2001). Thus, impact hammers may be more harmful than vibratory hammers because they produce more intense pressure waves and because the sounds produced do not elicit an avoidance response in fishes, which exposes them to harmful pressures for longer periods.

The degree to which an individual fish exposed to sound will be affected depends on a number of variables, including (1) species of fish, (2) fish size, (3) presence of a swim bladder, (4) physical condition of the fish, (5) peak sound pressure and frequency, (6) shape of the sound wave (rise time), (7) depth of the water around the pile, (8) depth of the fish in the water column, (9) amount of air in the water, (10) size and number of waves on the water surface, (11) bottom substrate composition and texture, (12) effectiveness of bubble curtain sound/pressure attenuation technology, (13) tidal currents, and (14) presence of predators.

Depending on these factors, effects on fish can range from changes in behavior to immediate mortality. Minimal data exists on the SPL required to injure fish. Short-term exposure to peak SPLs above 190 dB (re:1 μ Pa) is thought to impose physical harm on fish (Hastings 2002). However, 155 dB (re:1 μ Pa) may be sufficient to stun small fish. Stunned fish, while perhaps not physically injured, are more susceptible to predation. Small fish are more prone to injury by intense sound than are larger fish of the same species (Yelverton et al. 1975). For example, a number of surfperches (*Cymatogaster aggregata* and *Embiotoca lateralis*) were killed during impact pile driving (Stadler pers. obs. 2002). Most of the dead fish were the smaller *C. aggregata* and similar sized specimens of *E. lateralis*, even though many larger *E. lateralis* were in the same area. Dissections revealed that the swim bladder of the smallest fish (80 millimeter [mm] forklength [FL]) was completely destroyed, while that of the largest individual (170 mm FL) was nearly intact, indicating a size-dependent effect. The SPLs that killed these fish are unknown. Of the reported fish kills associated with pile driving, all have occurred during use of an impact hammer on hollow-steel piles (Longmuir and Lively 2001; NMFS 2001, Stotz and Colby 2001; NMFS 2003).

Systems using air bubbles have been successfully designed to reduce the adverse effects of underwater SPLs on fish. Both confined (i.e., metal or fabric sleeve) and unconfined air bubble systems have been shown to attenuate underwater sound pressures (Longmuir and Lively 2001; Christopherson and Wilson 2002; Reyff and Donovan 2003). When using an unconfined air bubble system in areas of strong currents, it is critical that the pile be fully contained within the bubble curtain. To accomplish this when designing the system, adequate air flow and ring

spacing, both vertically and in terms of distance from the pile, are factors that should be considered.

4.5.1.2 Recommended Conservation Measures

The following recommended conservation measures for pile driving should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Install hollow steel piles with an impact hammer at a time of year when larval and juvenile stages of fish species with designated EFH are not present.

If the first measure is not possible, then the following measures regarding pile driving should be incorporated when practicable to minimize adverse effects:

- Drive piles during low tide when they are located in intertidal and shallow subtidal areas.
- Use a vibratory hammer when driving hollow steel piles. When impact hammers are required due to seismic stability or substrate type, drive the pile as deep as possible with a vibratory hammer before using the impact hammer.

Implement measures to attenuate the sound should SPLs exceed the 180 dB (re: 1 μ Pa) threshold. If sound pressure levels are anticipated to exceed acceptable limits, implement appropriate mitigation measures when practicable. Methods to reduce the sound pressure levels include, but are not limited to, the following:

- Surround the pile with an air bubble curtain system or air-filled coffer dam.
- Because the sound produced has a direct relationship to the force used to drive the pile, use a smaller hammer to reduce sound pressures.
- Use a hydraulic hammer if impact driving cannot be avoided. The force of the hammer blow can be controlled with hydraulic hammers; reducing the impact force will reduce the intensity of the resulting sound.
- Drive piles when the current is reduced (i.e., centered around slack current) in areas of strong current to minimize the number of fish exposed to adverse levels of underwater sound.

4.5.2 Pile Removal

4.5.2.1 Potential Adverse Impacts

The primary adverse effect of removing piles is the suspension of sediments, which may result in harmful levels of turbidity and release of contaminants contained in those sediments (Section 4.1). The methods that are generally utilized for pile removal are vibratory removal, breaking or cutting below the mudline, direct pull, and use of a clamshell. Vibratory pile removal tends to cause the sediments to slough off at the mudline, resulting in relatively low levels of suspended sediments and contaminants. Vibratory removal of piles is gaining popularity because it can be used on all types of piles, providing that they are structurally sound. Breaking or cutting the pile below the mudline may suspend only small amounts of sediment, providing that the stub is left in place, and little digging is required to access the pile. Direct pull or use of a clamshell to remove broken piles may, however, suspend large amounts of sediment and contaminants. When the

piling is pulled from the substrate using these two methods, sediments clinging to the piling will slough off as it is raised through the water column, producing a potentially harmful plume of turbidity and/or contaminants. The use of a clamshell may suspend additional sediment if it penetrates the substrate while grabbing the piling.

While there is a potential to adversely affect EFH during the removal of piles, many of the piles removed in Alaska are old creosote-treated timber piles. In some cases, the long-term benefits to EFH obtained by removing a chronic source of contamination may outweigh the temporary adverse effects of turbidity.

4.5.2.2 Recommended Conservation Measures

The following recommended conservation measures for pile removal should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Remove piles completely rather than cutting or breaking them off, if they are structurally sound.
- Minimize the suspension of sediments and disturbance of the substrate when removing piles. Measures to help accomplish this include, but are not limited to, the following:
 - When practicable, remove piles with a vibratory hammer, rather than using the direct pull or clamshell method.
 - Remove the pile slowly to allow sediment to slough off at, or near, the mudline.
 - The operator should first hit or vibrate the pile to break the bond between the sediment and the pile to minimize the potential for the pile to break, as well as to reduce the amount of sediment sloughing off the pile during removal.
 - Encircle the pile, or piles, with a silt curtain that extends from the surface of the water to the substrate.
- Complete each pass of the clamshell to minimize suspension of sediment if pile stubs are removed with a clamshell.
- Place piles on a barge equipped with a basin to contain attached sediment and runoff water after removal. Creosote-treated timber piles should be disposed of properly to prevent reuse in the marine environment, and all debris, including attached contaminated sediments, should be disposed of in an approved upland facility.
- Using a pile driver, drive broken/cut stubs far enough below the mudline to prevent release of contaminants into the water column as an alternative to their removal.

4.6 Overwater Structures (From NMFS 2005)

Overwater structures include commercial and residential piers and docks, floating breakwaters, barges, rafts, booms, and mooring buoys. These structures typically are located in intertidal areas out to about 49 feet (15 meters) below the area exposed by the mean lower low tide (i.e., the shallow subtidal zone).

4.6.1 Potential Adverse Impacts

Overwater structures and associated developments may adversely affect EFH in a variety of ways, primarily by: (1) changes in ambient light conditions, (2) alteration of the wave and current energy regime, (3) introduction of contaminants into the marine environment, and (4) activities associated with the use and operation of the facilities (Nightingale and Simenstad 2001b).

Overwater structures can create shade, which reduces the light levels below the structure. The size, shape, and intensity of the shadow cast by a particular structure depends upon its height, width, construction materials, and orientation. High and narrow piers and docks produce narrower, more diffuse shadows than do low and wide structures. In addition, less light is reflected underneath structures built with light-absorbing materials (e.g., wood) than under structures built with light-reflecting materials (e.g., concrete or steel). Structures that are oriented north-south produce a shadow that moves across the bottom throughout the day, resulting in a smaller area of permanent shade than those that are oriented east-west.

The shadow cast by an overwater structure affects the plant and animal communities below the structure. Distributions of plants, invertebrates, and fishes appear severely limited in under-dock environments when compared to adjacent, unshaded, vegetated habitats. Under-pier light levels can fall below threshold amounts for the photosynthesis of diatoms, benthic algae, eelgrass, and associated epiphytes. These photosynthesizers are an essential part of nearshore habitat and the estuarine and nearshore foodwebs that support many species of marine and estuarine fishes. Eelgrass and other macrophytes can be reduced or eliminated through partial shading of the substrate.

Fishes rely on visual cues for spatial orientation, prey capture, schooling, predator avoidance, and migration. The reduced-light conditions found under an overwater structure may limit the ability of fishes, especially juveniles and larvae, to perform these essential activities. Shading from overwater structures may also reduce prey organism abundance and the complexity of the habitat by reducing aquatic vegetation and phytoplankton abundance (Kahler et al. 2000; Haas et al. 2002). Glasby (1999) found that epibiotic assemblages on pier pilings at marinas subject to shading were markedly different than in surrounding areas. Other studies have shown shaded epibenthos to be reduced relative to that in open areas. These factors are thought to be responsible for the observed reductions in juvenile fish populations found under piers and the reduced growth and survival of fishes held in cages under piers, when compared to open habitats (Able et al. 1998; Duffy-Anderson and Able 1999).

Treated wood used for pilings and docks releases contaminants into saltwater environs. PAHs are commonly released from creosote-treated wood. PAHs can cause a variety of deleterious effects (cancer, reproductive anomalies, immune dysfunction, and growth and development impairment) to exposed fish (Johnson et al. 1999; Johnson 2000; Stehr et al. 2000). Wood also is commonly treated with other chemicals such as ammoniacal copper zinc arsenate and chromated copper arsenate (Poston 2001). These preservatives are known to leach into marine waters for a relatively short time after installation, but the rate of leaching varies considerably, depending on many factors. Concrete and steel, on the other hand, are relatively inert and do not leach contaminants into the water.

Construction and maintenance of overwater structures often involve driving pilings (Section 4.5) and dredging navigation channels (Section 4.1). Both activities may also adversely affect EFH.

While the effect of some individual overwater structures on EFH may be minimal, the overall impact may be substantial when considered cumulatively.

4.6.2 Recommended Conservation Measures

The following recommended conservation measures for overwater structures should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Use upland boat storage whenever possible to minimize need for overwater structures.
- Locate overwater structures in deep enough waters to avoid intertidal and shade impacts, minimize or preclude dredging, minimize groundings, and avoid displacement of submerged aquatic vegetation, as determined by a preconstruction survey.
- Design piers, docks, and floats to be multiuse facilities to reduce the overall number of such structures and to limit impacted nearshore habitat.
- Incorporate measures that increase the ambient light transmission under piers and docks. These measures include, but are not limited to, the following:
 - Maximize the height of the structure and minimize the width to decrease the shade footprint.
 - Use reflective materials (e.g., concrete or steel instead of materials that absorb light such as wood) on the underside of the dock to reflect ambient light.
 - Use the fewest number of pilings necessary to support the structures to allow light into under-pier areas and minimize impacts to the substrate.
 - Align piers, docks, and floats in a north-south orientation to allow the arc of the sun to cross perpendicular to the structure and to reduce the duration of light limitation.
- Use floating rather than fixed breakwaters whenever possible, and remove them during periods of low dock use. Encourage seasonal use of docks and off-season haul-out.
- Locate floats in deep water to avoid light limitation and grounding impacts to the intertidal or shallow subtidal zone.
- Maintain at least 1 foot (0.30 meter) of water between the substrate and the bottom of the float at extreme low tide.
- Conduct in-water work when managed species and prey species are least likely to be impacted.
- To the extent practicable, avoid the use of treated wood timbers or pilings. If practicable, use alternative materials such as untreated wood, concrete, or steel.
- Mitigate for unavoidable impacts to benthic habitats. Mitigation should be adequate, monitored, and adaptively managed.

4.7 Flood Control/Shoreline Protection (From NMFS 2005)

Structures designed to protect humans from flooding events can result in varying degrees of change in the physical, chemical, and biological characteristics of shoreline and riparian habitat. These structures also can have long-term adverse effects on tidal marsh and estuarine habitats. Tidal marshes are highly variable, but typically have freshwater vegetation at the landward side, saltwater vegetation at the seaward side, and gradients of species in between that are in equilibrium with the prevailing climatic, hydrographic, geological, and biological features of the coast. These systems normally drain through tidal creeks that empty into the bay or estuary. Freshwater entering along the upper edges of the marsh drains across the surface and enters the tidal creeks. Structures placed for coastal shoreline protection may include concrete or wood seawalls, rip-rap revetments (sloping piles of rock placed against the toe of the dune or bluff in danger of erosion from wave action), dynamic cobble revetments (natural cobble placed on an eroding beach to dissipate wave energy and prevent sand loss), vegetative plantings, and sandbags.

4.7.1 Potential Adverse Impacts

Dikes, levees, ditches, or other water controls at the upper end of a tidal marsh can cut off all tributaries feeding the marsh, preventing the flow of freshwater, annual renewal of sediments and nutrients, and the formation of new marshes. Water controls within the marsh can intercept and carry away freshwater drainage, thus blocking freshwater from flowing across seaward portions of the marsh, or conversely increase the speed of runoff of freshwater to the bay or estuary. This can result in lowering the water table, which may permit saltwater intrusion into the marsh, and create migration barriers for aquatic species. In deeper channels where anoxic conditions prevail, large quantities of hydrogen sulfide may be produced that are toxic to marsh grasses and other aquatic life (NMFS 2008). Acid conditions of these channels can also result in release of heavy metals from the sediments.

Long-term effects of shoreline protection structures on tidal marshes include land subsidence (sometimes even submergence), soil compaction, conversion to terrestrial vegetation, greatly reduced invertebrate populations, and general loss of productive wetland characteristics (NMFS 2005). Alteration of the hydrology of coastal salt marshes can reduce estuarine productivity, restrict suitable habitat for aquatic species, and result in salinity extremes during droughts and floods (NMFS 2008). Armoring shorelines to prevent erosion and to maintain or create shoreline real estate can reduce the amount of intertidal habitat, and affects nearshore processes and the ecology of numerous species (Williams and Thom 2001). Hydraulic effects on the shoreline include increased energy seaward of the armoring, reflected wave energy, dry beach narrowing, substrate coarsening, beach steepening, changes in sediment storage capacity, loss of organic debris, and downdrift sediment starvation (Williams and Thom 2001). Installation of breakwaters and jetties can result in community changes from burial or removal of resident biota, changes in cover and preferred prey species, and predator attraction (Williams and Thom 2001). As with armoring, breakwaters and jetties modify hydrology and nearshore sediment transport, as well as movement of larval forms of many species (Williams and Thom 2001).

4.7.2 Recommended Conservation Measures

The following recommended conservation measures for flood and shoreline protection should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Avoid or minimize the loss of coastal wetlands as much as possible, including encouraging coastal wetland habitat preservation.
- Do not dike or drain tidal marshlands or estuaries.
- Wherever possible, use soft approaches (such as beach nourishment, vegetative plantings, and placement of LWD) in lieu of “hard” shoreline stabilization and modifications (such as concrete bulkheads and seawalls, concrete or rock revetments).
- Ensure that the hydrodynamics and sedimentation patterns are properly modeled and that the design avoids erosion to adjacent properties when “hard” shoreline stabilization is deemed necessary.
- Include efforts to preserve and enhance fishery habitat (e.g., provide new gravel for spawning or nursery habitats; remove barriers to natural fish passage; and use of weirs, grade control structures, and low flow channels to provide the proper depth and velocity for fish) to offset impacts.
- Avoid installing new water control structures in tidal marshes and freshwater streams. If the installation of new structures cannot be avoided, ensure that they are designed to allow optimal fish passage and natural water circulation.
- Ensure water control structures are monitored for potential alteration of water temperature, dissolved oxygen concentration, and other parameters.
- Use seasonal restrictions to avoid impacts to habitat during species critical life history stages (e.g., spawning, egg, and larval development periods). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
- Address the cumulative impacts of past, present and foreseeable future development activities on aquatic habitats by considering them in the review process for flood control and shoreline protection projects.
- Use an adaptive management plan with ecological indicators to oversee monitoring and to ensure that mitigation objectives are met. Take corrective action as needed.

4.8 Log Transfer Facilities/In-Water Log Storage (From NMFS 2005)

Rivers, estuaries, and bays were historically the primary ways to transport and store logs in the Pacific Northwest, and log storage continues in some tidal areas today. Using estuaries and bays and nearby uplands for storage of logs is common in Alaska, with most log transfer facilities (LTFs) found in Southeast Alaska and a few located in Prince William Sound. LTFs are facilities that are constructed wholly or in part in waterways and used to transfer commercially harvested logs to or from a vessel or log raft, or for consolidating logs for incorporation into log rafts (USEPA 2000b). LTFs may use a crane, A-frame structure, conveyor, slide, or ramp to

move logs from land into the water. Logs can also be placed in the water at the site by helicopters.

4.8.1 Potential Adverse Impacts

Log handling and storage in the estuaries and intertidal zones can result in modification of benthic habitat and water quality degradation within the area of bark deposition (Levings and Northcote 2004). EFH may be physically impacted by activities associated with LTFs. LTFs may cause shading and other indirect effects similar in many ways to those of floating docks and other over-water structures (Section 4.6).

Bark and wood debris may accumulate as a result of the abrasion of logs from transfer equipment. After the logs have entered the water, they usually are bundled into rafts and hooked to a tug for shipment. In the process, bark and other wood debris can pile up on the ocean floor. The debris can smother clams, mussels, seaweed, kelp, and grasses, with the bark sometimes remaining for decades. Accumulation of bark debris in shallow and deep-water environments has resulted in locally decreased benthic species richness and abundance (Kirkpatrick et al. 1998; Jackson 1986).

Log storage may also result in a release of soluble organic compounds within the bark pile. Log bark may affect groundfish habitat by significantly increasing oxygen demand within the area of accumulation (Pacific Northwest Pollution Control Council 1971). High oxygen demand can lead to an anaerobic zone within the bark pile where toxic sulfide compounds are generated, particularly in brackish and marine waters. Reduced oxygen levels, anaerobic conditions, and the presence of toxic sulfide compounds can result in reduced localized habitat value for groundfish species and their forage base. In addition, soils at onshore facilities where logs are decked can become contaminated with gasoline, diesel fuel, solvents, etc., from trucks and heavy equipment. These contaminants could leach into nearshore EFH.

4.8.2 Recommended Conservation Measures

The following recommended conservation measures for log transfer and storage facilities should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

The physical, chemical, and biological impacts of LTF operations can be substantially reduced by adherence to appropriate siting and operational constraints. In 1985, the Alaska Timber Task Force (ATTF) developed guidelines to “delineate the physical requirements necessary to construct a log transfer and associated facilities, and in context with requirements of applicable law and regulations, methods to avoid or control potential impacts from these facilities on water quality, aquatic and other resources.” Since 1985, the ATTF guidelines have been applied to new LTFs through the requirements of NPDES permits and other state and federal programs (USEPA 1996). Adherence to the ATTF operational and siting guidelines and BMPs in the NPDES General Permit will reduce (1) the amount of bark and wood debris that enters the marine and coastal environment, (2) the potential for displacement or harm to aquatic species, and (3) the accumulation of bark and wood debris on the ocean floor. The following conservation measures reflect those guidelines.

- Restrict or eliminate storage and handling of logs from waters where state and federal water quality standards cannot be met at all times outside of the authorized zone of deposition.
- Minimize potential impacts of log storage by employing effective bark and wood debris control, collection, and disposal methods at log dumps, raft building areas, and mill-side handling zones; avoiding free-fall dumping of logs; using easy let-down devices for placing logs in the water; and bundling logs before water storage (bundles should not be broken except on land and at millside).
- Do not store logs in the water if they will ground at any time or shade sensitive aquatic vegetation such as eelgrass.
- Avoid siting log-storage areas and LTFs in sensitive habitat and areas important for specified species, as required by the ATTF guidelines.
- Site log storage areas and LTFs in areas with good currents and tidal exchanges.
- Use land-based storage sites where possible, with the goal of eliminating in-water storage of logs.
- Also see the following link for LTF guidelines:
http://www.fs.fed.us/r10/TLMP/F_PLAN/APPEND_G.PDF.

4.9 Utility Line, Cables, and Pipeline Installation

With the continued development of coastal regions comes greater demand for the installation of cables, utility lines for power and other services, and pipelines for water, sewage, and other utilities. The installation of pipelines, utility lines, and cables can have direct and indirect impacts on the offshore, nearshore, estuarine, wetland, beach, and rocky shore coastal zone habitats. Many of the direct impacts occur during construction, such as ground disturbance in the clearing of the right-of-way, access roads, and equipment staging areas. Indirect impacts can include increased turbidity, saltwater intrusion, accelerated erosion, and introduction of urban and industrial pollutants due to ground clearing and construction.

4.9.1 Potential Adverse Impacts

Adverse effects on EFH from the installation of pipelines, utility lines, and cables can occur through (1) destruction of organisms and habitat, (2) turbidity impacts, (3) resuspension and release of contaminants, (4) changes in hydrology, and (5) destruction of vertically complex hard bottom habitat (e.g., hard corals and vegetated rocky reef).

Destruction of organisms and habitats can occur in pipeline or cable right-of-way. This destruction can lead to long-term or permanent damage depending on the degree and type of habitat disturbance and the mitigation measures employed. Shallow-water environments, rocky reefs, nearshore and offshore rises, wetlands, and estuaries are more likely to be adversely impacted than open-water habitats. This is due to their higher sustained biomass and lower water volumes, which decrease their ability to dilute and disperse suspended sediments (Gowen 1978).

Because vegetated coastal wetlands provide forage for and protection of commercially important invertebrates and fish, marsh degradation due to plant mortality, soil erosion, or submergence will eventually decrease productivity. Vegetation loss and reduced soil elevation within pipeline

construction corridors should be expected with the use of double-ditching techniques (Polasek 1997). Subsea pipelines that are placed on the substrate have the potential to create physical barriers to benthic invertebrates during migration and movement. Furthermore, erosion around buried pipelines and cables can lead to uncovering of the structure and the formation of escarpments. This, in turn, can interfere with the migratory patterns of benthic species (NMFS 2008).

4.9.2 Recommended Conservation Measures

The following recommended conservation measures for cable and utility line installation should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Align crossings along the least environmentally damaging route. Avoid sensitive habitats such as hard bottom (e.g., rocky reefs), cold-water corals, submerged aquatic vegetation, oyster reefs, emergent marsh, and mud flats.
- Use horizontal directional drilling where cables or pipelines would cross anadromous fish streams, salt marsh, vegetated inter-tidal zones, or steep erodible bluff areas adjacent to the intertidal zone.
- Store and contain excavated material on uplands. If storage in wetlands or waters cannot be avoided, use alternate stockpiles to allow continuation of sheet flow. Store stockpiled materials on construction cloth rather than bare marsh surfaces, sea grasses, or reefs.
- Backfill excavated wetlands with either the same or comparable material capable of supporting similar wetland vegetation. Restore original marsh elevations. Stockpile topsoil and organic surface material such as root mats separately, and return it to the surface of the restored site. Use adequate material so that the proper pre-project elevation is attained following settling and compaction of the material. After backfilling, implement erosion protection measures where needed.
- Use existing rights-of-way whenever possible to lessen overall encroachment and disturbance of wetlands.
- Bury pipelines and submerged cables where possible. Unburied pipelines, or pipelines buried in areas where scouring or wave activity eventually exposes them, run a much greater risk of damage leading to leaks or spills.
- Remove inactive pipelines and submerged cables unless they are located in sensitive areas (e.g., marsh, reefs, sea grass). If allowed to remain in place, ensure that pipelines are properly pigged, purged, filled with seawater, and capped before abandonment in place.
- Use silt curtains or other barriers to reduce turbidity and sedimentation whenever possible near the project site.
- Limit access for equipment to the immediate project area. Tracked vehicles are preferred over wheeled vehicles. Consider using mats and boards to avoid sensitive areas. Caution equipment operators to avoid sensitive areas. Clearly mark sensitive areas to ensure that equipment operators do not traverse them.

- Limit construction equipment to the minimum size necessary to complete the work. Use shallow-draft equipment to minimize effects and to eliminate the necessity for temporary access channels. Use the push-ditch method, in which the trench is immediately backfilled, to minimize the impact duration when possible.
- Conduct construction during the time of year when it will have the least impact on sensitive habitats and species.
- Suspend transmission lines beneath existing bridges or conduct directional boring under streams to reduce the environmental impact. If transmission lines span streams, site towers at least 200 feet from streams.
- For activities on the Continental Shelf, to avoid and minimize adverse impacts to managed species, implement the following to the extent practicable:
 - Shunt drill cuttings through a conduit and either discharge the cuttings near the sea floor, or transport them ashore.
 - Locate drilling and production structures, including pipelines, at least 1 mile (1.6 kilometers) from the base of a hard-bottom habitat.
 - Bury pipelines at least 3 feet (0.9 meter) beneath the sea floor whenever possible. Particular considerations (i.e., currents, ice scour) may require deeper burial or weighting to maintain adequate cover. Buried pipeline and cables should be examined periodically for maintenance of adequate cover.
 - Locate alignments along routes that will minimize damage to marine and estuarine habitat. Avoid laying cable over high-relief bottom habitat and across live bottom habitats such as coral and sponge.

4.10 Mariculture

Productive embayments are often used for commercial culturing and harvesting operations. These locations provide protected waters for geoduck, oyster, and mussel culturing. In 1988, Alaska passed the Alaska Aquatic Farming Act (AAF Act) which is designed to encourage establishment and growth of an aquatic farming industry in the state. The AAF Act establishes four criteria for issuance of an aquatic farm permit, including the requirement that the farm may not significantly affect fisheries, wildlife, or other habitats in an adverse manner. Aquatic farm permits are issued by the Alaska Department of Natural Resources (ADNR).

4.10.1 Potential Adverse Impacts

Shellfish aquaculture tends to have less impact on EFH than finfish aquaculture because the shellfish generally are not fed or treated with chemicals (OSPAR Commission 2009). Adverse impacts to EFH by mariculture operations include (1) risk of introducing undesirable species and disease, (2) physical disturbance of intertidal and subtidal areas, and (3) impacts on estuarine food webs, including disruption of eelgrass habitat (e.g., dumping of shell on eelgrass beds, repeated mechanical raking or trampling, and impacts from predator exclusion netting, though few studies have documented impacts). Hydraulic dredges used to harvest oysters in coastal bays can cause long-term adverse impacts to eelgrass beds by reducing or eliminating the beds (Phillips 1984).

The rearing of non-native species may pose a risk of escape or accidental release into areas where they would adversely affect the ecological balance. Escape or other release into the environment can result in competition with native, wild species and genetic dilution (NMFS 2005). Movement of mariculture facility components (e.g. docks, cages) between locations also may be a vector for introducing non-native species. In 2010, the invasive tunicate *Didemnum vexillum* was found associated with an oyster aquaculture facility in Sitka, Alaska.

Concern has also been expressed about extensive shellfish culture in estuaries and its impact on estuarine food webs. Oysters are efficient filter feeders and reduce microalgae and zooplankton that are also food for salmon prey species. The extent to which this may adversely affect managed prey species is unknown. However, because bivalves remove suspended sediments and phytoplankton from the water column, mariculture may actually improve water quality in eutrophic areas and can assist in recycling nutrients from water column to the sediment (Emmett 2002).

Mariculture facilities can be attractive to bird and mammal species both as a food source and shelter/resting facilities. Seals in particular have been known to prey on shellfish in cages and use mariculture facilities as haul outs (OSPAR Commission 2009). This can result in economic loss to the facility, danger to employees and possibly injury or death for the offending animal(s). Diving birds may also be attracted to the cages and have been known to become entangled. Increased boat traffic, human presence, and the use of scaring devices also may adversely affect resident bird and mammal species not directly utilizing the mariculture facilities.

4.10.2 Recommended Conservation Measures

The following recommended conservation measures for mariculture facilities should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Site mariculture operations away from kelp or eelgrass beds. If mariculture operations are to be located adjacent to existing kelp or eelgrass beds, monitor these beds on an annual basis and resite the mariculture facility if monitoring reveals adverse effects.
- Do not enclose or impound tidally influenced wetlands for mariculture. Take into account the size of the facility, migratory patterns, competing uses, hydrographic conditions, and upstream uses when siting facilities.
- Undertake a thorough scientific review and risk assessment before any non-native species are introduced.
- Encourage development of harvesting methods to minimize impacts on plant communities and the loss of food and/or habitat to fish populations during harvesting operations.
- Provide appropriate mitigation for the unavoidable, extensive, or permanent loss of plant communities.
- Ensure that mariculture facilities, spat, and related items transported from other areas are free of nonindigenous species. For control of *Didemnum tunicates*, remove nets, floats,

and other structures from salt water periodically and allow them to dry thoroughly, and/or soak them in fresh water.

Coastal/Marine Activities

5.1 Point-Source Discharges

Contaminants enter waterways through point and nonpoint sources. Pollutants of nonpoint source origins tend to enter aquatic systems as relatively diffuse contaminant streams primarily from atmospheric and terrestrial sources (see Section 2.1 for the discussion on nonpoint source pollution). This differs from point source pollutants, which are generally introduced via some type of pipe, culvert, or similar outfall structure. These discharge facilities typically are associated with domestic or industrial activities, or in conjunction with collected runoff from roadways and other developed portions of the coastal landscape. Waste streams from sewage treatment facilities and watershed runoff may be combined in a single discharge. Both point source and nonpoint source discharges introduce inorganic and organic contaminants into aquatic habitats, where they may become bioavailable to living marine resources.

The practice of disposing of waste materials into rivers, estuaries, and marine waters is not a modern phenomenon; it has been used as a preferred method since the beginning of human civilization (Ludwig and Gould 1988; Islam and Tanaka 2004). Nevertheless, when the full spectrum of emissions from land-based activities is taken into account, the use of coastal waters as a repository for anthropogenic waste has not previously been practiced on as large or intense a global scale as in recent decades (Williams 1996). Identifying the sources and effects of anthropogenic contaminants in near-coastal areas of the US is an ongoing scientific effort (USEPA 1999).

5.1.1 Potential Adverse Impacts (Adopted from NMFS 2008)

The Clean Water Act (CWA) includes important provisions to address acute or chronic water pollution emanating from point source discharges. Under the NPDES program, most point-source discharges are regulated by the state or EPA. While the NPDES program has led to ecological improvements in waters of the United States, point sources continue to introduce pollutants into the aquatic environment, albeit at reduced levels.

Determining the fate and effect of natural and synthetic contaminants in the environment requires an interdisciplinary approach to identify and evaluate all processes sensitive to pollutants. This is critical as adverse effects may be manifested at the biochemical level in organisms (Luoma 1996) in a manner particular to the species or life stage exposed. Exposure to pollutants can inhibit (1) basic detoxification mechanisms, e.g., production of metallothioneins or antioxidant enzymes; (2) disease resistance; (3) the ability of individuals or populations to counteract pollutant-induced metabolic stress; (4) reproductive processes including gamete development and embryonic viability; (5) growth and successful development through early life stages; (6) normal processes including feeding rate, respiration, osmoregulation; and (7) overall

Darwinian fitness (Capuzzo and Sassner 1977; Widdows et al. 1990; Nelson et al. 1991; Stiles et al. 1991; Luoma 1996; Thurberg and Gould 2005).

The nature and extent of a pollutant's dispersal depends on a variety of factors including site-specific ecological conditions, the physical state of the contaminant introduced into the aquatic environment, and the inherent chemical properties of the substance. Soluble or miscible substances usually enter waterways in an aqueous phase, ultimately becoming adsorbed onto organic and inorganic particles (Wu et al. 2005). However, contaminants also enter aquatic systems as either particle-borne suspensions or as solutes (Bishop 1984; Turner and Millward 2002). Physical factors, such as the presence of significant currents or a strong thermocline or pycnocline, influence the spatial extent of contaminant dispersal. In particular, turbulent mixing, or diffusion, disperses contaminant patches in coastal waters resulting in larger, comparatively diluted contaminant distributions further away from the initial point source—the mixing zone (Bishop 1984). Subsequent biological activity and geochemical processes intercede and typically result in contaminant partitioning between the aqueous and particulate phases (Turner and Millward 2002).

Physical dispersion, biological activity, and other ecological factors play significant roles in the distribution of contaminants in aquatic habitats; however, the partitioning of contaminants is largely governed by certain ambient environmental conditions, notably salinity, pH, and the physical nature of local sediments (Turekian 1978; McElroy et al. 1989; Turner and Millward 2002; Leppard and Droppo 2003; Wu et al. 2005). Typically, highly reactive suspended particles serve as important carriers of aquatic contaminants and are largely responsible for their bioavailability, transport, and ecological fate as they disperse into receiving waters (Turner and Millward 2002). Additionally, hyporheic exchange between overlying water and groundwater can alter salinity, dissolved oxygen concentration, and other water chemistry aspects in ways that can influence the affinity of local sediment types for particular contaminants or otherwise affect contaminant behavior (Ren and Packman 2002).

Discharge sites may also modify habitat by creating adverse impacts to sensitive areas such as freshwater shorelines and wetlands, emergent marshes, sea grasses, and kelp beds if located improperly. Extreme discharge velocities of effluent may cause scouring at the discharge site, and may also entrain particulates and thereby create turbidity plumes. These turbidity plumes of suspended particulates can reduce light penetration and lower the rate of photosynthesis and the primary productivity of an aquatic area while elevated turbidity persists. The contents of the suspended material can react with the dissolved oxygen in the water and result in oxygen depletion, or smother submerged aquatic vegetation sites, including eelgrass beds and kelp beds. Accumulation of outfall sediments may also alter the composition and abundance of infaunal or epibenthic invertebrate communities (Ferraro et al. 1991). Many benthic organisms are quite sensitive to grain size, and accumulation of sediments can also submerge food organisms (Section 4.2.2).

5.1.2 Recommended Conservation Measures

The following recommended conservation measures for point source discharges should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Locate discharge points in coastal waters well away from shellfish beds, sea grass beds, corals, and other similar fragile and productive habitats.
- Reduce potentially high velocities by diffusing effluent to acceptable velocities.
- Determine baseline benthic productivity by sampling before any construction activity related to installation of new outfalls to facilitate monitoring of environmental changes.
- Provide for mitigation when degradation or loss of habitat occurs from placement and operation of the outfall structure and pipeline.
- Institute source-control programs that effectively reduce noxious materials to avoid introducing these materials into the waste stream.
- Ensure compliance with pollutant discharge permits, which set effluent limitations and/or specify operation procedures, performance standards, or BMPs. These efforts rely on the implementation of BMPs to control polluted runoff (USEPA 1993).
- Treat discharges to the maximum extent practicable, including up-to-date methodologies for reducing discharges of biocides (e.g., chlorine) and other toxic substances.
- Use land-treatment and upland disposal/storage techniques where possible. Limit the use of vegetated wetlands as natural filters and pollutant assimilators for large-scale discharges to those instances where other less damaging alternatives are not available.
- Avoid siting pipelines and treatment facilities in wetlands and streams.

5.2 Seafood Processing Waste—Shoreside and Vessel Operation

Seafood processing is conducted throughout much of coastal Alaska. Processing facilities may be vessel-based or located onshore (ADEC 2010a). Seafood processing is any activity that modifies the physical condition of a fishery resource (ADEC 2010b). With the exception of fresh market fish, some form of processing involving butchering, evisceration, precooking, or cooking is necessary to bring the catch to market. Precooking or blanching facilitates the removal of skin, bone, shell, gills, and other materials. Seafood processing facilities generally consist of mechanisms to offload the harvest from fishing boats; tanks to hold the seafood until the processing lines are ready to accept them; processing lines, process water, and waste collection systems; treatment and discharge facilities; processed seafood storage areas; and necessary support facilities such as electrical generators, boilers, retorts, water desalinators, offices, and living quarters. In addition, recreational fish cleaning at marinas and small harbors can produce a large quantity of fish waste.

Pollutants of concern from seafood processing wastewater are primarily components of the biological wastes generated by processing raw seafood into a marketable form, chemicals used to maintain sanitary conditions for processing equipment and fish containment structures, and refrigerants (ammonia and freon) that may leak from refrigeration systems used to preserve seafood (ADEC 2010b). Biological wastes include fish parts; heads, fins, bones, and entrails; as well as chemicals, which are primarily disinfectants that must be used in accordance with EPA specifications.

5.2.1 Potential Adverse Impacts

Seafood processing operations have the potential to adversely affect EFH through the discharge of nutrients, chemicals, fish byproducts, and “stickwater” (water and entrained organics originating from the draining or pressing of steam-cooked fish products). EPA investigations illustrate that receiving water quality is directly influenced by the effluent discharge. In areas with strong currents and high tidal ranges, waste materials disperse rapidly. In areas of quieter waters, waste materials can accumulate and result in shell banks, sludge piles, dissolved oxygen depressions, and associated aesthetic problems (Stewart and Tangarone 1977). If adequate disposal technology is not available or employed in processing facilities that generate large quantities of nutrient rich fish waste, there is a potential to saturate designated mixing zones (LaLiberte and Ewing 2006; USEPA 1993).

Eventually, the chronic increase in accumulating nutrient load can cause eutrophication and create anoxic and hypoxic conditions. The impacts and effects of hypoxic conditions are well documented in coastal benthos and estuarine habitat (Rose 2009; Breitburg et al. 2009; Levin et al. 2009; Brandt et al. 2005). Seafood processing discharges influence nutrient loading, eutrophication, and anoxic and hypoxic conditions significantly influencing marine species diversity and water quality (Theriault et al. 2006; Roy Consultants 2003; Lotze et al. 2003). Ammonia, sulfides and micro toxin levels are also shown to be amplified in these areas (Lalonde et al. 2008). Impacts to marine water carrying capacity as a result of the rate of decomposition are further influenced by seasonal changes in water temperature as well as water depth (Verity et al. 2006; Ahumada et al. 2004).

Processors discharging fish waste are required to obtain permits. Various water quality standards, including those for biological oxygen demand; total suspended solids, fecal coliform bacteria, oil and grease, pHs, and temperature are all considerations in the issuance of such permits. Although fish waste is biodegradable, fish parts that are ground to fine particles may remain suspended for some time, thereby overburdening habitats from particle suspension (NMFS 2005). Localized effects depend upon wide differences in habitats and seafood processing methods.

In Alaska, seafood processors are allowed to deposit fish parts in a zone of deposit (ZOD) (USEPA 2001). This can alter benthic habitat, reduce locally associated invertebrate populations, and lower dissolved oxygen levels in overlying waters. Impacts from accumulated processing wastes are not limited to the area covered by the ZOD. Severe anoxic and reducing conditions occur adjacent to effluent piles (USEPA 1979). Examples of localized damage to benthic environment include several acres of bottom driven anoxic by piles of decomposing waste up to 26 feet (7.9 meters) deep. Juvenile and adult stages of flatfish are drawn to these areas for food sources. One effect of this attraction may lead to increased predation on juvenile fish species by other flatfishes, diving seabirds, and marine mammals drawn to the food source (NMFS 2005). However, due to the difficulty in monitoring these areas, impacts to species can go undetected.

Scum and foam from seafood waste deposits can also occur on the water surface and/or increase turbidity. Turbidity decreases light penetration into the water column, reducing primary production. Reduced primary production decreases the amount of food available for

consumption by higher trophic level organisms. In addition, stickwater takes the form of a fine gel or slime that can concentrate on surface waters and move onshore to cover intertidal areas.

5.2.2 Recommended Conservation Measures

The following recommended conservation measures for fish processing waste should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- To the maximum extent practicable, base effluent limitations on site-specific water quality concerns.
- Encourage the use of secondary or wastewater treatment systems where possible.
- Do not allow designation of new ZODs for fish processing waste and instead seek disposal options that avoid an accumulation of waste. Explore options to eliminate or reduce ZODs at existing facilities.
- Promote sound recreational fish waste management through a combination of fish-cleaning restrictions, public education, and proper disposal of fish waste.
- Encourage alternative uses of fish processing wastes (e.g., fertilizer for agriculture and animal feed).
- Explore options for additional research. Some improvements in waste processing have occurred, but the technology-based effluent guidelines have not changed in 20 years.
- Monitor biological and chemical changes to the site of seafood processing waste discharges.

5.3 Water Intake Structures/Discharge Plumes

Withdrawals of riverine, estuarine, and marine waters are common for a variety of uses such as to cool power-generating stations and create temporary ice roads and ice ponds. In the case of power plants, the subsequent discharge of heated and/or chemically treated discharge water can also occur.

5.3.1 Potential Adverse Impacts

Water intake structures and effluent discharges can interfere with or disrupt EFH functions in the source or receiving waters by (1) entrainment, (2) impingement, (3) degrading water quality, (4) operation and maintenance, and (5) construction-related impacts.

Entrainment is the withdrawal of aquatic organisms along with the cooling water into the cooling system. These organisms are usually the egg and larval stages of aquatic species, including managed species and their prey. Entrainment can subject these life stages to adverse conditions resulting from the effects of increased heat, antifouling chemicals, physical abrasion, rapid pressure changes, and other detrimental effects. Long-term water withdrawal may adversely affect fish and shellfish populations by adding another source of mortality to the early life stage, which often determines recruitment and year-class strength (Travnichek et al. 1993).

Impingement occurs when organisms that are too large to pass through in-plant screening devices become stuck against the screening device or remain in the forebay sections of the system until they are removed by other means (Grimes 1975; Hanson et al. 1977; Helvey and Dorn 1987; Helvey 1985; Langford et al. 1978; Moazzam and Rizvi 1980). The organisms cannot escape due to the water flow that either pushes them against the screen or prevents them from exiting the intake tunnel. Similar to entrainment, the withdrawal of water can trap particular species, especially when visual acuity is reduced (Helvey 1985).

Thermal effluents in riverine and inshore habitats can cause severe problems by directly altering benthic communities or killing organisms, especially larval fish. Temperature influences biochemical processes of the environment, and the behavior (e.g., migration) and physiology (e.g., metabolism) of these organisms (Blaxter 1969). Power plants may use once-through cooling biocides, such as sodium hypochlorite and sodium bisulfate which are extremely toxic to aquatic life, to periodically clean the intake and discharge structures.

5.3.2 Recommended Conservation Measures

The following recommended conservation measures for water intakes and discharges should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Locate facilities that rely on surface waters for cooling in areas other than estuaries, inlets, heads of submarine canyons, rock reefs, or small coastal embayments where managed species or their prey concentrate. Locate discharge points in areas with low concentrations of living marine resources. Incorporate cooling towers at discharge points to control temperature, and use safeguards to ensure against release of pollutants into the aquatic environment in concentrations that reduce the quality of EFH.
- Design intake structures to minimize entrainment or impingement. Use velocity caps that produce horizontal intake/discharge currents and ensure that intake velocities across the intake screen do not exceed 0.5 foot (0.15 meter) per second.
- Design power plant cooling structures to meet the best technology available requirements as developed pursuant to section 316(b) of the CWA. Use alternative cooling strategies, such as closed cooling systems, to completely avoid entrainment or impingement impacts in all industries that require cooling water. When alternative cooling strategies are not feasible, other options may include fish diversion or avoidance systems; fish return systems that convey organisms away from the intake; mechanical screen systems that prevent organisms from entering the intake system; and, if impacts are unavoidable, habitat restoration measures to mitigate for expected losses of juvenile fish, larvae, and eggs.
- Regulate discharge temperatures (both heated and cooled effluent) so they do not appreciably alter the ambient temperature to an extent that could cause a change in species assemblages and ecosystem function in the receiving waters. Implement technologies to diffuse heated effluent.
- Avoid the use of biocides (e.g., chlorine) to prevent fouling where possible. Implement the least damaging antifouling alternatives.

- Treat all discharge water from outfall structures to meet state water quality standards at the terminus of the pipe. Ensure that pipes extend a substantial distance offshore and are buried deep enough not to affect shoreline processes. Set buildings and associated structures far enough back from the shoreline to preclude the need for bank armoring.

5.4 Oil and Gas Exploration, Development, and Production

Two agencies, the Bureau of Ocean Energy Management (BOEM) and the Bureau of Safety and Environmental Enforcement (BSEE) are responsible for regulating oil and gas operations on the Outer Continental Shelf (OCS). These activities were formerly regulated by the Bureau of Ocean Energy Management, Regulation, and Enforcement and prior to that the Minerals Management Service (MMS). BOEM is responsible for leasing, plan administration, environmental studies, NEPA analysis, resource evaluation, economic analysis and renewable energy. BSEE is responsible for all field operations including permitting and research, inspections, offshore regulatory programs, oil spill response, and training and environmental compliance functions. The ADNIR Division of Oil and Gas exercises similar authority over State waters (ADNIR1999). Offshore petroleum exploration, development, and production activities have been conducted in Alaska waters or on the Alaska OCS in since the 1960s (Kenai Peninsula Borough 2004). Offshore exploration, development, and production of natural gas and oil reserves have been, and continue to be, important aspects of the U.S. economy. As demand for energy resources grows, the debate over trying to balance the development of oil and gas resources and the protection of the environment will also continue.

5.4.1 Potential Adverse Impacts

Offshore oil and gas operations can be classified into exploration, development, and production activities (which includes transportation). These activities occur at different depths in a variety of habitats, and can cause an assortment of physical, chemical, and biological disturbances (NMFS 2005; Helvey 2002). (Some of these disturbances are listed below; however, not all of the potential disturbances in this list apply to every type of activity.)

- Noise from seismic surveys, vessel traffic, and construction of drilling platforms or islands
- Physical alterations to habitat from the construction, presence, and eventual decommissioning and removal of facilities such as islands or platforms, storage and production facilities, and pipelines to onshore common carrier pipelines, storage facilities, or refineries
- Waste discharges, including well drilling fluids, produced waters, surface runoff and deck drainage, domestic waste waters generated from the offshore facility, solid waste from wells (drilling muds and cuttings), and other trash and debris from human activities associated with the facility
- Oil spills
- Platform storage and pipeline decommissioning

As discussed in Section 4.5 (Pile Driving), noise generates sound pressure that may disrupt or damage marine life. Oil and gas activities may generate noise from drilling activities, construction, production facility operations, seismic exploration, and supply vessel and barge

movements. Research suggests that the noise from seismic surveys associated with oil exploration may cause fish to move away from the acoustic pulse and display an alarm response (McCauley et al. 2000), affecting both fish distribution and catch rates (Engas et al. 1996). However, while there is agreement that noise from seismic surveys affects the behavior of fish, there are differences of opinion regarding the magnitude of those effects (McCauley et al. 2003; Gausland 2003; Wardle 2001).

Activities such as vessel anchoring, platform or artificial island construction, pipeline laying (Section 4.9), dredging, and pipeline burial can change bottom habitat by altering substrates used for feeding or shelter. Disturbances to the associated epifaunal communities, which may provide feeding or predator escape habitat, may also result. Benthic organisms, especially prey species, may avoid recolonizing disturbed areas if the substrate composition is changed or if facilities are left in place after production ends. Dredging, trenching, and pipe laying generate spoils that may be disposed of on land or in the marine environment where sedimentation may smother benthic habitat and organisms. Most activities associated with oil and gas operations are, however, conducted under permits and regulations that require companies to minimize impacts or to avoid construction or other disturbances in sensitive marine habitats (Section 4.2.2).

EPA and the State of Alaska issue permits for discharge of drilling muds and cuttings to ensure the activities meet Alaska water quality standards. The discharge of muds and cuttings from exploratory and construction activities may change the sea floor and suspend fine-grained mineral particles in the water column. This may affect feeding, nursery, and shelter habitat for various life stages of managed species. Drilling muds and cuttings may adversely affect bottom-dwelling organisms at the site by covering immobile forms or forcing mobile forms to migrate. Suspended particulates may reduce light penetration and lower the rate of photosynthesis and the primary productivity of the aquatic area, especially if suspended for long intervals. High levels of suspended particulates may reduce feeding ability for groundfish and other fish species, leading to limited growth. The contents of the suspended material may react with the dissolved oxygen in the water and result in oxygen depletion. In addition, the discharge of oil drilling muds can change the chemical and physical characteristics of benthic sediments at the disposal site by introducing toxic chemical constituents. Changes in water clarity and the addition of contaminants may reduce or eliminate the suitability of water bodies as habitat for fish species and their prey (NMFS 1998a, 1998b).

Federal and state laws and regulations require numerous oil spill prevention and cleanup response measures. The industry takes the initiative to prevent oil spills and uses the most current BMPs and state-of-the-art technology in oil spill prevention and response. However, spills from oil and gas development remain a potential source of contamination to the marine environment. Offshore oil and gas development, in any given geographic area, may result in some amount of oil entering the environment. Most spills are small; although large spills do occur (e.g., the *Exxon Valdez* in March 1989 and the *Deepwater Horizon* in April 2010). Many factors determine the degree of damage from a spill, including the type of oil, size and duration of the spill, its geographic location, and the season. Oil is toxic to all marine organisms at high concentrations, but certain species are more sensitive than others. In general, the early life stages (eggs and larvae) are most sensitive; juveniles are less sensitive; and adults are least sensitive (Rice et al. 2000).

Both large and small quantities of oil can affect habitats and living marine resources. Oil, characterized as petroleum and any derivatives, can be a major stressor to inshore fish habitats. Oil can kill marine organisms, reduce their fitness through sublethal effects, and disrupt the structure and function of the marine ecosystem (NRC 2003). Short-term impacts include interference with the reproduction, development, growth and behavior (e.g., spawning and feeding) of fishes, especially at early life-history stages (Gould et al. 1994). Petroleum compounds are known to have carcinogenic and mutagenic properties (Larsen 1992). Oil spills may cover and degrade coastal habitats and associated benthic communities or may produce a slick on the surface waters, which disrupts the pelagic community. These impacts may eventually lead to disruption of community organization and dynamics in affected regions. Oil can persist in sediments for years after the initial contamination (NRC 2003), interfering with physiological and metabolic processes of demersal fishes (Vandermeulen and Mossman 1996).

Accidental discharge of oil can occur during almost any stage of exploration, development, or production on the OCS or in nearshore coastal areas. Sources include equipment malfunction, ship collisions, pipeline breaks, other human error, or severe storms. Support activities associated with product recovery and transportation may also contribute to oil spills (NMFS 2005). Both large and small quantities of oil can affect habitats and living marine resources. Chronic small oil spills are a potential problem because residual oil can build up in sediments and affect living marine resources. Low levels of petroleum components (e.g., PAHs) from such chronic pollution may accumulate in fish tissues and cause lethal and sublethal effects, particularly during embryonic development. Low-level chronic exposure alters embryonic development in fish, resulting in reductions in growth and subsequent marine survival (Carls et al. 1999; Heintz et al. 1999, 2000).

A major oil spill (e.g., 50,000 barrels) can produce a surface slick covering several hundred square kilometers. If the oil spill moves toward land, habitats and species could be affected by oil reaching the near-shore environment. Immediately after a large spill, aromatic hydrocarbons would be toxic to some organisms. Waters beneath and surrounding the surface slick would be oil-contaminated. Physical and biological forces act to reduce oil concentrations with depth and distance (NMFS 2005); generally the lighter-fraction aromatic hydrocarbons evaporate rapidly, particularly during high winds and wave activity. Heavier oil fractions may settle through the water column. Suspended sediment can adsorb and carry oil to the seabed. Hydrocarbons may be solubilized by wave action, which may enhance adsorption to sediments. The sediments then sink to the seabed, contaminating benthic sediments.

Carls et al. (2003) demonstrated that tides and the resultant hydraulic gradients move groundwater containing soluble and slightly soluble contaminants (such as oil) from beaches surrounding streams into the hyporheic zone where pink salmon eggs incubate. Oil reaching nearshore areas may affect productive nursery grounds or areas containing high densities of fish eggs and larvae. An oil spill near an especially important habitat (e.g., a gyre where fish or invertebrate larvae are concentrated) could cause a disproportionately high loss of a population of marine organisms. Other aquatic biota at risk would be eggs, larvae, and planktonic organisms in the upper seawater column. Because they are small, they absorb contaminants quickly. They are also at risk because they cannot actively avoid exposure. Their proximity to the surface may make them vulnerable to photo-enhanced toxicity effects, which can multiply the toxicity of hydrocarbons (Barron et al. 2003). Population reductions due to delayed and

indirect effects of PAH in tidal sediments postponed recovery among some species for more than a decade following the *Exxon Valdez* oil spill (Peterson et al. 2003).

Habitats that are susceptible to damage from oil spills include not just the low-energy coastal bays and estuaries where oil may accumulate, but also high-energy cobble environments where wave action drives oil into sediments. Many of the beaches in Prince William Sound with the highest persistence of oil following the *Exxon Valdez* oil spill were high-energy environments containing large cobbles overlain with boulders. These beaches were pounded by storm waves that drove the oil into and well below the surface (Michel and Hayes 1999). Oil that mixes into bottom sediments may persist for years. Subsurface oil was still detected in beach sediments of Prince William Sound 12 years after the *Exxon Valdez* oil spill, much of it unweathered and more prevalent in the lower intertidal biotic zone than at higher tidal elevations (Short et al. 2002, 2004). The unknown impact of an oil-related event near and within ice is an added concern. Should oil become trapped in ice, it could affect habitat for months or years after the initial event. It could also move into a different region (NMFS 2005).

Oil and gas platforms may consist of a lattice-work of pilings, beams, and pipes that support diverse fish and invertebrate populations and are considered de facto artificial reefs (Love and Westphal 1990; Love et al. 1994; Love et al. 1999; Helvey 2002). Because decommissioning includes plugging and abandoning all wells and removing the platforms and associated structures from the ocean, impacts to EFH are possible during removal. The demolition phase may generate underwater sound pressure waves (Section 4.5.2), impacting on marine organisms. Taking out these midwater structures may remove habitat for invertebrates and fish that associate with them. In some areas of the United States, offshore oil and gas platforms are left in place after decommissioning, thereby providing permanent habitat for some organisms.

The potential disturbances and associated adverse impacts on the marine environment have been reduced through operating procedures required by regulatory agencies and, in many cases, self-imposed by facilities operators. Most of the activities associated with oil and gas operations are conducted under permits and regulations that require companies to minimize impacts or avoid construction in sensitive marine habitats. For example, the discharge of muds and cuttings is subject to EPA environmental standards, effluent limitations, and related requirements. New technological advances in operating procedures also reduce the potential for impacts.

5.4.2 Recommended Conservation Measures

The following recommended conservation measures for oil and gas exploration and development should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH:

- Avoid the discharge of produced waters into marine waters and estuaries. Reinject produced waters into the oil formation whenever possible.
- Avoid discharge of muds and cuttings into the marine and estuarine environment. Use methods to grind and reinject such wastes down an approved injection well or use onshore disposal wherever possible. When not possible, provide for a monitoring plan to ensure that the discharge meets EPA effluent limitations and related requirements.

- To the extent practicable, avoid the placement of fill to support construction of causeways or structures in the nearshore marine environment.
- As required by federal and state regulatory agencies, encourage the use of geographic response strategies that identify EFH and environmentally sensitive areas. Identify appropriate cleanup methods and response equipment.
- Evaluate potential impacts that may result to EFH that may result from activities carried out during the decommissioning phase of oil and gas facilities. Minimize such impacts to the extent practicable.
- Vessel operations and shipping activities should be familiar with Alaska Geographic Response Strategies (GRS) which detail environmentally sensitive areas of Alaska's coastline. Currently, GRSs exist for the many different regions and areas including Southeast Alaska, Southcentral Alaska, Kodiak Island, Prince William Sound, Cook Inlet, Bristol Bay, Northwest Arctic, North Slope, and the Aleutian Islands (see <http://www.dec.state.ak.us/spar/perp/grs/home.htm>).

5.5 Habitat Restoration and Enhancement

Habitat loss and degradation are major, long-term threats to the sustainability of fishery resources (NMFS 2002). Viable coastal and estuarine habitats are important to maintaining healthy fish stocks. Good water quality and quantity, appropriate substrate, ample food sources, and adequate shelter from predators are needed to sustain fisheries. Restoration and/or enhancement of coastal and riverine habitat that supports managed fisheries and their prey will assist in sustaining and rebuilding fish stocks by increasing or improving ecological structure and functions. Habitat restoration and enhancement may include, but is not limited to, improvement of coastal wetland tidal exchange or reestablishment of natural hydrology; dam or berm removal; fish passage barrier removal or modification; road-related sediment source reduction; natural or artificial reef, substrate, or habitat creation; establishment or repair of riparian buffer zones; improvement of freshwater habitats that support anadromous fishes; planting of native coastal wetland and submerged aquatic vegetation; and improvements to feeding, shade or refuge, spawning, and rearing areas that are essential to fisheries.

5.5.1 Potential Adverse Impacts

The implementation of restoration and enhancement activities may have localized and temporary adverse impacts on EFH. Possible impacts can include (1) localized nonpoint source pollution such as influx of sediment or nutrients, (2) interference with spawning and migration periods, (3) temporary removal feeding opportunities, (4) indirect effects from construction phase of the activity, (5) direct disturbance or removal of native species, and (6) temporary or permanent habitat disturbance.

Habitat restoration activities that include the removal of invasive species may cause disturbances of native species. For example, netting and trapping of invasive fish species may result in unwanted bycatch of native fish and other aquatic species.

The temporary or permanent habitat disturbance associated with restoration or enhancement activities can cause adverse impacts. Fish passage restoration and other hydrologic restoration activities, such as the removal of culverts or other in-stream structures, installation of fishways,

or other in-water activities will require temporary rerouting of flows around the project area. This could temporarily disturb on-site or adjacent habitats by altering hydrologic conditions and flows during project implementation.

Artificial reefs are sometimes used for habitat enhancement, however these structures could create a loss of EFH habitat upon which the reef material is placed or the use of inappropriate materials for construction. Usually, reef materials are set upon flat sand bottoms or “biological deserts,” which end up burying or smothering bottom-dwelling organisms at the site or even preventing mobile forms (e.g., benthic-oriented fish species) from using the area as habitat. Some materials used as artificial reef may be inappropriate for the marine environment (e.g., automobile tires or compressed incinerator ash) and can serve as sources of toxic releases or physical damage to existing habitat when breaking free of their anchoring systems (Collins et al. 1994).

5.5.2 Recommended Conservation Measures

The following recommended conservation measures for habitat restoration and enhancement should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Use BMPs to minimize and avoid potential impacts to EFH during restoration activities. BMPs should include, but are not limited to, the following:
 - Use turbidity curtains, hay bales, and erosion mats.
 - Plan staging areas in advance, and keep them to a minimum size.
 - Establish buffer areas around sensitive resources.
 - Remove invasive plant and animal species from the proposed action area before starting work. Plant only native plant species. Identify and implement measures to ensure native vegetation or revegetation success (Section 4.4).
 - Establish temporary access pathways before restoration activities to minimize adverse impacts from project implementation.
- Avoid restoration work during critical life stages for fish such as spawning, nursery, and migration. Determine these periods before project implementation to reduce or avoid any potential impacts.
- Provide adequate training and education for volunteers and project contractors to ensure minimal impact to the restoration site. Train volunteers in the use of low-impact techniques for planting, equipment handling, and any other activities associated with the restoration.
- Conduct monitoring before, during, and after project implementation to ensure compliance with project design and restoration criteria.
- To the extent practicable, mitigate any unavoidable damage to EFH within a reasonable time after the impacts occur.
- Remove and, if necessary, restore any temporary access pathways and staging areas used in the restoration effort.

- Determine benthic productivity by sampling before any construction activity in the case of subtidal enhancement (e.g., artificial reefs). Avoid areas of high productivity to the maximum extent possible. Develop a sampling design with input from state and federal resource agencies. Before construction, evaluate of the impact resulting from the change in habitat (e.g., sand bottom to rocky reef). During post-construction monitoring, examine the effectiveness of the structures for increasing habitat productivity.

5.6 Marine Mining

Mining activities, which are also described in Sections 3.1.1 and 3.1.2 of the EFH EIS (NMFS 2005), can lead to the direct loss or degradation of EFH for certain species. Offshore mining, such as the extraction of gravel and gold in the Bering Sea, can increase turbidity, and resuspension of organic materials could impact eggs and recently hatched larvae in the area. Mining large quantities of beach gravel can also impact turbidity, and may significantly affect the transport and deposition of sand and gravel along the shore, both at the mining site and down-current (NMFS 2005).

Offshore dredging and the discharge of spoils have the potential to affect aquatic resources via habitat alteration, including turbidity; entrainment of organisms; exposure to trace metals; noise and disturbances; and fuel spills (MMS 1991). Previous mining operations off Nome resulted in considerable localized substrate alteration. Sediment fines destabilized by mining operations were redistributed by local currents and sea conditions (Jewett 1999). Further, evidence suggests that recolonization of benthic communities to their original structure may not occur after mining disturbance; instead, a somewhat different assemblage may result. Actual recovery times for a community to stabilize (i.e., recolonization of dredged sites to comparable density, biomass, and number of taxa) are unknown. Studies associated with the Nome Offshore Placer Project showed that even seven years post-mining, seafloor habitats and species assemblages had not recovered to pre-disturbance conditions (Gardner and Jewett 1994).

5.6.1 Potential Adverse Impacts

Impacts from mining on EFH include both physical impacts (i.e., intertidal dredging) and chemical impacts (i.e., additives such as flocculants) (NMFS 2005). Physical impacts may include the removal of substrates that serve as habitat for fish and invertebrates; habitat creation or conversion in less productive or uninhabitable sites, such as anoxic holes or silt bottom; burial of productive habitats, such as in near-shore disposal sites (as in beach nourishment); release of harmful or toxic materials either in association with actual mining, or in connection with machinery and materials used for mining; creation of harmful turbidity levels; and adverse modification of hydrologic conditions so as to cause erosion of desirable habitats. Submarine disposal of mine tailings can also alter the behavior of marine organisms. Submarine mine tailings may not provide suitable habitat for some benthic organisms. In laboratory experiments, benthic dwelling flatfishes (Johnson et al. 1998a) and crabs (Johnson et al. 1998b) strongly avoided mine tailings.

During beach gravel mining, water turbidity increases and the resuspension of organic materials can affect less motile organisms (i.e., eggs and recently hatched larvae) in the area. Benthic habitats can be damaged or destroyed by these actions. Changes in bathymetry and bottom type may also alter population and migrations patterns (Hurme and Pullen 1988).

Offshore gold placer mining in the Norton Sound region has occurred for many years. Western Gold Exploration & Mining Company (WestGold) conducted the largest and most notable project. WestGold's operation, the Nome Offshore Placer Project, began in late 1985 and continued through September 1990. The project mined the seafloor with a 558 foot dredge vessel incorporating a bucket ladder system of 134 buckets. Each bucket had a 1.1 cubic yard capacity. The dredge could operate in water depths of up to 148 feet and cut to a depth of 10 feet below the seafloor. Typically, 10,000 to 20,000 cubic yards of material were processed per day and mining occurred in water depths of 20 to 60 feet.

Studies done regarding the WestGold project list several impacts offshore placer mining may have to the benthic community such as habitat loss, alteration, re-suspension of fine sediments, removal of benthic infauna and epifauna, and injured marine organisms. Injured organisms may not reach maturity to reproduce and/or be subject to increased predation. The long term result of such disturbances is an overall decrease in benthic species and their habitat.

WestGold's studies documented that deeper waters (deeper than 20 feet) support a more diverse and higher number of species complexes, especially in the cobble habitats. These studies also suggest significant storm events and longshore currents cause extensive mixing of nearshore sediments and alteration of the sea floor. These natural events occur within nearshore waters less than 25 feet in depth (Jewett 1999). Ice gouging is also a common occurrence in the region. The seaward edge of the ice typically extends to the 60 foot isobaths and may be anchored by ice keels in the depth from 30 to 60 feet (Jewett 1999).

These studies further conclude the re-colonization of species after the disturbance occurs at a slow rate and a wide range of impact occurs. Suspended sediments can travel well outside the disturbed area and settle on other undisturbed marine substrates. Sediment was found in red king crab stomachs, but whether this was due to increases in suspended sediment or associated with a food source is not known. Some sediment is probably ingested while feeding on tube worms, starfish, and sea urchins. Fine sediments may inhibit growth in some species and smother benthic organisms.

Benthic communities do not recover quickly from rapid change and effects may not be easily measured. NMFS studies related to effects on benthic substrates and their inhabitants (NMFS 2005), also find that many seafloor organisms are slow growing and reach their age of maturity (spawning age) later in their life history. Additionally, in Alaskan waters, many species' life history traits are unknown. Another important factor is that video analysis documents even the smallest of epifauna (sponge, tunicate, or sea pen) will be in association with a larger fish or crab. Direct association is unknown, however it is recognized that the larger species are often attracted to the structure, likely for cover or feeding.

5.6.2 Recommended Conservation Measures

The following recommended conservation measures for marine mining should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- To the extent practicable, avoid mining in waters containing sensitive marine benthic habitat, including EFH (e.g., spawning, migrating, and feeding sites).

- Minimize the areal extent and depth of extraction to reduce recolonization times.
- Monitor turbidity during operations, and cease operations if turbidity exceeds predetermined threshold levels. Use sediment or turbidity curtains to limit the spread of suspended sediments and minimize the area affected.
- Monitor individual mining operations to avoid and minimize cumulative impacts. For instance, three mining operations in an intertidal area could impact EFH, whereas one may not. Disturbance of previously contaminated mining areas may cause additional loss of EFH.
- Use seasonal restrictions as appropriate to avoid and minimize impacts to EFH during critical life history stages of managed species (e.g., migration and spawning).
- Deposit tailings within as small an area as possible.

Chapter 6

References

References Cited

- Abbe, T.B. and D.R. Montgomery. 1996. "Large woody debris jams, channel hydraulics, and habitat formation in large rivers." *Regulated Rivers: Research and Management*. 12:201-221.
<http://www.cems.uvm.edu/ce361/papers/abbe1996.pdf>
- Abbott, R. and E. Bing-Sawyer. 2002. Assessment of pile driving impacts on the Sacramento blackfish (*Othodon microlepidotus*). Draft report prepared for Caltrans District 4. October 10, 2002.
- Able, K.W., J.P. Manderson, and A.L. Studholme. 1998. "The distribution of shallow water juvenile fishes in an urban estuary: the effects of man-made structures in the lower Hudson River." *Estuaries*. 21:731-744.
- Ahumada, R., A. Rudolf, and S. Contreras. 2004. Evaluation of Coastal Waters Receiving Fish Processing Waste: Lota Bay as a Case Study. *Environmental Monitoring and Assessment*. Vol 90, Numbers 1-3, pp. 89-99.
- Alaska Department of Environmental Conservation (ADEC). 2010a. Ocean Discharge Criteria Evaluation Alaska Offshore Seafood Processors APDES General Permit AKG523000. Prepared by Tetra Tech, 10306 Eaton Place Suite 340, Fairfax, VA 22030. 152 pp.
- ADEC. 2010b. Wastewater Discharge Authorization Program, 555 Cordova Street, Anchorage, AK 99501. Fact Sheet Alaska Offshore Seafood Processors General Permit AKG523000. 43 pp.
- Alaska Department of Fish and Game (ADF&G) and Alaska Department of Public Transportation of Public Facilities (ADOT&PF), Memorandum of Agreement for the Design, Permitting, and Construction of Culverts for Fish Passage. August 2001.
http://www.sf.adfg.state.ak.us/Static/fish_passage/PDFs/dot_adfg_fishpass080301.pdf
- Alaska Department of Natural Resources (ADNR). 1999. Cook Inlet Areawide 1999 Oil and Gas Lease Sale, Final Finding of the Director. Volume II. Appendix B: "Laws and Regulations Pertaining to Oil and Gas Exploration, Development, Production, and Transportation."
- American Fisheries Society. 2000. AFS Policy Statement #13: Effects of Surface Mining on Aquatic Resources in North America (Revised). (Abbreviated)
http://www.fisheries.org/afs/docs/policy_13f.pdf
- Arkoosh, M.R., E. Casillas, E. Clemons, P. Huffman, A.N. Kagley, T. Collier, and J.E. Stein. 2001. "Increased susceptibility of juvenile chinook salmon (*Oncorhynchus tshawytscha*) to vibriosis after exposure to chlorinated and aromatic compounds found in contaminated urban estuaries." *Journal of Aquatic Animal Health*. 13:257-268.
- Arruda, J.A., G.R. Marzolf, R.T. Faulk. 1983. The role of suspended sediments in the nutrition of zooplankton in turbid reservoirs. *Ecology*. 64(5):1225-35.

- Atlantic States Marine Fisheries Commission. 1992. Fishery management plan for inshore stocks of winter flounder. Washington (DC): ASMFC. FMR No. 21. 138 p.
- Baldwin D.H., J. A. Spromberg, T. K Collier, and N. L. Scholz. 2009. A fish of many scales: extrapolating sublethal pesticide exposures to the productivity of wild salmon populations. *Ecological Applications*. 19(8): 2004-2015.
- Baldwin, D. H., J. F. Sandahl, J. L. Labenia, and N. L. Scholz. 2003. Sublethal effects of copper on coho salmon: Impacts on nonoverlapping receptor pathways in the peripheral olfactory nervous system. *Environmental Toxicology and Chemistry*. 22:2266-2274.
- Barr BW. 1993. Environmental impacts of small boat navigation: vessel/sediment interactions and management implications. In: Magoon OT, editor. Coastal Zone '93: proceedings of the eighth Symposium on Coastal and Ocean Management; 1993 Jul 19-23; New Orleans, LA. American Shore and Beach Preservation Association. p 1756-70.
- Barron, M.G., M.G. Carls, J.W. Short, and S.D. Rice. 2003. Photoenhanced toxicity of aqueous phase and chemically dispersed weathered Alaska North Slope crude oil to Pacific herring eggs and larvae. *Environmental Toxicology and Chemistry*. 22(3):650-660.
- Barry, K. L., J.A. Grout, C.D. Levings, B.H. Nidle, and G.E. Piercey. 2000. "Impacts of acid mine drainage on juvenile salmonids in an estuary near Britannia Beach in Howe Sound British Columbia." *Canadian Journal of Fisheries and Aquatic Sciences*. 57(10): 2031-2043.
- Barsh, R., Bell, J., Barr, B., Taylor, S., Wilson, A., and Wilbur, R. 2007. Preliminary Evidence for Phenanthrene, A Polycyclic Aromatic Hydrocarbon (PAH), in Paving Materials used in San Juan County, WA.
- Beach, D. 2002. Coastal Sprawl: the effects of urban design on aquatic ecosystems in the United States. Pew Oceans Commission, Arlington, Virginia.
- Belford, D.A. and W.R. Gould. 1989. "An evaluation of trout passage through six highway culverts in Montana." *North American Journal of Fisheries Management*. 9(4):437-445.
- Benfield, M.C. and T. J. Minello. 1996. "Relative effects of turbidity and light intensity on reactive distance and feeding of an estuarine fish." *Environmental Biology of Fishes*. 46:211-216.
- Beschta, R.L., R.E. Bilby, G.W. Brown, L.B. Holtby, and T.D. Hofstra. 1987. Stream temperature and aquatic habitat: fisheries and forestry interactions. In Salo, E., T. Cundy, eds. *Streamside management: forestry and fishery interactions*. Contribution 57. Seattle: University of Washington, College of Forest Resources: 191-232. 437-445.
- Bilby, R.E., K. Sullivan, and S.H. Duncan. 1989. "The generation and fate of road-surface sediment in forested watersheds of southwestern Washington." *Forest Science*. 35:453-468.
- Bishop, JM. 1984. *Applied oceanography*. McCormick ME, Bhattacharyya R, editors. New York (NY): John Wiley & Sons. 252 p.
- Bisson, P.A., J.L. Nielsen, and J.W. Ward. 1988. "Summer production of coho salmon stocked in Mount St. Helens streams 3-6 years after the 1980 eruption." *Transactions of the American Fisheries Society*. 117(4):322-335.

- Blaxter, J. H. S. 1969. Development: Eggs and larvae. In W. S. Hoar., and D. J. Randall. eds. Fish Physiology. Vol. 3. Academic Press, Inc. New York, NY. pp. 177-252.
- Brandt, S., S. Ludsin, D. Mason, B. Boicourt, M. Roman, and D. Kimmel. 2005. Hypoxia Effects on the Living Resources of the Northern Gulf of Mexico. National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory. NOAA Great Lakes Research Laboratory web site: http://www.glerl.noaa.gov/res/Task_rpts/2005/epludsin05-4.html
- Breitburg, D.J., Craig, J.K., Fulford, R.S., Rose, K.A., Boynton, W.R., Brady, D.C., Ciotti, R.J., Daiz, R.J., Friedland, K.D., Hagy, J.D., Hart, D.R., Hines, A.H., Houde, E.D., Kolesar, S.E., Nixon, S.W., Rice, J.A., Secor, D.H., Targett, T.E. 2009. Nutrient Enrichment and Fisheries Exploitation: Interactive Effects on Estuarine Living Resources and their Management. *Hydrobiologia* 629:31-47.
- Brix, K.V., D.K. DeForest, and W.J. Adams 2001. Assessing acute and chronic copper risks to freshwater aquatic life using species sensitivity distributions for different taxonomic groups. *Environmental Toxicology and Chemistry*. 20(8): 1846-1856.
- Brunke, M. and T. Gonser. 1997. The ecological significance of exchange processes between rivers and groundwater. *Freshwater Biology*, vol 37, 1-33.
- Buhl, KJ and S.J. Hamilton. 1991. Relative sensitivity of early life stages of arctic grayling, coho salmon, and rainbow trout to nine inorganics. *Ecotoxicology and Environmental Safety*. 2:184-197.
- Burdick D.M. and F.T. Short. 1999. The effects of boat docks on eelgrass beds in coastal waters of Massachusetts. *Environmental Management*. 23(2):231-40.
- CalTrans. 2001. Fisheries Impact Assessment, Pile Installation Demonstration Project for the San Francisco - Oakland Bay Bridge, East Span Seismic Safety Project, August 2001. 59 pp.
- Capuzzo J.M., and J.J. Sassner Jr. 1977. The effect of chromium on filtration rates and metabolic activity of *Mytilus edulis* L. and *Mya arenaria* L. In: Vernberg FJ, and others, editors. Physiological responses of marine biota to pollutants. San Diego (CA): Academic Press. p 225-37.
- Cardwell, R.D., M.I. Carr, and E.W. Sanborn. 1980. Water quality and flushing of five Puget Sound marinas. Technical Report No. 56. Washington Department of Fisheries Research and Development. Olympia, Washington. 77 pp.
- Carls, M.G., R.E. Thomas, and S.D. Rice. 2003. "Mechanism for transport of oil-contaminated water into pink salmon redds." *Mar. Ecol. Prog. Ser.* 248:245-255.
- Carls, M.G., S.D. Rice, and J.E. Hose. 1999. "Sensitivity of fish embryos to weathered crude oil: Part 1. Low level exposure during incubation causes malformations and genetic damage in larval Pacific herring (*Clupea pallasii*)." *Environmental Toxicology and Chemistry*. 18:481-493.
- Carlson, T.J., G. Ploskey, R.L. Johnson, R.P. Mueller, M.A. Weiland, and P.N. Johnson. 2001. Observations of the behavior and distribution of fish in relation to the Columbia River navigation channel and channel maintenance activities. Prepared for the U.S. Army, Corps of

- Engineers, Portland District by Pacific Northwest National Laboratory, U.S. Department of Energy, Richland, WA. 35 pp. + appendices.
- Castro, J. 2003. Geomorphologic impacts of culvert replacement and removal: avoiding channel incision. U.S. Fish and Wildlife Service—Oregon Fish and Wildlife Office, Portland, Oregon.
- Cederholm, C.J. and L.M. Reid. 1987. Impact of forest management on coho salmon (*Oncorhynchus kisutch*) populations of the Clearwater Rivers, Washington: A project summary. *In* Streamside management: forestry and fishery interactions. Salo, E.O, and T.W. Cundy, eds. College of Forest Resources, University of Washington, Seattle, Washington. University of Washington, Institute of Forest Resources. Contribution No. 57.
- Celewycz, A.G. and A.C. Wertheimer. 1994. Distribution, abundance, size, and growth of juvenile pink and chum salmon in western Prince William Sound after the Exxon Valdez oil spill. Chapter 2. *In*: A.C. Wertheimer, et al. (Eds.) Impact of the oil spill on juvenile pink and chum salmon and their prey in critical nearshore habitats. Exxon Valdez Oil Spill, State/Federal Damage Assessment Final Report. Alaska Fisheries Science Center, Auke Bay Laboratory, Juneau, Alaska.
- Center for Streamside Studies (CSS).2002. “Environmental impacts of hardrock mining in Eastern Washington.” College of Forest Resources and Ocean and Fishery Sciences, University of Washington, Seattle, WA.
- Center for Watershed Protection (CWP). 2003. Impacts of Impervious Cover on Aquatic Systems. Elliott City, MD, www.cwp.org. 141 pp.
- Chapman, D.W. 1988. “Critical review of variables used to define effects of fines in redds of large salmonids.” Transactions of the American Fisheries Society. 117(1):1-21.
- Christie, D., E. Allen, and G. J. Jobsis. 1993. Diversions. *In* Bryan, C.F. and D.A. Rutherford eds. Impacts on warmwater streams: Guidelines for evaluation. pp. 181-186. Southern Division, American Fisheries Society, Little Rock, AR.
- Christopherson, A. and J. Wilson. 2002. Technical Letter Report Regarding the San Francisco-Oakland Bay Bridge East Span Project Noise Energy Attenuation Mitigation. Peratrovich, Nottingham & Drage, Inc. Anchorage, Alaska. 27 pp.
- Clancy, C.G. and D.R. Reichmuth. 1990. “A detachable fishway for steep culverts.” North American Journal of Fisheries Management. 10(2):244-246.
- Cloern, J.E. 1987. “Turbidity as a control on phytoplankton biomass and productivity in estuaries.” *Continental Shelf Research*. 7:1367-1381.
- Collins, K.J., A.C. Jensen, A.P.M. Lockwood, and S.J. Lockwood. 1994. “Coastal structures, waste materials and fishery enhancement.” Bulletin of Marine Science. 55(203):1240-1250.
- Conner, Billy, Director Alaska University Transportation Center. University of Alaska, Fairbanks PO Box 755900. 2007 Interview in Building Alaska. http://www.buildingalaskamovie.com/interviews_billy.html

- Corbett, C.W., M. Wahl, D.E. Porter, D. Edwards, and C. Moise. 1997. "Nonpoint source runoff modeling: A comparison of a forested watershed and an urban watershed on the South Carolina coast." *Journal of Experimental Marine Biology and Ecology*. 213(1):133-149.
- Culp, J.M. and R.W. Davies. 1983. An assessment of the effects of streambank clear cutting on macroinvertebrate communities in a managed watershed. Canadian Technical Report of Fisheries and Aquatic Sciences. No. 1208. 116 pp.
- Deegan L.A. and R.N. Buchsbaum. 2005. The effect of habitat loss and degradation on fisheries. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline on fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 67-96.
- DeLorenzo, M.E., G.I. Scott, and P.E. Ross. 2001. "Toxicity of pesticides to aquatic microorganisms: A review." *Environmental Toxicology and Chemistry*. 20:84-98.
- Dennison, W.C. 1987. "Effect of light on seagrass photosynthesis, growth and depth distribution." *Aquatic Botany*. 27:15-26.
- Dethloff, G., Schlenk, D., Khan, S., Bailey, H.C., 1999. The Effects of Copper on Blood and Biochemical Parameters of Rainbow Trout (*Oncorhynchus mykiss*) *Arch. Environ. Contam. Toxicol.* 36, 415–423
- Dolat, S.W. 1997. Acoustic measurements during the Baldwin Bridge demolition (final, dated March 14, 1997). Prepared for White Oak Construction by Sonalysts, Inc, Waterford, CT. 34 pp. + appendices.
- Duffy-Anderson, J.T., and K.W. Able. 1999. "Effects of municipal piers on the growth of juvenile fishes in the Hudson River estuary: a study across a pier edge." *Mar. Biol.* 133:409-418.
- Dugan, J.E., D.M. Hubbard, D.L. Martin, J.M. Engle, D.M. Richards, G.E. Davis, K.D. Lafferty, and R.F. Ambrose. 2000. Macrofauna communities of exposed sandy beaches on the Southern California mainland and Channel Islands. pp 339-346. In Brown, D.R., K.L. Mitchell, and H.W. Chang, eds. Proceedings of the Fifth California Islands Symposium. Minerals Management Service Publication # 99-0038.
- Emmett, B. 2002. A discussion document associated with shellfish aquaculture in Baynes Sound. Prepared for Mr. Joe Truscott, Coast and Marine Planning Office, Ministry of Sustainable Resource Management, 78 Blanshard St., Victoria, B.C. V8W 9M2, Canada.
- Engås, A., S. Lokkeborg, E. Ona, A.V. Soldal. 1996. Effects of seismic shooting on local abundance and catch rates of cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*). *Canadian Journal of Fisheries and Aquatic Sciences*. 53:2238-49.
- Enger, P.S., H.E. Karlsen, F.R. Knudsen, and O. Sand. 1993. Detection and reaction of fish to infrasound. *Fish Behaviour in Relation to Fishing Operations*, 1993, pp. 108-112, ICES marine science symposia. Copenhagen. Vol. 196.
- Evans, W.A., B. Johnston. 1980. Fish migration and fish passage: a practical guide to solving fish passage problems. Rev. ed. EM-7100-2. Washington DC. U.S. Department of Agriculture, Forest Service. 163 pp.

- Everest, F.H., R.L. Beschta, J.C. Scrivener, K.V. Koski, J.R. Sedell, and C.J. Cederholm. 1987. Fine sediment and salmonid production B a paradox. In: Salo, E.; Cundy, T. eds. Streamside management: forestry and fishery interactions: proceedings of a symposium held at the University of Washington, February 12-14, 1986. Contribution 57. Seattle: University of Washington, Institute of Forestry Resources. pp. 98-142.
- Fajen, O.F. and J.B. Layzer. 1993. Agricultural practices. In Bryan, C.F. and D.A. Rutherford, eds. Impacts on warmwater streams: Guidelines for evaluation. pp. 257-267. Southern Division, American Fisheries Society. Little Rock, AR.
- Farag, A.M., D.A. Skaar, E. Nimick, C. MacConnell, and C. Hogstrand. 2003. Characterizing aquatic health using salmonids mortality, physiology, and biomass estimates in streams with elevated concentrations of arsenic, cadmium, copper, lead, and zinc in the Boulder River Watershed, Montana. Transaction of the American Fisheries Society 132(3): 450-457.
- Fay, V. 2002. Alaska Aquatic Nuisance Species Management Plan. Alaska Department of Fish and Game Publication. Juneau, AK. http://www.adfg.state.ak.us/special/invasive/ak_ansmp.pdf.
- Feist B.E., Anderson J.J., Miyamoto R. 1996. Potential impacts of pile driving on juvenile pink (*Oncorhynchus gorbuscha*) and chum (*O. keta*) salmon behavior and distribution. Seattle (WA): Fisheries Research Institute-University of Washington. FRI-UW-9603. 58 pp.
- Ferraro, S.P., R.C. Swartz, F.A. Cole, and D.W. Schults. 1991. "Temporal changes in the benthos along a pollution gradient: discriminating the effects of natural phenomena from sewage-industrial wastewater effects." Estuarine Coastal Shelf Science. 33:383-407.
- Flowers, B. 2004. Domestic water conservation: Greywater, rainwater and other innovations. Internet search on November 6, 2009. <http://www.csa.com/discoveryguides/water/overview.php>
- Fresh, K.L., B.W. Williams, S. Wyllie-Echeverria, and T. Wyllie-Echeverria. 2001. Mitigating impacts of overwater floats on eelgrass *Zostera marina* L. in Puget Sound, Washington. In: Proceedings of Puget Sound Research 2001-The fifth Puget Sound Research Conference; 2001 Feb 12-14; Bellevue, WA. Olympia (WA): Puget Sound Action Team.
- Fresh, K. 1997. The role of competition and predation in the decline of Pacific salmon and steelhead. In Stouter, D., P. Bisson, and R.J. Naiman, eds. *Pacific Salmon and Their Ecosystems: Status and Future Options*. Chapman and Hall, New York.
- Fulton, M.H., G.I. Scott, A. Fortner, T.F. Bidleman, and B. Ngabe. 1993. "The effects of urbanization on small high salinity estuaries of the southeastern United States." Archives for Environmental Contamination and Toxicology. 25(4):476-484.
- Furniss, M. J., T.D. Roelofs, and C.S. Yee. 1991. Road construction and maintenance. In Meehan W.R., ed. Influences of forest and rangeland management on salmonid fishes and their habitats. Special Publication 19. Bethesda, MD. American Fisheries Society. pp. 297-323.
- Gandy, C.J., J.W.N. Smith, and A.P. Jarvis. 2007. Attenuation of mining derived pollutants in the hyporheic zone: A Literature Review. Science of the Total Environment. 373 pp 435-446.

- Gardner, L.A. and S.C. Jewett. 1994. To Evaluate the Suitability of a Coarse-Grain Hydraulic Bucket Sampler for Marine Placer Deposits and Mine Tailings Sites. 1993 Benthic Monitoring Results Final Report. Document No. 6938-001-400 Box :16.
- Gausland, Ingebert. 2003. Report for Norwegian Oil Industry Association (OLF): Seismic Surveys Impact on Fish and Fisheries. Stavanger, March 2003.
- Glasby, T.M. 1999. "Effects of shading on subtidal epibiotic assemblages." *J. Exp. Mar. Biol. Ecol.* 234(1999). pp. 275-290.
- Goldstein, J.N., D.F. Woodward, and A.M. Farag. 1999. Movement of adult Chinook salmon during spawning migration in a metals-contaminated system, Coeur d'Alene River, Idaho. *Transactions of the American Fisheries Society.* 128:121-129.
- Good, J.W. 1987. "Mitigating estuarine development impacts in the Pacific Northwest: from concept to practice." *Northwest Environmental Journal.* Vol. 3. No. 1.
- Gould E, Clark P.E, Thurberg F.P. 1994. Pollutant effects on demersal fishes. In: Langton RW, Pearce JB, Gibson JA, editors. *Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management.* Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 30-41.
- Gowen, A.W. 1978. The Environmental Effects of OCS Pipelines. Initial Findings. New England River Basins Commission. Boston, MA. 4:24-43
- Grebmeier, J.M., J.E. Overland, S.E. Moore, E.V. Farley, E.C. Carmack, L.W. Cooper, K.E. Frey, J.H. Helle, F.A. McLaughlin, and S.L. McNutt. 2006. A major ecosystem shift in the Northern Bering Sea.
- Gregory, S.V. and P.A. Bisson. 1997. Degradation and loss of anadromous salmonid habitat in the Pacific Northwest. In Stouder, J.D., P.A. Bisson, and R.J. Naiman, eds. *Pacific Salmon and Their Ecosystems: Status and Future Options*, pp. 277-314. Chapman and Hall, New York.
- Grimes, C.B. 1975. "Entrapment of fishes on intake water screens at a steam electric generating station." *Chesapeake Science.* 16:172-177.
- Grosenheider KE, PR Bloom, TR Halbach, and Johnson, M. R. 2005. A Review of the Current Literature Regarding Polycyclic Aromatic Hydrocarbons in Asphalt Pavement. Mn/DOT Contract No. 81655. University of Minnesota, Minneapolis, MN, USA.
- Groundwater Protection Council. 2010. State Groundwater Fact Sheets. http://www.gwpc.org/e-library/documents/state_fact_sheets/alaska.pdf. Ground Water Protection Council, 13308 N. MacArthur Blvd., Oklahoma City, OK 73142.
- Haas, M.A., C.A. Simenstad, J.R. Cordell, D.A. Beauchamp, and B.S. Miller. 2002. Effects of large overwater structures on epibenthic juvenile salmon prey assemblages in Puget Sound, Washington. Final Research Report No. WA-RD 550.1. Prepared for the Washington State Transportation Commission, Washington State Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration. 114 pp.

- Hansen, J.A., Lipton J., and Welsh P.G. 2002. Relative sensitivity of bull trout (*Salvelinus confluentus*) and rainbow trout (*Oncorhynchus mykiss*) to acute copper toxicity. *Environmental toxicology and chemistry*. 21 (3): 633-639
- Hansen, J. A., J. C. A. Marr, J. Lipton, D. Cacela, and H. L. Bergman. 1999a. Difference in neurobiological responses of chinook salmon (*Oncorhynchus tshawytscha*) and rainbow trout (*Oncorhynchus mykiss*) exposed to copper and cobalt: behavioral avoidance. *Environmental Toxicology and Chemistry*. 18:1972-1978.
- Hansen, J. A., J. D. Rose, R. A. Jenkins, K. G. Gerow, and H. L. Bergman. 1999b. Chinook salmon (*Oncorhynchus tshawytscha*) and rainbow trout (*Oncorhynchus mykiss*) exposed to copper: neurophysiological and histological effects on the olfactory system. *Environmental Toxicology and Chemistry*. 18:1979-1991.
- Hanson, C.H., J.R. White, and H.W. Li. 1977. "Entrapment and impingement of fishes by power plant cooling water intakes: an overview." *Marine Fisheries Review*. 39:7-17.
- Hastings, M.C. 2002. Clarification of the meaning of sound pressure levels and the known effects of sound on fish. Document in support of Biological Assessment for San Francisco-Oakland Bay Bridge East Span Seismic Safety Project. August 26, 2002. Revised August 27, 2002. 8 pp.
- Heifetz, J., M.L. Murphy, and K.V. Koski. 1986. (Effects of logging on winter habitat of juvenile salmonids in Alaskan streams." *North American Journal of Fisheries Management*. 6:52-58.
- Heintz, R.A., S.D. Rice, A.C. Wertheimer, R.F. Bradshaw, F.P. Thrower, J.E. Joyce, and J.W. Short. 2000. "Delayed effects on growth and marine survival of pink salmon *Oncorhynchus gorbuscha*, after exposure to crude oil during embryonic development." *Mar. Ecol. Prog. Ser.* 208:205-216.
- Heintz, R.A., J.W. Short, and S.D. Rice. 1999. Sensitivity of fish embryos to weathered crude oil: Part II. Incubating downstream from weathered Exxon Valdez crude oil caused increased mortality of pink salmon (*Onchorhynchus gorbuscha*) embryos. *Environmental Toxicology and Chemistry*. 18:494-503.
- Heinz Center. 2002. Dam removal: science and decision making. Washington (DC): The H. John Heinz III Center for Science, Economics, and the Environment. 236 p.
- Helvey, M. 2002. "Are southern California oil and gas platforms essential fish habitat?" *ICES Journal of Marine Science*. 59:S266-S271.
- Helvey, M. and P.B. Dorn. 1987. "Selective removal of reef fish associated with an offshore cooling-water intake structure." *J. Applied Ecology*. 24:1-12.
- Helvey, M. 1985. "Behavioral factors influencing fish entrapment at offshore cooling-water intake structures in southern California." *Marine Fisheries Review*. 47:18-26.
- Herke, W.H. and B.D. Rogers. 1993. Maintenance of the estuarine environment. Pages 263-286 in C.C. Kohler and W.A. Hubert, editors. *Inland fisheries management in North America*. American Fisheries Society, Bethesda, Maryland.

- Hicks, B.J., J.D. Hall, P.A. Bisson, and J.R. Sedell, J.R. 1991. Responses of salmonids to habitat changes. In: Meehan, W.R. (Ed.) 1991. Influences of forest and rangeland management on salmonid fishes and their habitats. Special Publication 19. Bethesda, MD: American Fisheries Society: 483-518.
- Hoagland, K.D., J.P. Carder, and R.L. Spawn. 1996. Effects of organic toxic substances. pp. 469-496. *In* Stevenson, R.J., M.L. Bothwell, and R.L. Lowe, eds. *Algal Ecology: Freshwater Benthic Ecosystems*. Academic Press. New York, NY.
- Holler, J.D. 1990. "Nonpoint source phosphorus control by a combination wet detention/filtration facility in Kissimmee, Florida." *Florida Scientist*. 53(1):28-37.
- Horner, R., C. May, E. Livingston, and J. Maxted. 1999. Impervious cover, aquatic community health, and stormwater BMP's: is there a relationship? *In* Proceedings of the Sixth Biennial Stormwater Research and Watershed Management Conference. Sept. 14-17, 1999. Tampa Florida. Southwest Florida Water Management District. Available on line: www.stormwater-resources.com/proceedings_of_the_sixth_biennia.htm.
- Hoss, D.E. and G.W. Thayer. 1993. The importance of habitat to the early life history of estuarine dependent fishes. *American Fisheries Society Symposium*. 14:147-158.
- Hurme, A.K. and E.J. Pullen. 1988. Biological effects of marine sand mining and fill placement for beach replenishment: Lesson for other use. *Marine Mining*. Vol. 7.
- Islam Md. S. and Tanaka M. 2004. Impacts of pollution on coastal and marine ecosystems including coastal and marine fisheries and approach for management: a review and synthesis. *Marine Pollution Bulletin*. 48(7-8):624-49.
- Jackson, R.G. 1986. "Effects of bark accumulation on benthic infaunal at a log transfer facility in Southeast Alaska." *Marine Pollution Bulletin*. 17(6):258-262.
- Jacobson K.C., M.R. Arkoosh, A.N. Kagley, E.R. Clemons, T.K. Collier, Casillas. 2003. Cumulative effects of natural and anthropogenic stress on immune function and disease resistance in juvenile Chinook salmon. *J. Aquat. Anim. Health*. 15:1-12
- Jennings, S.R., D.R. Neuman, and P.S. Blicher. 2008. *Acid Mine Drainage and Effects on Fish Health and Ecology: A Review*. Reclamation Research Group Publication, Bozeman, MT.
- Jennings, S.R., J.D. Dollhopf, and W.I. Inskeep. 2000. Acid production from sulfide minerals using hydrogen peroxide weathering. *Applied Geochemistry*. 15:235-243.
- Jewett, S.C. 1999. Assessment of Red King Crabs Following Offshore Placer Gold Mining in Norton Sound. Reprinted from *Alaska Fishery Research Bulletin*. Vol. 6 No. 1, Summer 1999.
- Johnson, L. L., Collier, T. K., Stein, J. E., 2002. An Analysis in Support of Sediment Quality Thresholds for Polycyclic Aromatic Hydrocarbons (PAHs) to Protect Estuarine Fish. *Aquatic Conservation: Marine and Freshwater Ecosystems*. Vol 12 Issue 5, Pages 517 – 538.
- Johnson, L. 2000. An analysis in support of sediment quality thresholds for polycyclic aromatic hydrocarbons (PAHs) to protect estuarine fish. White Paper from National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, Washington. 29 p.

- Johnson, L., S.Y. Sol, G.M. Ylitalo, T. Hom, B. French, O.P. Olson, and T.K. Collier. 1999. "Reproductive injury in English sole (*Pleuronectes vetulus*) from the Hylebos Waterway, Commencement Bay, Washington." *Journal of Aquatic Ecosystem Stress and Recovery*. 6:289-310.
- Johnson, S.W., S.D. Rice, and D.A. Moles. 1998a. Effects of submarine mine tailings disposal on juvenile yellowfin sole (*Pleuronectes asper*): a laboratory study. *Marine Pollution Bulletin*. 36:278-287.
- Johnson, S.W., R.P. Stone, and D.C. Love. 1998b. Avoidance behavior of ovigerous Tanner crabs (*Chionoecetes bairdi*) exposed to mine tailings: a laboratory study. *Alaska Fish. Res. Bull.* 5:39-45.
- Kahler, T., M. Grassley, and D. Beauchamp. 2000. A summary of the effects of bulkheads, piers, and other artificial structures and shorezone development on ESA listed salmonids in lakes. Final Report to the City of Bellevue, Washington. 74 pp.
- Kenai Peninsula Borough. 2004. Cook Inlet Oil and Gas, Kenai Peninsula Borough Oil and Gas History. <http://www.cookinletoilandgas.org/kpb/history.htm>
- Kennish, M.J., 2001. Environmental Threats and Environmental Future of Estuaries. *Environmental Conservation*. 29:78-107.
- Kennish, M.J. 1998. *Pollution Impacts on Marine Biotic Communities*. CRC Press, New York, NY. 310 pp.
- Kennish, M.J., 1997. *Practical Handbook of Estuarine and Marine Pollution*. CRC Press Inc.
- Kilmartin, M.P. 1989. Hydrology of reclaimed open cast coal mined land: A Review. *International Journal of Surface Mining*. 3:71-82
- Kirkpatrick, B., T.C. Shirley, and C.E. O'Clair. 1998. Deep-water bark accumulation and benthos richness at log transfer and storage facilities. *Alaska Fishery Research Bulletin*. 5(2):103-115.
- Klein, R. 1997. The effects of marinas and boating activities upon tidal waters. Community and Environmental Defense Services. Owings Mills, Maryland. 23 pp.
- Knudsen, F.R., C.B. Schreck, S.M. Knapp, P.S. Enger, and O. Sand. 1997. "Infrasound produces flight and avoidance responses in Pacific juvenile salmonids." *Journal of Fish Biology*. 51:824-829.
- Knudsen, F.R., P.S. Enger, and O. Sand. 1994. "Avoidance responses to low frequency sound in downstream migrating Atlantic salmon smolt, *Salmo salar*." *Journal of Fish Biology*. 45:227-233.
- Kohler, C.C. and W.R. Courtenay, Jr. 1986. "Introduction of aquatic species." *Fisheries*. 11(2):39-42. Proceedings of the Seventh International Zebra Mussel and Aquatic Nuisance Species Conference. 1997.

- Koski, K.V. 1992. Restoring stream habitats affected by logging activities. Pages 343-404 in G. W. Thayer (editor) Restoring the nation's marine environment. Publication UM-SG-TS-92-06. Maryland Sea Grant College, College Park, MD.
- Koski, K.V. 1981. The survival and quality of two stocks of chum salmon (*Oncorhynchus keta*) from egg deposition to emergence. Rapp. P.-v. Reun. Conx. int. Explor. Mer, 178:330-333.
- Kuipers, P.E. 2000. Hardrock Reclamation Bonding Practices in the Western United States. Report To: National Wildlife Federation. 2260 Baseline Road, Suite 100, Boulder Colorado, 80302.
- Laetz CA., D.H Baldwin, T. K Collier, V. Hebert, J. D.Stark, and N. L. Scholz. 2009. The Synergistic Toxicity of Pesticide Mixtures: Implications for Risk Assessment and the Conservation of Endangered Pacific Salmon. Environmental Health Perspectives. Volume 117 number 3: 348 - 353.
- LaLiberte, D., and Ewing, R.D., 2006. Effects on Puget Sound Chinook Salmon NPDES Authorized Toxic Discharges. Combined Report. April 17, 2006
- Lalonde, B.A., P.Jackman, K. Doe, C. Garron, and J. Aube. 2008. Toxicity Testing of Sediment Collected in the Vicinity of effluent Discharges from Seafood Processing Plants in the Maritimes. Environmental Contamination and Technology. Vol 56, Number 3, pp389-396.
- Langford, T.E., N.J. Utting, and R.H.A. Holmes. 1978. Factors affecting the impingement of fishes on power station cooling-water intake screens. *In* Physiology and Behaviour of Marine Organisms. D.S. McLusky and A.J. Berry, eds. pp. 281-288. Pergamon Press, Oxford and New York.
- Larsen PF. 1992. An overview of the environmental quality of the Gulf of Maine. *In*: The Gulf of Maine. Silver Spring (MD): NOAA Coastal Ocean Program Synthesis Series No. 1. p 71-95.
- Larson, K. and C. Moehl. 1990. Entrainment of anadromous fish by hopper dredge at the mouth of the Columbia River. *In* C.A. Simenstad, ed. Effects of dredging on anadromous Pacific coast fishes. University of Washington Sea Grant. pp. 102-112.
- Leppard, G.G. and I.G. Droppo. 2003. The need and means to characterize sediment structure and behaviour prior to the selection and implementation of remediation plans. Hydrobiologia. 494:313-7.
- Levin, L. A., W. Ekau, A.J. Gooday, F. Jorissen, J.J. Middelburg, W. Naqvi, C. Neira, N.N. Rabalais, and J. Zhang. 2009. Effects of natural and human-induced hypoxia on coastal benthos. Biogeosciences. 6, 3563–3654.
- Levings, C.D. and T. G. Northcote. 2004. Effects of forestry on estuarine ecosystems supporting fishes. *In* T.G. Northcote and G.F.Hartman, editors, Fishes and Forestry Worldwide Watershed Interactions and Management, Blackwell Publishing, pp 320 -335.
- Lewis-Russ, A. 1997. Ground Water Quality. *In*: Marcus, J.J., ed., Mining Environmental Handbook, Effects of Mining on the Environment and American Environmental Controls on Mining, Imperial College Press, London, pp. 162-165.

- Logan, D. 2007. Perspective on Ecotoxicology of PAHs to Fish. Human and Ecological Risk Assessment, Volume 13, Number 2, March 2007, pp. 302-316(15).
- Longmuir, C. and T. Lively. 2001. Bubble curtain systems for use during marine pile driving. Report by Fraser River Pile & Dredge Ltd., New Westminster, British Columbia. 9 pp.
- Lotze, H., I. Milewski, B. Worm, and Z. Koller. 2003 Nutrient Pollution: A Eutrophication Survey of Eelgrass Beds in Estuaries and Coastal Bays in Northern and Eastern New Brunswick. Conservation Council of New Brunswick Inc.
- Love, M.S., M. Nishimoto, D. Schroeder, and J. Caselle. 1999. The ecological role of natural reefs and oil and gas production platforms on rocky reef fishes in southern California: Final interim report. U.S. Geological Survey, Biological Resources Division. USGS/BRD/CR-1999-007. 208 pp.
- Love, M., J. Hyland, A. Egeling, T. Herrlinger, A. Brooks, and E. Imamura. 1994. "A pilot study of the distribution and abundance of rockfishes in relation to natural environmental factors and an offshore oil and gas production platform off the coast of southern California." Bulletin Marine Science. 55(2-3): 1062-1085.
- Love, M.S. and W. Westphal. 1990. Comparison of fishes taken by a sportfishing party vessel around oil platforms and adjacent natural reefs near Santa Barbara, California. Fishery Bulletin, U.S. 88:599-605.
- Luce, A. and M. Crowe. 2001. "Invertebrate terrestrial diversity along a gravel road on Barrie Island, Ontario, Canada." Great Lakes Entomologist. 34(1):55-60 SPR-SUM.
- Luchetti, G. and R. Feurstenburg. 1993. Relative fish use in urban and non-urban streams. Proceedings of a conference on Wild Salmon. Vancouver, British Columbia, Canada.
- Ludwig, M. and E. Gould. 1988. Contaminant input, fate and biological effects. In: Pacheco AL, editor. Woods Hole (MA): US Department of Commerce. NOAA/NMFS/Northeast Fisheries Science Center. NOAA Technical Memorandum NMFS-F/NEC 56. p. 305-322.
- Luoma, S.N. 1996. The developing framework of marine ecotoxicology: pollutants as a variable in marine ecosystems. Journal of Experimental Marine Biology and Ecology. 200:29-55.
- MacDonald, L.H., R.W. Sampson, and D.M. Anderson. 2001. "Runoff and road erosion at the plot and road segment scales, St. John, U.S. Virgin Islands." Earth Surface Processes and Landforms. 26:251-272.
- Mahler B.J., P.C. Van Metre, T.J. Bashara, J.T. Wilson and D.A. Johns. 2005. Parking lot sealcoat: An Unrecognized Source of Urban Polycyclic Aromatic Hydrocarbons. Environ. Sci. Technol. 39(15): 5560- 66.
- Markham, V.D. 2006. U.S. National Report on Population and the Environment. New Canaan (CT): Center for Environment and Population. 67 pp.
- Martin, D. J. and D. J. Grotefendt. 2001. Buffer Zones and LWD supply. Project Report prepared for Alaska Forest Association and Alaska Department of Environmental Conservation. Community Water Quality Grant No: NP-01-12.

- Martin, D.J. and A. Shelly. 2004. Status and trends of fish habitat condition on private timberlands in southeast Alaska: 2003 Summary. Report to Sealaska Corporation and Alaska Department of Natural Resources, Juneau, Alaska.
- Maser, C. and J.R. Sedell. 1994. From the Forest to the Sea: the Ecology of Wood in Streams, Estuaries and Oceans. St. Lucie Press, Delray Beach, FL. 200 pp.
- May, C., R. Horner, J. Karr, B. Mar, and E. Welch. 1997. Effects of urbanization on small streams in the Puget Sound lowland ecoregion. *Watershed Protection Techniques*. 2(4):483-494.
- McCarthy S.G., Incardona, J.P., Scholz, N.L., 2008. Coastal Storms, Toxic Runoff, and the Sustainable Conservation of Fish and Fisheries. *American Fisheries Society. Symposium* 64:7-27.
- McCauley, R.D., J. Fewtrell, and A.N. Popper. 2003. "High intensity anthropogenic sound damages fish ears." *J. Acoust. Soc. AM*. 113 (1), January 2003. pp. 638-642.
- McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M.-N. Jenner, J. D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch and K. McCabe. 2000. Marine seismic surveys: Analysis and propagation of air-gun signals; and the effects of exposure on humpback whales, sea turtles, fishes and squid. Centre for Marine Science and Technology, Curtin University, R99-15, Perth, Western Australia. 185 pp.
- McElroy A, Farrington J, and Teal J. 1989. Bioavailability of polycyclic aromatic hydrocarbons in the aquatic environment. In: Varanasi U, editor. *Metabolism of polycyclic aromatic hydrocarbons in the aquatic environment*. Boca Raton (FL): CRC Press. pp. 2-39.
- McGee, S., R. Piorkowski, R. and G. Ruiz. 2006. Analysis of recent vessel arrivals and ballast in Alaska: Toward assessing ship-mediated invasion risk. *Marine Pollution Bulletin*. 52 (2006) 1634-1645.
- McGraw, K. and D. Armstrong. 1990. Fish entrainment by dredges in Grays Harbor, Washington. In C.A. Simenstad, ed. *Effects of dredging on anadromous Pacific coast fishes*. University of Washington Sea Grant. pp. 113-131.
- Meehan, W.R., W.A. Farr, D.M. Bishop, and J.H. Patric. 1969. Some effects of clearcutting on salmon habitat of two southeast Alaska streams. U.S. Department of Agriculture, Forest Service. General Technical Report PNW-82. Institute of Northern Forests, Pacific Northwest Forest and Range Experiment Station.
- Michel, J. and M.O. Hayes. 1999. "Weathering patterns of oil residues eight years after the Exxon Valdez oil spill." *Marine Pollution Bulletin*. 38(10):855-863.
- Minerals Management Service (MMS). 1991. Alaska Outer Continental Shelf (OCS) Mining Program. Norton Sound Lease Sale. Final Environmental Impact Statement. March 1991
- Mitsch W.J., and Gosselink J.G. 1993. *Wetlands*. 2nd ed. New York (NY): Van Nostrand Reinhold. 722 pp.
- Moazzam, M. and S.H.N. Rizvi. 1980. "Fish entrapment in the seawater intake of a power plant at Karachi coast." *Environ. Biology of Fishes*. 5:49-57.

- Moles, A. and N. Hale. 2003. Use of physiological responses in *Mytilus trossulus* as integrative bioindicators of sewage pollution. *Marine Pollution Bulletin*. 46:954-958.
- Moles, A. and B. Norcross. 1995. Sediment preference in juvenile pacific flatfishes. *Netherlands Journal of Sea Research*. Volume 34, Issues 1-3. pp. 177-182.
- Montgomery, D.R., R.D. Smith, K.M. Schmidt, and G.R. Pess. 1995. "Pool Spacing in Forest Channels." *Water Resources Research*. 31:1097-1105.
- Moore, A. and Waring, C.P. 2001. "The effects of a synthetic pyrethroid pesticide on some aspects of reproduction in Atlantic salmon (*Salmo salar* L)." *Aquatic Toxicology*. 52:1-12.
- Muir, D. C. G., R. J. Norstrom, and M. Simon. 1988. Organochlorine contaminants in arctic marine food chains: accumulation of specific polychlorinated biphenyls and chlordan-related compounds. *Environmental Science and Technology* 22:1071-1078.
- Murphy, M.L., S.W. Johnson, and D.J. Csepp. 2000. "A comparison of fish assemblages in eelgrass and adjacent subtidal habitats near Craig, Alaska." *AK. Fish. Res. J.* 7:11-21. Murphy, M.L. 1995. Forestry impacts on freshwater habitat of anadromous salmonids in the Pacific Northwest and Alaska. Requirements for protection and restoration. U.S. Dep. Commer., NOAA Coastal Ocean Program, Decision Analysis Series No. 7, 156 + xxii p.
- Murphy, M.L. and K.V. Koski. 1989. Input and depletion of woody debris in Alaska streams and implications for streamside management. *North American Journal of Fisheries Management* 9, 427-436.
- Murty, A. S. 1986. Toxicity of Pesticides to Fish. Volume 2. CRC Press, Boca Raton, FL.
- Mutz, M. 1998. Stream system restoration in a strip-mining region, eastern Germany: dimension, problems, and first steps. *Aquatic Conservation: Marine and Freshwater Ecosystems*. Aquatic Conservation, March 6. *Freshwater Ecosystems*. 8:159-166.
- Myren, R.T. and R.J. Ellis. 1984. Evapotranspiration in forest succession and long-term effects upon fishery resources: a consideration for management of our old-growth forests. pp. 183-186. In Meehan, M.R., T.R. Merrill, Jr., and T.A. Hanley, eds. *Fish and wildlife relationships in old growth forests*. American Institute of Fishery Research Biologists.
- Sheavly, S.B.. 2007. "National Marine Debris Monitoring Program: Final Program Report, Data Analysis and Summary." Prepared for U.S. Environmental Protection Agency by Ocean Conservancy, Grant Number X83053401-02. 76 pp.
http://www.oceanconservancy.org/site/DocServer/NMDMP_Report_April_2008.pdf?docID=4601
- NMFS (National Marine Fisheries Service). 2011. Anadromous Salmonid Passage Facility Design. NMFS, Northwest Region, Portland, Oregon. <http://www.nwr.noaa.gov/Salmon-Hydropower/FERC/upload/Fish-Passage-Design.pdf>
- NMFS. 2009. National Marine Fisheries Service Endangered Species Act Section 7 consultation: Environmental Protection Agency registration of pesticides containing carbofuran, carbaryl, and methomyl. In *Biological Opinion*. (U.S. Department of Commerce, Silver Spring, MD). pp 591.

- NMFS. 2008. Impacts to Marine Fisheries Habitat from Nonfishing Activities in the Northeastern United States. Northeast Regional Office Gloucester, Massachusetts NOAA Technical Memorandum NMFS-NE-209.
- NMFS. 2005. Final Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska, Appendix G Non-fishing Impacts to Essential Fish Habitat and Recommended Conservation Measures.
- NMFS. 2004. Draft National Gravel Extraction Policy. 1335 East-West Highway, Silver Spring, MD 20910. <http://www.nmfs.noaa.gov/habitat/habitatprotection/pdf/gravelguidance.pdf>
- NMFS. 2003. Biological Opinion for the Benicia-Martinez New Bridge Project, Southwest Region, Santa Rosa, California. Admin. Rec. 151422SWR02SR6292.
- NMFS. 2002. Environmental Assessment, NMFS' Restoration Plan for the Community-Based Restoration Program. Prepared by the NOAA Restoration Center, Office of Habitat Conservation. Silver Spring, MD.
- NMFS. 2001. Biological Opinion for the San Francisco-Oakland Bay Bridge East Span Seismic Safety Project. Southwest Region, Santa Rosa, California. Admin. Rec. 151422SWR99SR190.
- NMFS. 1998a. Draft document - Non-fishing threats and water quality: A reference for EFH consultation.
- NMFS. 1998b. Final recommendations: Essential Fish Habitat for Pacific Coast Groundfish. Prepared by: The Core Team for EFH for Pacific Coast Groundfish June 3, 1998. 2725 Montlake Blvd. E. Seattle, WA 98112. http://www.psmfc.org/efh/groundfish_desc.pdf.
- National Oceanic and Atmospheric Agency (NOAA). 2010. Office of Ocean and Coastal Resource Management. Ocean and Coastal Management in Alaska. <http://coastalmanagement.noaa.gov/mystate/ak.html>.
- National Research Council (NRC). 2003. Cumulative Environmental Effects of Oil and Gas Activities on Alaska's North Slope. Committee on the Cumulative Environmental Effects of Oil and Gas Activities on Alaska's North Slope. The National Academies Press, Washington, D.C. Prepublication Copy. 452 pp. (www.nap.edu).
- NRC. 1999. Committee on Hardrock Mining. Hardrock Mining on Federal Lands. Appendix B. Potential Environmental Impacts of Hardrock Mining. (http://www.nap.edu/html/hardrock_fed_land/appB.html).
- NRC. 1996. Upstream: salmon and society in the Pacific Northwest. Report of the committee on protection and management of Pacific Northwest anadromous salmonids. Board on Environmental Studies and Toxicology, and Commission on Life Sciences. National Academy Press. Washington, D.C. 20055.
- NRC. 1989. Irrigation-induced water quality problems: what can be learned from the San Joaquin Valley experience. National Academy Press, Washington, D.C.
- Neff, J. M. 2002. Bioaccumulation in Marine Organisms. Effect of Contaminants from Oil Well Produced Water. Elsevier Science Ltd: Kidlington, Oxford, UK.

- Neff, J. M. 1985. Polycyclic aromatic hydrocarbons. pp. 416-454. IN: G. M. Rand and S. R. Petrocelli, eds. *Fundamentals of Aquatic Toxicology. Methods and Applications*. Taylor & Francis:New York.
- Nelson D, Miller J, Rusanowsky D, Greig R, Sennefelder G, Mercaldo-Allen R, Kuropat C, Gould E, Thurberg F, Calabrese A. 1991. Comparative reproductive success of winter flounder in Long Island Sound: a three-year study (biology, biochemistry, and chemistry). *Estuaries* 14(3):318-31.
- Newell, R.C., L.J. Seiderer, and D.R. Hitchcock. 1998. "The impact of dredging on biological resources of the sea bed." *Oceanography and Marine Biology Annual Review*. 36:127-178.
- Nightingale, B. and C.A. Simenstad. 2001a. Dredging activities: Marine issues. Washington State Transportation Center, University of Washington, Seattle, WA 98105. (Document available through the National Technical Information Service, Springfield, VA 22616).
- Nightingale, B. and C.A. Simenstad. 2001b. Overwater Structures: Marine Issues. White paper submitted to Washington Department of Fish and Wildlife, Washington Department of Ecology and Washington Department of Transportation. www.wa.gov/wdfw/hab. 133 pp.
- Northcote, T.G. and G.F. Hartman. 2004. *Fishes and Forestry - Worldwide Watershed Interactions and Management*, Blackwell Publishing, Oxford, UK, 789 pp.
- Northwest Power Planning Council. 1986. Compilation of information on salmon and steelhead losses in the Columbia River Basin. Columbia River Basin and Wildlife Program. Portland, OR.
- O'Hearn, J. 1997. Surface Water Quantity. In: Marcus, J.J., ed., *Mining Environmental Handbook, Effects of Mining on the Environment and American Environmental Controls on Mining*, Imperial College Press, London, pp. 221-225.
- Omori, M., S. Van der Spoel, C.P. Norman. 1994. Impact of human activities on pelagic biogeography. *Progress in Oceanography*. 34 (2-3):211-219.
- Oregon Water Resource Research Institute (OWRRI). 1995. Gravel disturbance impacts on salmon habitat and stream health, volume 1. Summary report. Oregon State University, Corvallis, Oregon. (Also available Vol. II: Technical background report). Available from Oregon Division of State Lands, Salem, Oregon, 503-378-3805.
- OSPAR Commission. 2009. *Assessment of Impacts of Mariculture*. Publication Number: 442/2009. London, UK
- Pacific Fishery Management Council (PFMC). 1999. Appendix A: Identification and description of essential fish habitat, adverse impacts, and recommended conservation measures for salmon. Amendment 14 to the Pacific Coast Salmon Plan. Portland, OR. 146 pp.
- Pacific Northwest Pollution Control Council. 1971. Log storage and rafting in public waters. Task Force report. p. 56
- Packer, D.B., Griffin K., McGlynn K.E. 2005. National Marine Fisheries Service national gravel extraction guidance. Washington (DC): US Department of Commerce. NOAA Technical

Memorandum NMFS-F/SPO-70. [cited 2008 Jul 15]. 27 p. Available from:
<http://www.nmfs.noaa.gov/habitat/habitatprotection/anadfish/gravel.htm>.

- Peplow, D. and R. Edmonds. 2004. The effects of mine waste contamination at multiple levels of biological organization. *Ecological Engineering*. 24: 1-2, p101-119.
- Peterson, C. H., S. D. Rice, J. W. Short, D. Esler, J. L. Bodkin, B. E. Ballachey, and D. B. Irons. 2003. Long-term ecosystem response to the Exxon Valdez oil spill. *Science*. 302: 2082-2086.
- Phillips, R.C. 1984. The ecology of eelgrass meadows in the Pacific Northwest: a community profile. U.S. Fish and Wildlife Service. FWS/OBS-84/24. 85 pp.
- Polasek, L.G. 1997. Assessment of wetland habitat alterations resulting from construction of a pipeline through coastal marshes in Orange County, Texas. Final Report: Texas Parks and Wildlife Department, Port Arthur, TX. 40 pp.
- Poston, T. 2001. Treated wood issues associated with overwater structures in marine and freshwater environments. White Paper submitted to Washington Department of Fish and Wildlife, Washington Department of Ecology and Washington Department of Transportation by Batelle. 85 pp.
- Preston, B.L. 2002. "Indirect effects in aquatic ecotoxicology: implications for ecological risk assessment." *Environmental Management*. 29:311-323.
- Ralph, S., G. Poole, L. Conquest, and R. Naiman. 1994. "Stream channel morphology and woody debris in logged and unlogged basins in western Washington." *Can. J. Fish. Aquatic Sciences*. 51:37-51.
- Rand, G.M. (Editor). 1995. *Fundamentals of Aquatic Toxicology: Effects, Environmental Fate and Risk Assessment*. Taylor and Francis Publishing. Second Edition. Taylor and Francis, Washington, D.C.
- Raymond, H. 1979. "Effects of dams and impoundment on migrations of juvenile chinook salmon and steelhead from the Snake River, 1966 to 1975." *Trans. Amer. Fish. Soc.* 108:505-529.
- Reiser, D.W., T. Nightengale, N. Hendrix, S. Beck. 2005. Effects of Pulse type Flows on Benthic Macroinvertebrates and Fish: A Review and Synthesis of Information. R2 Resources Consultants, Inc. for Pacific Gas & Electric Company.
- Ren J, and Packman A. 2002. Effects of background water composition on stream-subsurface exchange of submicron colloids. *Journal of Environmental Engineering*. 128(7):624-34.
- Reyff, J.A. 2003. Underwater sound levels associated with seismic retrofit construction of the Richmond-San Rafael Bridge. Document in support of Biological Assessment for the Richmond-San Rafael Bridge Seismic Safety Project. January 31, 2003. 18 pp.
- Reyff, J.A and P. Donovan. 2003. Benicia-Martinez Bridge Bubble Curtain Test - Underwater Sound Measurement Data. Memo to Caltrans dated January 31, 2003. 3 pp.

- Rice, S.D., J.W. Short, R.A. Heintz, M.G. Carls, and A. Moles. 2000. Life-history consequences of oil pollution in fish natal habitat. pp. 1210-1215. *In* Catania, P., ed. Energy 2000. Balaban Publishers, Lancaster, England.
- Richardson WJ, Greene CR, Malme CI, Thomas DH. 1995. Marine mammals and noise. San Diego (CA): Academic Press. 576 p.
- Robinson W.E., and Pederson J. 2005. Contamination, habitat degradation, overfishing - An "either-or" debate? *In*: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 1-10.
- Rogers, P.H. and M. Cox. 1988. Underwater sound as a biological stimulus. pp. 131-149. *In* Sensory biology of aquatic animals. Atema, J, R.R. Fay, A.N. Popper, and W.N. Tavolga, eds. Springer-Verlag. New York.
- Rose, K.A., A.T. Adamack, C.A. Murphy, S.E. Sable, S.E. Kolesar, J.K. Craig, D.J. Breitburg, P. Thomas, M.H. Brouwer, C.F. Cerco, and S. Diamond. 2009. Does hypoxia have population-level effects on coastal fish? Musings from the virtual world. *Journal of Experimental Marine Biology and Ecology*. In Press.
- Rosecchi, E., A.J. Crivelli, G. Catsadorakis. 1993. The establishment and impact of *Pseudorasbora parva*, an exotic fish species introduced into lake Mikri Prespa (northwestern Greece). *Aquatic Conservation: Marine and Freshwater Ecosystems* 3:223-231.
- Roy Consultants Ltd., NATECH Environmental Services Inc. and OCL Group. Environmental Management Consultants. 2003. Lamèque Bay environmental management study. Report No. 133-01.
- Safavi, H.R. 1996. Quality control of urban runoff and sound management. *Hydrobiologia: Diapause in the Crustacea*. pp. 131 -141.
- Saiki, M.K., D.T. Castleberry, T.W. May, B.A. Martin, and F.N. Bullard. 1995. Copper, cadmium, and zinc concentrations in aquatic food-chains from the upper Sacramento River (California) and selected tributaries. *Archives of Environmental Contamination and Toxicology*. 29(4):484-491.
- Sand, O., P.S. Enger, H.E. Karlsen, F. Knudsen, T. Kvernstuen. 2000. "Avoidance responses to infrasound in downstream migrating European silver eels, *Anguilla anguilla*." *Environmental Biology of Fishes*. 57:327-336.
- Sandahl, J.F., D. H. Baldwin, J. J. Jenkins, and N.L. Scholz. 2007a. Odor-evoked field potentials as indicators of sublethal neurotoxicity in juvenile coho salmon (*Oncorhynchus kisutch*) exposed to copper, chlorpyrifos, or esfenvalerate. *Canadian Journal of Fisheries Aquatic Sciences* 64, 404-413.
- Sandahl, J.F., D.H. Baldwin, J.J. Jenkins, and N.L. Scholz. 2007b. A sensory system at the interface between urban stormwater runoff and salmon survival. *Environmental Science and Technology*. 41:2998-3004.

- Sandahl J.F., D. H. Baldwin, J. J. Jenkins, and N. L. Scholz. 2005. Comparative Thresholds for Acetylcholinesterase Inhibition and Behavioral Impairment in Coho Salmon Exposed to Chlorpyrifos. Setac Press. Vol. 24, No. 1: 136-145.
- Scholz, N.L., N.K. Truelove, B.L. French, B.A. Berejikian, T.P. Quinn, E. Casillas, and T.K. Collier. 2000. "Diazinon disrupts antipredator and homing behaviors in chinook salmon (*Oncorhynchus tshawytscha*).\" Canadian Journal of Fisheries and Aquatic Sciences. 57:1911-1918.
- Scott G.I., M.H. Fulton, D.W. Moore, E.F. Wirth, G.T. Chandler, P.B. Key, J.W. Daugomah, E.D. Strozier, J. Devane, J.R. Clark, M.A. Lewis, D.B. Finley, W. Ellenberg, and K.J. Karnaky. 1999. "Assessment of risk reduction strategies for the management of agricultural nonpoint source pesticide runoff in estuarine ecosystems.\" Toxicology and Industrial Health. 15:200-213.
- Scrivener, J.T. and M.J. Brownlee. 1989. "Effects of forest harvesting on spawning gravel and incubation survival of chum (*Oncorhynchus keta*) and coho (*O. kisutch*) salmon in Carnation Creek, British Columbia.\" Canadian Journal of Fisheries and Aquatic Sciences. 46(4):681-696.
- Sedell, J.R., and K.J. Luchessa. 1982. Using the historical record as an aid to salmonid habitat enhancement. In Armantrout, N.B. (ed.), Acquisition and utilization of aquatic habitat inventory information, p. 210-222. American Fisheries Society, Western Division, Bethesda, MD.
- Sengupta, M. 1993. Environmental Impacts of Mining: Monitoring, Restoration, and Control. CRC Press, Inc. 2000 Corporate Blvd., N.W. Boca Raton, FL. 33431. p.1.
- Shafer, D.J. 2002. Recommendations to minimize potential impacts to seagrasses from single-family residential dock structures in the Pacific Northwest. U.S. Army Corps of Engineers, Seattle, WA. 28 p.
- Short, J. W., M. R. Lindeberg, P. M. Harris, J. M. Maselko, J. J. Pella, and S. D. Rice. 2004. Estimate of oil persisting on beaches of Prince William Sound, 12 after the Exxon Valdez oil spill. Environmental Science and Technology. 38(1): 19-25.
- Short, Jeffrey W., Stanley D. Rice, Ron A. Heintz, Mark G. Carls, and Adam Moles. 2003. Long-term Effects of Crude Oil on Developing Fish: Lessons from the Exxon Valdez Oil Spill. Energy Sources. 25: 509-517.
- Short, J.W., M.R. Lindeberg, P.M. Harris, J. Maselko, and S.D. Rice. 2002. Vertical Oil Distribution Within the Intertidal Zone 12 Years After the *EXXON VALDEZ* Oil Spill in Prince William Sound, Alaska. Pp. 57-72 In: Proceedings of the Twenty-fifth Arctic and Marine Oilspill Program (AMOP) Technical Seminar. Environment Canada, Ottawa, Ontario.
- Sidele, R.C., A.J. Pearce, and C.L. O'Loughlin. 1985. Hillslope stability and land use. Water Resources Monograph 11. Washington D.C.: American Geophysical Union 140 pp.
- Simon, J.A., and Sobieraj, J.A., 2006. Contributions of Common Sources of Polycyclic Aromatic Hydrocarbons to Soil Contamination. Journal of Remediation. Vol 16, Issue 3, p25-35

- Sogard, S.M. and K.W. Able. 1991. "A comparison of eelgrass, sea lettuce macroalgae and marsh creeks as habitats for epibenthic fishes and decapods." *Estuarine, Coastal and Shelf Science*. 33, 501-519.
- Solley, Wayne B. 1997. Estimates of Water Use in the Western United States in 1990 and Water-Use Trends 1960-90. Report to the Western Water Policy Review Advisory Commission U.S. Geological Survey. Reston, Virginia. 19pp.
- Sophocleous, M. 2002. Interactions between groundwater and surface water: The State of the Science. *Hydrogeology Journal* 10:52-67.
- Spence, B.C., G.A. Lomnický, R.M. Hughes, and R.P. Novitzki. 1996. An ecosystem approach to salmonid conservation. TR-4501-96-6057. ManTech Environmental Research Services Corp., Corvallis, OR. 356 pp. (Available from the NMFS Habitat Branch, Portland, OR).
- Spromberg J.A. and J.P. Meador. 2005. Relating results of chronic toxicity responses to population-level effects: modeling effects on wild Chinook salmon populations. *Integrated Environmental Assessment and Management*. 1, 9-21.
- Stadler, J.H. 2002. Personal observation of fish-kill occurring during pile driving activity at the Winslow Ferry Terminal, Winslow, WA. October 7, 2002. Fish Biologist, DOC/NOAA/National Marine Fisheries Service/HCD, Lacey, WA.
- Stehr, C.M., D.W. Brown, T. Hom, B.F. Anulacion, W.L. Reichert, and T.K. Collier. 2000. "Exposure of juvenile chinook and chum salmon to chemical contaminants in the Hylebos Waterway of Commencement Bay, Tacoma, Washington." *Journal of Aquatic Ecosystem Stress and Recovery*. 7:215-227.
- Stewart, R. K. and D.R. Tangarone. 1977. Water Quality Investigations Related to Seafood Processing Wastewater Discharges at Dutch Harbor, Alaska - October 1975 and October 1976. Region X, U.S. Environmental Protection Agency. Working Paper #EPA 910/8-77-100. 78 pp.
- Stiles, S., J. Choromanski, D. Nelson, J. Miller, R. Grieg, and G. Sennefelder. 1991. Early reproductive success of the hard clam (*Mercenaria mercenaria*) from five sites in Long Island Sound. *Estuaries*. 14(3):332-42.
- Stocker, M. 2002. Fish, mollusks and other sea animals' use of sound, and the impact of anthropogenic noise in the marine acoustic environment. *Journal of Acoustical Society of America*. 112(5):2431.
- Stotz, T. and J. Colby. 2001. January 2001 dive report for Mukilteo wingwall replacement project. Washington State Ferries Memorandum. 5 pp. + appendices.
- Sturdevant, M.V., A.C. Wertheimer, and J.L. Lum. 1996. Diets of juvenile pink and chum salmon in oiled and non-oiled nearshore habitats in Prince William Sound, 1989 and 1990. pp. 578-592. In: S.D. Rice, et al. (Eds.) American Fisheries Society Symposium 18, Proceedings of the Exxon Valdez Oil Spill Symposium.
- Sturdevant, M.V., A.C. Wertheimer, and J.L. Lum. 1994. Diet of juvenile pink and chum salmon in oiled and non-oiled nearshore habitats in Prince William Sound, 1989 and 1990. Chapter 4. In: A.C. Wertheimer, et al. (Eds.) Impact of the oil spill on juvenile pink and chum salmon

- and their prey in critical nearshore habitats. Exxon Valdez Oil Spill, State/Federal damage Assessment Final Report. Alaska Fisheries Science Center, Auke Bay Laboratory, Juneau, Alaska.
- Swanston, D.N. 1974. The forest ecosystem of southeast Alaska. Soil mass movement. General Technical Report PNW-17. U.S. Department of Agriculture, Forest Service. Pacific Northwest Forest and Range Experiment Station. Portland, OR.
- Teaf, C.M. 2008. "Polycyclic Aromatic Hydrocarbons (PAHs) in Urban Soil: A Florida Risk Assessment Perspective," *International Journal of Soil, Sediment and Water*: Vol. 1: Iss. 2, Article 2. Available at: <http://scholarworks.umass.edu/intljssw/vol1/iss2/2>
- Theriault, M.H., S.C. Courtenay, C. Godin and W.B. Ritchie. 2006. Evaluation of the Community Aquatic Monitoring Program (CAMP) to assess the health of four coastal areas within the southern Gulf of St. Lawrence with special reference to the impacts of effluent from seafood processing plants. *Can. Tech. Rep. Fish. Aquat. Sci.* 2649: vii + 60 p.
- Thurberg, F.P. and E. Gould. 2005. Pollutant effects upon cod, haddock, pollock, and flounder of the inshore fisheries of Massachusetts and Cape Cod Bays. In: Buchsbaum R, Pederson J, Robinson WE, editors. *The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation*. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 43-66.
- Travnichek, V.H., A.V. Zale, and W.L. Fisher. 1993. "Entrainment of ichthyoplankton by a warmwater hydroelectric facility." *Trans. Amer. Fish. Soc.* 122:709-716.
- Trombulak, S.C. and C.A. Frissell. 2000. "Review of ecological effects of roads on terrestrial and aquatic communities." *Conservation Biology*. 14(10):18-30. February.
- Turekian K. 1978. *The Fate of Estuaries*. Washington (DC): US Environmental Protection Agency. EPA-600/9-78-038. p 27-38.
- Turner, A., and G.E. Millward 2002. Suspended particles: their role in estuarine biogeochemical cycles. *Estuarine, Coastal and Shelf Science*. 55:857-83.
- U.S. Army Corps of Engineers (USACE). 1993. *Engineering and Design: Environmental; Engineering for Small Boat Basins*. EM 1110-2-1206. Dept. of the Army, CECW-EH-W. Washington DC.
- US Department of Agriculture (USDA). 2008a. *Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings*. National Technology and Development Program, Report 0877 1801-SDTDC. May 2008.
- USDA Forest Service. 2008b. *Tongass Monitoring and Evaluation Report – Appendix B*
http://www.fs.fed.us/r10/tongass/projects/tlmp/2008_monitoring_report/index2008.shtml
- USDA. 2004. *Tongass Monitoring and Evaluation Report – Fish Habitat*
http://www.fs.fed.us/r10/tongass/projects/tlmp/2004_monitoring_report/index.shtml

- USDA Forest Service. 2003. R10-MB-481a. Tongass Land Management Provision. Final Supplemental Environmental Impact Statement - Roadless Area Evaluation for Wilderness Recommendations. http://www.tongass-seis.net/seis/pdf/Volume_I.pdf
- US Environmental Protection Agency (USEPA). 2005. National management measures to control nonpoint source pollution from urban areas. Washington (DC): US EPA Office of Water. EPA-841-B-05-004. 518 p.
- USEPA. 2002. National Water Quality Inventory: 2000 Report to Congress. EPA-841-R-02-001. EPA Office of Water, Washington, D.C.
- USEPA. 2001. Reissuance of the NPDES General Permit for Seafood Processors Operating Throughout Alaska in Waters of the United States (NPDES General Permit No. AK-G52-0000) Federal Register: July 27, 2001. U.S. Environmental Protection Agency (EPA), Region X.
- USEPA. 2000a. Environmental Screening Checklist and Workbook for the Water Transportation Industry. August 2000.
- USEPA, Region 10. 2000b. Authorization to discharge under the National Pollutant Discharge Elimination System (NPDES) for Section 402 modifications of Section 404 permits for log Transfer Facilities which received a Section 404 permit prior to October 22, 1985. NPDES Permit Number AK-G70-0000. March 2000. 1200 Sixth Avenue, OW-130 Seattle, Washington 98101.
- USEPA. 1999. Combined sewer overflow management fact sheet: pollution prevention. Washington (DC): US EPA Office of Water. EPA 832-F-99-038. 9 p.
- USEPA, Region 10. 1996. Authorization to discharge under the National Pollutant Discharge Elimination System (NPDES) for Section 402 modifications of Section 404 permits for log Transfer Facilities which received a Section 404 permit prior to October 22, 1985. NPDES Permit Number AK-G70-1000. EPA Response to Comments from September 1996 Public Notice <http://info.dec.state.ak.us/DECPermit/water31rtc.pdf>.
- USEPA. 1995. National Water Quality Inventory: 1994 Report to Congress. EPA-841-R-95-005. EPA Office of Water, Washington, D.C.
- USEPA. 1993. Guidance for specifying management measures for sources of nonpoint pollution in coastal waters. EPA Office of Water. 840-B-92-002. 500+ pp.
- USEPA. 1979. Impact of Seafood Cannery Waste on the Benthic Biota and Adjacent Waters at Dutch Harbor, Alaska.
- Vandermeulen, J.H. and D Mossman . 1996. Sources of variability in seasonal hepatic microsomal oxygenase activity in winter flounder (*Pleuronectes americanus*) from a coal tar contaminated estuary. Canadian Journal of Fisheries and Aquatic Sciences. 53:(8) 1741-1753, 10.1139/f96-026.
- Van der Veer, H., M.J.N. Bergmen, and J.J. Beukema. 1985. "Dredging activities in the Dutch Wadden Sea effects on macrobenthic infauna." Netherlands Journal for Sea Research. 19:183-190.

- Verity, P.G., M. Alber and S.B. Bricker. 2006. Development of Hypoxia in well-mixed subtropical estuaries in the Southeastern USA. Estuaries and Coasts: Volume 29, Number 4 August, 2006 p.665-673
- Walker, D., R. Lukatelich, R.G. Bastyan and A.J. McComb. 1989. "The effect of boat moorings on seagrass beds near Perth, Western Australia." *Aquatic Botany*. 36:69-77. In Shafer, D.J. 2002. Recommendations to minimize potential impacts to seagrasses from single-family residential dock structures in the Pacific Northwest. U.S. Army Corps of Engineers, Seattle, WA. 28 pp.
- Wardle, C.S., T.J. Carter, G.G. Urquhart, A.D.F. Johnstone, A.M. Ziolkowski, G. Hampson, and D. Mackie. 2001. Effects of seismic airguns on marine fish. Fisheries Research Services, Marine Laboratory. Continental Shelf Research, 21 (8-10). pp. 1005-1027.
- Warrington, P.D. 1999. Impacts of outboard motors on the aquatic environment. <http://www.nalms.org/bclss/impactsoutboard.htm>.
- Washington Department of Fish and Wildlife. 1998. Gold and fish. Rules and regulations for mineral prospecting and mining in Washington State. Draft, February 1998. Olympia, WA.
- Weaver, T.M. and J.J. Fraley. 1993. "A method to measure emergence success of westslope cutthroat trout fry from varying substrate compositions in a natural stream channel." *North American Journal of Fisheries Management*. 13(4):817-822.
- Weiss, P.T., LeFevere, G., and Gulliver, J.S. 2008. Contamination of Soil and Groundwater Due to Stormwater Infiltration Practices: A Literature Review - Project Report No.515. University of Minnesota Stormwater Assessment Project, St. Anthony Falls Laboratory University of Minnesota. <http://proteus.pca.state.mn.us/water/stormwater/index.html>
- West, C., L. Galloway, and J. Lyon. 1995. Mines, Stormwater Pollution, and You. Mineral Policy Center, Washington, D.C.
- Widdows J, Burns KA, Menon NR, Page D, Soria S. 1990. Measurement of physiological energetics (scope for growth) and chemical contaminants in mussel (*Arca zebra*) 220 transplanted along a contamination gradient in Bermuda. *Journal of Experimental Marine Biology and Ecology*. 138:99-117.
- Williams C. 1996. Combatting marine pollution from land-based activities: Australian initiatives. *Ocean & Coastal Management*. 33(1-3):87-112.
- Williams, G.D. and R.M. Thom. 2001. Marine and estuarine shoreline modification issues. White paper submitted to Washington Department of Fish and Wildlife, Washington Department of Ecology and Washington Department of Transportation. www.wa.gov/wdfw/hab/ahg. 99 pp.
- Wu, Y., R. Falconer, and B. Lin. 2005. Modeling trace metal concentration distributions in estuarine waters. *Estuarine, Coastal and Shelf Science*. 64:699-709.
- Würsig, B., C.R. Greene, Jr., and T.A. Jefferson. 2000. "Development of an air bubble curtain to reduce underwater noise of percussive pile driving." *Marine Environmental Research*. 49:79-93.

- Wyllie-Echeverria, S. and R.C. Phillips. 1994. pp. 1-4. *In* Wyllie-Echeverria, S., A.M. Olson and M.J. Herselman, eds. Seagrass science and policy in the Pacific Northwest: proceedings of a seminar series (SMA 94-1) EPA 910/R-94-004. 63 pp.
- Yelverton, J.T., D.R. Richmond, W. Hicks, K. Saunders, and R. Fletcher. 1975. The relationship between fish size and their response to underwater blast. Lovelace Foundation for Medical Education and Research, Albuquerque, NM.
- Young, M.K., W.A. Hubert, and T.A. Wesche. 1991. "Selection of measures of substrate composition to estimate survival to emergence of salmonids and to detect changes in stream substrates." *North American Journal of Fisheries Management*. 11 (3):339-346.
- Younger, P. L., S.A. Banwart, and R.S. Hedin. 2002. *Mine Water: Hydrology, Pollution, Remediation.* NY, NY, Springer Pub.
- Younger, P.L. 2000. The Adoption and Adaptation of Passive Treatment Technologies for Mine Waters in the United Kingdom. – *Mine Water and the Environment*, 19: 84—97.
- Zale, A.V., O.E. Maughan, D.J. Orth, and W. Layher. 1993. Withdrawals. *In* Bryan, C.F and D.A. Rutherford, eds. *Impacts on warmwater streams: Guidelines for evaluation*. Pp. 271-281. Southern Division, American Fisheries Society, Little Rock, AR.

Additional Resources

- Addison, R.F. and T.G. Smith. 1996. "Trends in organochlorine residue concentrations in ringed seal (*Phoca hispida*) from Holman, Northwest Territories 1972-1991." *Arctic*. 51:253-561.
- Agency for Toxic Substance and Disease Registry (ATSDR). 2006. 2005 CERCLA Priority List of Hazardous Substances. Available at <http://www.atsdr.cdc.gov/cercla/05list.html>.
- Alaska Department of Fish and Game and Alaska Department of Public Transportation of Public Facilities, Memorandum of Agreement for the Design, Permitting, and Construction of Culverts for Fish Passage. August 2001.
http://www.sf.adg.state.ak.us/SARR/fishpassage/pdfs/dot_adfg_fishpass080301.pdf.
- Alaska Department of Transportation and Public Facilities Annual Report on the Lynn Canal Marine Habitat Enhancement Project. 2008.
- Alaska Division of Public Health. 2003. PCB blood test results from St. Lawrence Island recommendations for consumption of traditional foods. *State of Alaska Epidemiology Bulletin*. 7(1): 1-5.
- Alaska Regulations for Pesticide Control, 18 AAC 90, Pesticide Control, Effective September 30, 2007. Sarah Palin, Governor; Larry Hartig, Commissioner.
http://www.nmfs.noaa.gov/pr/pdfs/pesticide_biop.pdf
- Alaska Sea Grant. 2009. *Marine Debris in Alaska: Coordinating Our Efforts*. E. Ammann and M. Williams editors. Pub. no.: AK-SG-09-01. University of Alaska Fairbanks. 794 University Avenue, Suite 238, Fairbanks, AK 99709. 136p

- Alexander, M.D. and Caissie, D., 2003. Variability and comparison of hyporheic water temperatures and seepage fluxes in a small Atlantic salmon stream. *Ground Water*. 41(1), 72-82.
- American Association of Port Authorities (AAPA). Environmental Management Handbook. http://www.aapa-ports.org/govrelations/env_mgmt_hb.htm
- Aono, S, S. Tanabe, Y. Fujise, H. Kato, and R. Tatsukawa. 1997. "Persistent organochlorines in minke whale (*Balaenoptera acutorostrata*) and their prey species from the Antarctic and the north Pacific." *Env. Poll.* 98:81-89.
- Aquatic Invasive Species Research and Outreach: <http://www.nsgo.seagrant.org/research/nonindigenous/>.
- Arctic Monitoring and Assessment Programme. 2002. Arctic pollution 2002: Persistent organic pollutants, heavy metals, radioactivity, human health, changing pathways. Arctic Monitoring and Assessment Programme. Oslo Norway. pp. iii - 111.
- Baird, R.C. 1996. "Toward new paradigms in coastal resource management: Linkages and institutional effectiveness." Spagnolo, RJ; E. Ambrogio, F.J. Rielly, Jr., eds. *Estuaries*. 19(2A): 320-335.
- Baker, R. J., M. D. Knittel, and J. L. Fryer. 1983. Susceptibility of chinook salmon (*Oncorhynchus tshawytscha*) and rainbow trout (*Salmon gairdneri*) to infection with *Vibrio anguillarum* following sublethal copper exposure. *Journal of Fish Diseases*. 6:267-275.
- Barlocher, F. and Murdoch J.H., 1989. Hyporheic biofilms: a potential food source for interstitial animals. *Hydrobiologia*. 184, 61-67.
- Bay, S. and D. Greenstein. 1994. Toxic effects of elevated salinity and desalination waste brine. *In* J. Cross, ed. Southern California Coastal Water Research Project, Annual Report 1992-93, pp. 149-153. SCCWRP, Westminster, CA.
- Beasley, G. and Kineale, P. 2002. Reviewing the impact of metals and PAH's on Macroinvertebrates in Urban Watercourses. *Progress in Physical Geography*, vol.25, No.2 236-270.
- Beckmen, K.B., K.W. Pitcher, G.M. Ylitalo, M.M. Krahn, and K.A. Burek. 2001. Contaminants in Free-ranging Steller Sea Lions, 1998-2001: Organochlorines in Blood, Blubber, Feces and Prey. Workshop to Assess Contaminant Impacts on Steller Sea Lions in Alaska. Anchorage, AK, September 5-6, 2001. Sponsored by Auke Bay Laboratory.
- Beckmen, K.B. 2001. Blood organochlorines, immune function and health of free-ranging northern fur seal pups (*Callorhinus ursinus*). PhD. Dissertation. University of Alaska, Fairbanks. Fairbanks, Alaska. 151 pp.
- Beckmen, K.B., K.A. Burek, K.W. Pitcher, G.M. Ylitalo, and L.K. Duffy. *In press*. Mercury concentrations in the fur of Steller sea lions and northern fur seals from Alaska. *Mar. Poll. Bull.*
- Beckmen, K.B., G.M. Ylitalo, R.G. Towell, M.M. Krahn, T.M. O'Hara, and J.E. Blake. 1999. "Factors affecting organochlorine contaminant concentrations in milk and blood of northern fur seal (*Callorhinus ursinus*) dams and pups from St. George Island, Alaska." *Sci. Total Environ.* 231:183-200.

- Beechie, T., E. Beamer, and L. Wasserman. 1994. "Estimating coho rearing habitat and smolt production losses in a large river basin, and implications for habitat restoration." *North American Journal of Fisheries Management*. 14(4):797-811.
- Benaka, L., ed. 1999. *Fish Habitat: essential fish habitat and rehabilitation*. American Fisheries Society, Symposium 22, Bethesda, Maryland, 459 pp.
- Beschta, R.L., M.R. Pyles, A.E. Skaugset, and C.G. Surfleet. 2000. "Peakflow response to forest practices in the western Cascades of Oregon, U.S.A." *Journal of Hydrology*. 233:102-120.
- Bettinger, P., J. Sessions, and K.N. Johnson. 1998. "Ensuring the compatibility of aquatic habitat and commodity production goals in eastern Oregon with a Tabu search procedure." *Forest Science*. 44(1):96-112.
- Bilby, R.E. and J.W. Ward. 1991. "Characteristics and function of large woody debris in streams draining old-growth, clear-cut, and second-growth forests in southwestern Washington." *Canadian Journal of Fisheries and Aquatic Sciences*. 48:2499-2508.
- Bjornn, T.C., and Reiser, D.W. 1991. Habitat requirements of salmonids in streams. *In* Influences of forest and rangeland management on salmonid fishes and their habitats. *Edited by* W.R. Meehan. *Am. Fish. Soc. Spec. Publ.* 19: 83-138.
- Blanton, S.L., R.M. Thom, A.B. Borde, H. Diefenderfer, and J.A. Southard. 2002. Evaluation of methods to increase light under ferry terminals. Final Research Report prepared for Washington State Department of Transportation by Battelle, Pacific Northwest Division of Battelle Memorial Institute. PNNL-13714. 26 pp.
- Blanton, S.L., R.M. Thom, J.A. Southard. 2001. Documentation of ferry terminal shading, substrate composition, and algal and eelgrass coverage. Letter Report prepared for University of Washington, School of Aquatic and Fishery Sciences, Seattle, Washington by Battelle Marine Sciences Laboratory, Sequim, Washington. 17 pp.
- Bureau of Ocean Energy Management, Regulation and Enforcement. 2010
<http://www.boemre.gov/DeepwaterHorizon.htm>
- Bond, A.B., J.S. Stephens, Jr, D. Pondella, II, M.J. Allen, and M. Helvey. 1999. "A method for estimating marine habitat values based on fish guilds, with comparisons between sites in the Southern California Bight." *Bull. Mar. Science*. 64:219-242.
- Botkin, D., K. Cummins, T. Dunne, H. Regier, M. Sobel, L. Talbot, and L. Simpson. 1995. Status and Future of salmon of Western Oregon and Northern California: Findings and Options. Report #8. The Center for the Study of the Environment, Santa Barbara, California. 300 pp.
- Boulton, A.J., Findlay, S., Marmonier, A., Stanley, E.H., Valett, H.M., 1998 The Functional Significance of the Hyporheic Zone in Streams and Rivers. *Annual Review of Ecology and Systematics*. Vol. 29: 59-81.1998
- Boxall, G.D., Guillermo R., Li H. W., Landscape Topography and the Distribution of Lahontan Cutthroat Trout (*Oncorhynchus clarki henshawi*) in a high desert stream. *Environmental Biology of Fishes*. Vol 82 Number 1, May 2008

- Brady, N.C. and R.R. Weil. 1996. The nature and properties of soils. 11th ed. Prentice-Hall, Inc. Upper Saddle River, New Jersey 07458. 740 pp.
- Breitburg, D.L., Hondorp, D.W., Davies, L.A., and Diaz, R.J. 2008. Hypoxia, Nitrogen, and Fisheries: Integrating Effects Across Local and Global Landscapes. *Annual Review of Marine Science* Vol. 1: 329-349
- Brown, A. 1997. Groundwater Quantity. In: Marcus, J.J., ed., *Mining environmental handbook, effects of mining on the environment and American environmental controls on mining*, Imperial College Press, London, pp. 244-248.
- Bryant, M. D., M. D. Lukey, J.P. McDonell, R. S. Gubernick, and R. S. Aho. 2009. Seasonal Movement of Dolly Varden and Cutthroat Trout with Respect to Stream Discharge in a Second-Order Stream in Southeast Alaska. *North American Journal of Fisheries Management*. 29:1728-1742.
- Bue, B.G., S. Sharr, and J.E. Seeb. 1998. "Evidence of damage to pink salmon populations inhabiting Prince William Sound, Alaska, two generations after the *Exxon Valdez* oil spill." *Transactions of the American Fisheries Society*. 127: 35-43.
- Burroughs, E.R. Jr., G.R. Chalfant, and M.A. Townsend. 1976. Slope stability in road construction: a guide to the construction of stable roads in western Oregon and northern California. Portland, OR: U.S. Department of the Interior, Bureau of Land Management. 102 pp.
- Carr, M.H., T.W. Anderson, and M.A. Hixon. 2002. Biodiversity, population regulation, and the stability of coral-reef fish communities. *Proceedings of the National Academy of Sciences*. 99:11241-11245.
- Cederholm, C.J., D.B. Houston, D.L. Cole, and W.J. Scarlett. 1989. "Fate of coho salmon (*Oncorhynchus kisutch*) carcasses in spawning streams." *Canadian Journal of Fisheries and Aquatic Sciences*. 46, 1347-1355.
- Cederholm, C.J. and N.P. Peterson. 1985. "The retention of coho salmon (*Oncorhynchus kisutch*) carcasses by organic debris in small streams." *Canadian Journal of Fisheries and Aquatic Sciences*. 42:1222-1225.
- Chabreck, R.H. 1972. Vegetation, water and soil characteristics of the Louisiana coastal region. Louisiana State University Agriculture Experiment Station. Baton Rouge, LA.
- Chambers, J.R. 1992. Coastal degradation and fish population losses. pp 45-51. In Stroud, R.H. ed. *Stemming the tide of coastal fish habitat loss. Proceedings of a symposium on conservation of coastal fish habitat*. National Coalition for Marine Conservation, Inc., Savannah GA.
- Clayton, J.L. 1983. Evaluating slope stability prior to road construction. Res. Pap. INT-307. Ogden, UT. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 6 pp.
- Coffin, B.A. and R.D. Harr. 1992. Effects of forest cover on volume of water delivery to soil during rain-on-snow. Washington Department of Natural Resources Timber/Fish/Wildlife Program. TFW-SH1-92-001.

- Collins, B.D., D.R. Montgomery, and A.J. Sheikh. 2003. Reconstructing the historic riverine landscape of the Puget Lowland. pp 79-128. *In* Bolton, S, D.R. Montgomery, and D. Booth, eds. Restoration of Puget Sound Rivers. University of Washington Press. Seattle, WA.
- Collins, B.D., D.R. Montgomery, and A.D. Haas. 2002. "Historical changes in the distribution and functions of large wood in Puget Lowland rivers." *Canadian Journal of Fisheries and Aquatic Sciences*. 59:66-76.
- Collins, M.A. 1995. Dredging-induced near-field re-suspended sediment concentration and source strengths. Miscellaneous Paper D-95-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. NTIS No. AD A299 151.
- Craig, N.J., R.E. Turner, and J.W. Day, Jr. 1979. "Land loss in coastal Louisiana." *Environmental Management*. 3:134-144
- Cross, J.N. and L.G. Allen. 1993. Fishes. *In* Dailey, M.D. D.J. Reish, and J.W. Anderson, eds. Ecology of the Southern California Bight, Univ. Calif. Press, Berkeley, CA. Pp.459-540.
- Dahm, C. N., and H. M. Valett, Hyporheic zones, in *Methods in Stream Ecology*, edited by F. R. Hauer and G. A. Lamberti, pp. 107–119, Academic, San Diego, Calif., 1996.
- de Brito, A.P.X., D. Ueno, S. Takahasi, and S. Tanabe. 2002. "Contamination by organochlorine compounds in walleye pollock (*Theragra chalcogramma*) from the Bering Sea, Gulf of Alaska, and the Japan Sea." *Marine Pollution Bulletin*. 44:164-177.
- DeMaster, D., S. Atkinson, and R. Dearborn. 2001. Is it food? II Workshop. Alaska Sea Life Center, Seward, Alaska. May 30-31. Sponsored by National Marine Fisheries Service and Alaska Sea Grant Office.
- Department of Fisheries and Oceans Canada. 2007. Characterization of Existing Conditions in Lamèque Bay, New Brunswick.
- Department of the Interior, Bureau of Land Management, in cooperation with the Minerals Management Service. 1998. Northeast National Petroleum Reserve-Alaska, Final Integrated Activity Plan/Environmental Impact Statement. Table II.F.1. "Federal, State, and North Slope Borough Permits and/or Approvals for Oil and Gas Exploration and Development/Production Activities."
- Dooley, K.M., F.C. Knopf, and R. P. Gambrell. 1999. Final Report, pH Neutral Concrete for attached microalgae and enhanced carbon dioxide fixation – phase I. Submitted to Department of Energy, Award Number DE-AC26-98FT40411—01. 38 pp.
- Drinkwater, K.F. and K.T. Frank. 1994. "Effects of river regulation and diversion on marine fish and invertebrates." *Aquatic Conservation: Mar. Freshwat. Ecosyst.* 4(2):135-151.
- Dsa, J.V., Johnson, K.S., Lopez, D., Kanuckel, C. and Tumlinson, J. 2008. Residual toxicity of acid mine drainage-contaminated sediment to stream macroinvertebrates: Relative contribution of acidity vs. metals. *Water Air and Soil Pollution*. Vol 194, Number 1-4, 185-197.
- Ebeling, A.W., R.J. Larson, and W.S. Alevizon. 1980. Annual variability of reef-fish assemblages in kelp forest off Santa Barbara, California. *U.S. Natl. Mar. Fish. Serv. Fish. Bull.* 78:361-377.

- Eisler, R. 1987. Polycyclic aromatic hydrocarbon hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish and Wildlife Service Biological Report 85(1.11).
- Ellis, D.V. 1982. *Marine Tailings Disposal*. Ann Arbor Science Publishers. Ann Arbor, Michigan. 368 pp.
- Engås, Arill, Svein Løkkeborg, Egil Ona, and Aud Vold Soldal. 1996. "Effects of seismic shooting on local abundance and catch rates of cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*)." *Can. J. Fish Aquat. Sci.* 53: 2238-2249.
- Ewald, G., P. Larsson, H. Linge, L. Okla, and N. Szarzi. 1998. "Biotransport of organic pollutants to an inland Alaska lake by migrating sockeye salmon (*Oncorhynchus nerka*)." *Arctic*. 51:40-47.
- Ewing, R.D. 1999. Diminishing returns: salmon decline and pesticides. Oregon Pesticide Education Network, Eugene, Oregon. 52 pp.
- Faris, T.L. and K.D. Vaughan. 1985. Log transfer and storage facilities in Southeast Alaska: a review. USDA Forest Service General Technical Report PNW-174. Portland, OR.
- Farnworth, E.G., M.C. Nichols, C.N. Vann, L.G. Wolfson, R.W. Bosserman, P.R. Hendrix, F.B. Golley, and J.L. Cooley. 1979. Impacts of sediment and nutrients on biota in surface waters of the United States. U.S. Environmental Protection Agency. Athens, GA (USA), Oct 1979. Ecol. Res. Series. 331 pp.
- Fawcett, J.A. and H.S. Marcus. 1991. Are port growth and coastal management compatible? *Coastal Management*. Vol. 19. pp. 275-295.
- Feder, H.M., C.H. Turner, and C. Limbaugh. 1974. Observations on fishes associated with kelp beds in southern California. California Department of Fish and Game, Fish Bull. 160. 144 pp.
- Findlay, S. and Sobczak, W.V., 2000. Microbial communities in hyporheic sediments. In: *Streams and Ground Waters* (Jones, J.B. and Mulholland, P.J., Eds), pp. 287-306. Academic Press, London.
- Flanders, L.S. and J. Cariello. 2000. Tongass Road Condition Survey Report. Alaska Department of Fish and Game, Southeast Regional Office of the Habitat and Restoration Division, Alaska Department of Fish and Game, 802 3rd Street, Douglas, AK., 99824. Technical Report 00-7. 48 pp.
- Franco, J., S. Schad, and C.W. Cady. 1994. "California's experience with a voluntary approach to reducing nitrate contamination of groundwater: The Fertilizer Research and Education Program." *J. Soil and Water Conser.* 49: S76.
- Gayaldo, P., S. Wyllie-Echeverria, and K. Ewing. 2001. Transplantation and alteration of submarine environment for restoration of *Zostera marina* (eelgrass); a case study at Curtis Wharf (Port of Anacortes), Washington. Presented at Puget Sound Research 2001, February 12-14, 2001, Bellevue, WA.
- Gayraud, S. and Philippe, M., 2003. Influence of bed-sediment features on the interstitial habitat available for macroinvertebrates in 15 French streams. *International Review of Hydrobiology*. 88, 77-93.

- Geist, D.R., T.P. Hanrahan, E.V. Arntzen, G.A. McMichael, C.J. Murray, and Y. Chien. Pacific Northwest National Laboratory, Physicochemical characteristics of the hyporheic zone affect redd site selection of chum and fall chinook salmon, Columbia River, Report to Bonneville Power Administration. 2001.
- Geist, D.R., Jones, J., Murray, C.J., and Dauble, D.D.. Suitability criteria analyzed at the spatial scale of redd clusters improved estimates of fall chinook salmon (*Oncorhynchus tshawytscha*) spawning habitat use in the Hanford Reach, Columbia River. *Can. J. Fish. Aquat. Sci.* 57: 1636–1646. 2000
- Geist, D.R., and Dauble, D.D. Redd site selection and spawning habitat use by fall chinook salmon: the importance of geomorphic features in large rivers. *Environ. Manage.* 22: 655–669. 1998.
- Gende, G.M., Edwards, R.T., Willson, M.F., Wipfli M.S.. Pacific Salmon in Aquatic and Terrestrial Ecosystems. *BioScience*. Vol 52, No. 10, p. 917-928 Oct 2002
- Gibbons, D.R., W.R. Meehan, K.V. Koski, and T.R. Merrell, Jr. 1987. History of fisheries and forestry interactions in southeastern Alaska. In Salo, E.O. and T.W. Cundy, eds. *Streamside Management: Forestry and Fishery Interactions*. Contribution No. 57, University of Washington, College of Forest Resources, Seattle. pp. 297-329.
- Greenberg, C.H., S.H. Crownover, and D.R. Gordon. 1997. "Roadside soils: a corridor for invasion of xeric scrub by nonindigenous plants." *Natural Areas Journal*. 17(2):99-109.
- Gregory, R.S. 1993. "Effect of turbidity on the predator avoidance behavior of juvenile chinook salmon (*Oncorhynchus tshawytscha*)." *Canadian J. Fish. Aquatic Sciences*. 50:241-246.
- Gucinski, H., M.J. Furniss, R.R. Ziemer, and M.H. Brookes. 2000. *Forest Roads: A Synthesis of Scientific Information*, USDA Forest Service. June 2000. 117 pp.
- Hall, J.D., C.J. Cederholm, M.L. Murphy and K.V. Koski. 2004. Fish-forestry interactions in Oregon, Washington, and Alaska, USA. In T.G. Northcote and G.F. Hartman, editors, *Fishes and Forestry Worldwide Watershed Interactions and Management*, Blackwell Publishing, pp. 365-412.
- Hammond, C.J., S.M. Miller, and R.W. Prellwitz. 1988. Estimating the probability of landslide failure using Monte Carlo simulation. In *Proceedings of the 24th symposium on engineering geology and soils engineering*. February 29, 1988. Coeur d'Alene, ID. Utah State University, Department of Civil and Environmental Engineering, Logan, UT. pp. 319-331.
- Hanrahan, L., C. Falk, H.A. Anderson, L. Draheim, M. S. Kanarek, J. Olson, and The Great Lakes Consortium. 1999. "Serum PCB and DDE levels of frequent Great Lakes sport fish consumers - a first look." *Env. Res. Section A*. 80:S26-S37.
- Hancock, P.. Human Impacts on the Stream-Groundwater Exchange Zone. *Environmental Management*. Vol. 29, No. 6 p. 763-781, 2002
- Harvey, B.C. and T.E. Lisle. 1998. "Effects of suction dredging on stream: A review and an evaluation strategy." *Fisheries*. 23:8-17.

- Hastings, K., P. Hesp, and G. Kendrick. 1995. "Seagrass loss associated with boat moorings at Rottnest Island, Western Australia." *Ocean and Coastal Management*. 26:225-246. In Shafer, D.J. 2002. Recommendations to minimize potential impacts to seagrasses from single-family residential dock structures in the Pacific Northwest. U.S. Army Corps of Engineers, Seattle, WA. 28 pp.
- Heady, H.F. and R.D. Child. 1994. Rangeland ecology and management. Westview Press, Inc., Boulder, Colorado.
- Hecht, S.A., D.H. Baldwin, C.A. Mebane, T. Hawkes, S.J. Gross, and N.L. Scholz. 2007. An overview of sensory effects on juvenile salmonids exposed to dissolved copper: Applying a benchmark concentration approach to evaluate sublethal neurobehavioral toxicity. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-83, 39 p.
- Heiser, D.W., and E.L. Finn, Jr., 1970. Observations of juvenile chum and pink salmon in marina and bulkhead areas. Supplemental progress report, Puget Sound studies, Washington Department of Fisheries, Management and Research Division, Olympia, Washington.
- Helfman, G.S. 1981. The advantage to fishes of hovering in shade. *Copeia*. 1981(2):392-400.
- Hilderbrand, R.H., A.D. Lemly, C.A. Dolloff, and K.L. Harpster. 1998. "Design considerations for large woody debris placement in stream enhancement projects." *North American Journal of Fisheries Management*. 18 (1):161B167.
- Hoffman, D.J., Rattner, B.S., Burton, G.A., and Cairns, J. (Editors). 2003. Handbook of Ecotoxicology. CRC Press, Boca Raton, FL 1290 pp.
- Humphrey, D.N., Swett, M., 2006. Literature Review of the Water Quality Effects of Tire Derived Aggregate and Rubber Modified Asphalt Pavement. Prepared for: U.S. Environmental Protection Agency.
- Illinois Department of Public Health (IDPH). 2005. Environmental health fact sheet: polycyclic aromatic hydrocarbons. Available at <http://www.idph.state.il.us/envhealth/factsheets/polycyclicaromatichydrocarbons.htm>
- Ikonomou, M.G., S. Rayne, and R.F. Addison. 2002. "Exponential increases of the brominated flame retardants, polybrominated diphenyl ethers, in the Canadian Arctic from 1981 to 2000." *Environ. Sci. Technol.* 36:1886-1892.
- Independent Multidisciplinary Science Team. 2002. Recovery of Wild Salmonids in Western Oregon Lowlands. Technical Report 2002-1 to the Oregon Plan for Salmon and Watersheds, Governor's Natural Resources Office, Salem, OR.
- Iwasaki, Y., Kagaya, T., Miyamoto, K., and Matsuda, H. 2009. Effects of heavy metals on riverine benthic macro-invertebrate assemblages. *Environmental Toxicology and Chemistry*. Vol. 28, No. 2, p354-363.
- Johnson, K.L. 1992. Management for water quality on rangelands through best management practices: the Idaho approach. pp. 415-441. In Naiman, R.J., ed. Watershed management: Balancing sustainability and environmental change. Springer-Verlag, New York.

- Johnson, S.W., M.L. Murphy, D.J. Csepp, P. M. Harris, and J. F. Thedinga. 2003. A survey of fish assemblages in eelgrass and kelp habitats of southeastern Alaska. NOAA Technical Memorandum NMFS-AFSC-139, 39 pp.
- Johnson, S.W., J. Heifetz, and K.V. Koski. 1986. "Effects of logging on the abundance and seasonal distribution of juvenile steelhead in some southeastern Alaska USA streams." North American Journal of Fisheries Management. 6, 532-537.
- Jordan, T.E. and D.E. Weller. 1996. "Human contributions to terrestrial nitrogen flux: Assessing the sources and fates of anthropogenic fixed nitrogen." BioScience. 46:655.
- Kagan, R.A. 1991. The dredging dilemma: economic development and environmental protection in Oakland Harbor. Coastal Management. Vol. 19, pp. 313-341.
- Kauffman, J.B. and W.C. Krueger. 1984. "Livestock impacts on riparian ecosystems and streamside management implications—a review." Journal of Range Management. 37:430-438.
- Kawano, M., S. Matsushita, T. Inoue, H. Tanaka, and R. Tatsukawa. 1986. "Biological accumulation of chlordane compounds in marine organisms from the northern North Pacific and Bering Sea." Mar. Poll. Bull. 17:512-516.
- Kimmel, W. G. 1983. The impact of acid mine drainage on the stream ecosystem. Pennsylvania Coal: Resources, Technology, and Utilization. Pennsylvania Academic Science Publications: 424-437.
- King County Department of Natural Resources and Parametrix, Inc. 2002. Bioaccumulation and King County secondary treated effluent: data review, method evaluation, and potential on Puget Sound aquatic life. Unpublished paper in support of the draft Habitat Conservation Plan-in-progress. 38 pp + appendix.
- Klimley, A.P. and S.C. Beavers. 1998. "Playback of ATOC-type signal to bony fishes to evaluate phonotaxis." Journal of Acoustic Society of America. 104:2506-2510.
- Klinck, J., M. Dunbar, S. Brown, J. Nichols, A. Winter, C. Hughes and R. C. Playle. 2005. Influence of water chemistry and natural organic matter on active and passive uptake of inorganic mercury by gills of rainbow trout (*Oncorhynchus mykiss*). Aquatic Toxicology. 72:161-175.
- Kline, E.R. 1994. Potential biological consequences of submarine mine-tailings disposal: a literature synthesis. U.S. Dept. of the Interior, Bureau of Mines, Juneau, AK, OFR 36-94.
- Kondolf, G.M., Larsen, E.W., and Williams, J.G. 2000. Measuring and modeling the hydraulic environment for assessing instream flows. North American Journal of Fisheries Management. 20:1016-1028.
- Koski, K V. 1993. Riparian zone functions and interactions with sediment. In Proceedings of a Technical Workshop on Sediments, February 3-7, 1992, Corvallis, OR, Terrene Institute, Sept. 1993, pp 61-69.
- Koski, K.V., J. Heifetz, S. Johnson, M. Murphy, and J. Thedinga. 1984. Evaluation of buffer strips for protection of salmonid rearing habitat and implications for enhancement. In Hassler, T.J., ed.

Proceedings: Pacific Northwest Stream Habitat Management Workshop, American Fisheries Society, Humboldt State University, Arcata, CA. pp.138-155.

- Koski, K.V. 1975. The survival and fitness of two stocks of chum salmon (*Oncorhynchus keta*) from egg deposition to emergence in a controlled-stream environment at Big Beef Creek. Ph.D. Dissertation, University of Washington, Seattle, WA.
- Kriech A.J., Kurek J.T., Osborn L.V., Wissel H.L., and Sweeney B.J. 2002. Determination of Polycyclic Aromatic Compounds in Asphalt and in Corresponding Leachate Water [Polycyclic Aromatic Compounds](#), Volume 22, Number 3, 1 July 2002 , pp. 517-535(19).
- Kuhn, E.A., Papagiannakis, A.T., and Loge, F.J. 2005. Preliminary Analysis of the Impact of Cold Mix Asphalt Concreted on Air and Water Quality. *Bulletin of Environmental Contamination and Toxicology*. 74:501-508.
- Kuipers, J.R., Maest, A.S., MacHardy, K.A., and Lawson, G. 2006. Comparison of Predicted and Actual Water Quality at Hardrock Mines: The reliability of predictions in Environmental Impact Statements.
- Larimore, R.W. and P.W. Smith. 1963. The fishes of Champaign County, Illinois, as affected by 60 years of stream changes. *Illinois Natural History Survey Bulletin*. 28:299-382.
- Larsen, M.C. and J.E. Parks. 1997. How wide is a road? The association of roads and mass-wasting in a forested montane environment. *Earth Surface Processes and Landforms*. 22:835-848.
- LaSalle, M.W., D.G. Clarke, J. Homziak, J.D. Lunz, and T.J. Fredette. 1991. A framework for assessing the need for seasonal restrictions on dredging and disposal operations. Technical Report D-91-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. NTIS No. AD A240 567.
- Lee, G.F. and S. Taylor. 2000. Review of the water quality characteristics of Upper Newport Bay, Orange County CA and its Tributaries. California Coastal Conservancy, Oakland, CA 94612.
- Lee, D.C., J.R. Sedell, B.E. Rieman, R.F. Thurow, J.E. Williams, D. Burns, J. Clayton, L. Decker, R. Gresswell, R. House, P. Howell, K.N. Lee, K. MacDonald, J. McIntyre, S. McGivney, T. Noel, J.E. O'Connor, C.S. Overtone, D. Perkinson, K. Tu, and P. Van Eimeren. 1997. Broad-scale assessment of aquatic species and habitats. Vol III, Chapter 4. In Quigley, T.M. and S. J. Arbelbide, eds. An assessment of ecosystem components in the interior Columbia basin and portions of the Klamath and Great Basins. Gen. Tech. Rep. PNW-405. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.
- Leman, V.N. 1993. Spawning sites of chum salmon, *Oncorhynchus keta*: microhydrological regime and viability of progeny in redds (Kamchatka River Basin). *J. Ichthyol.* 33: 104–117.
- Leonard, J.N. 1994. Ocean outfalls for wastewater discharges – meeting CWA 403C requirements. Marine Technology Soc. '94, Conference Proceedings. Challenges and Opportunities in the Marine Environment, Washington, DC, 7-9 Sept. pp. 115-120.
- Lonsdale, W.N. and A.M. Lane. 1994. "Tourist vehicles as vectors of weed seeds in Dadoed National Park, northern Australia." *Biological Conservation*. 69(3):277-283.

- Lorenz, J.M., Eiler, J.H. 1989. Spawning habitat and redd characteristics of sockeye salmon in the glacial Taku River, British Columbia and Alaska. *Transactions of the American Fisheries Society* 118:495-502.
- Lorenz, Mitch. Review of OSI Project; Unalaska Bay 12 (DD-1982-0598), Alaska Fisheries Science Center. Enclosure to NMFS Alaska Region comments on AA-820598, Unalaska Bay 12, October 4, 2004.
- Madej, M.A. 2001. "Erosion and sediment delivery following removal of forest roads." *Earth Surface Processes and Landforms*. 26:175-190.
- Maest, A.S., Kuipers, J.R., Travers, C.L., and Atkins, D.A. 2005. Predicting water quality at hardrock mines: Methods and Models, Uncertainties, and State-of-the-Art.
- Malard, F., Galassi, D., Lafont, M., Dolédec, S. and Ward, J.V., 2003. Longitudinal patterns of invertebrates in the hyporheic zone of a glacial river. *Freshwater Biology*, 48, 1709-1725.
- Malcolm, I. A., C.Soulsby, , A. F Youngson,, D.M Hannah,, I. S McLaren, and A Thorne,. Hydrological Influences on Hyporheic Water Quality: Implications for Salmon Egg Survival Hydrological Process's, vol 18. p1543–1560, 2004
- Malcolm, I. A., C. Soulsby, , A. F Youngson,, D.M Hannah,.. Spatial and Temporal Variability of Groundwater – Surface Water Interactions in an Upland Salmon Spawning Stream: Implications for Egg Survival. *Hydrology: Science & Practice for the 21st century*. Vol II, 2004 p. 130-138, 2004
- Malcolm, I. A. , C. Soulsby, , A. F Youngson, and D.M Hannah. 2005. Catchment Scale Controls on Grounwater-Surfacewater Interactions in the Hyporheic Zone: Implications for Salmon Embryo Survival. *River Research and Applications*. Vol 21, 977-989, 2005
- Malmström, M.E., Berglund, S., and Jarsjo, J. 2008. Combined effects of Spatial Variable Flow and Minerology on the Attenuation of Acid Mine Drainage in Groundwater. *Applied Geo-Chemistry*. Vol 23 Issue 6, p 1419-1436.
- Marcus, M.D., M.K. Young, L.E. Noel, and B.A. Mullan. 1990. Salmonid-habitat relationships in the western United States: a review and indexed bibliography. General Technical Report RM-GTR-188. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.
- Marshall, M.C. and Hall, R.O. Jr. 2004. Hyporheic invertebrates affect N cycling and respiration in stream sediment microcosms. *Journal of the North American Benthological Society*. 23(3), 416-428.
- Matkin, C.O., E.L. Saulitis, G.M. Ellis, P. Olesiuk, and S.D. Rice. 2008. Ongoing population-level impacts on killer whales *Orcinus orca* following the 'Exxon Valdez' oil spill in Prince William Sound, Alaska. *Marine Ecology Progress Series* 356:269-281.
- May, C., R. Horner, J. Karr, B. Mar, and E. Welch. 1997. Effects of urbanization on small streams in the Puget Sound lowland ecoregion. *Watershed Protection Techniques* 2(4):483-494.

- McFadden, J.T. 1969. Dynamics and regulation of salmonid populations in streams. In: Northcote, T.E., ed. Symposium on salmonid populations in streams. Vancouver: University of British Columbia, Institute of Fisheries. pp. 313-329.
- McLusky, D.S., D.M. Bryant, and M. Elliot. 1992. "The impact of land-claim on macrobenthos, fish and shorebirds on the Forth Estuary, eastern Scotland." *Aquat. Conserv.: Mar. Freshwat. Ecosyst.* 2 (3):211-222.
- Mermillod-Blondin, F., Gaudet, J.-P., Gérino, M., Desrosiers, G and Creuzé des Châtelliers, M., 2003. Influence of macroinvertebrates on physico-chemical and microbial processes in hyporheic sediments. *Hydrological Processes*. 17, 779-794.
- Miller, D.J. and J.J. Geibel. 1973. Summary of blue rockfish and lingcod life histories; A reef ecology study; and giant kelp, *Macrocystis pyrifera*, experiments in Monterey Bay, California. California Dept. of Fish and Game, Fish Bull. 158.
- Minerals Management Service (MMS). 2003. OCS EIS/EA MMS 2003-055. Alaska Outer Continental Shelf Cook Inlet Planning Area, Oil and Gas Lease Sale 191 and 199, Final Environmental Impact Statement. Volume II (Section VII and Appendices). Appendix E: "Applicable Federal laws, Regulatory Responsibilities, and Executive Orders."
- Montgomery, D.R. 1994. "Road surface drainage, channel initiation, and slope instability." *Water Resources Research*. 30:1925-1932.
- Muir, D., B. Braune, B. DeMarch, R. Norstrom, R. Wagemann, L. Lockhart, B. Hargrave, D. Bright, R. Addison, J. Payne, and K. Reimer. 1999. "Spatial and temporal trends and effects of contaminants in the Canadian Arctic marine ecosystem: a review." *Sci Total Environ.* 230:83-144.
- Murphy, M.L. 1995. Forestry impacts on freshwater habitat of anadromous salmonids in the Pacific Northwest and Alaska—requirements for protection and restoration. U.S. Dep. Commer., NOAA Coastal Ocean Program, Decision Analysis Series No. 7, 156 + xxii p.
- Murphy, M.L. and K V. Koski. 1991. Reform of logging practices in Alaska. Pages 220-21 in B. White and I Guthrie, eds. *Pro. 15th Northe. Pac. Pink and Chum Salmon Workshop*, Parksville, BC. Can. Dep. Fish. Oceans, Vancouver.
- Murphy, M.L. and J.D. Hall. 1981. "Varied effects of clear-cut logging on predators and their habitat in small streams of the Cascade Mountains, Oregon." *Canadian Journal of Fisheries and Aquatic Sciences*. 38:137-145.
- NMFS. 2006. Letter from National Marine Fisheries Service, Alaska Region to U.S. Army Corps of Engineers, Alaska District, dated March 22, 2006. In response to Public Notice POA-2003-502-N, Ship Creek for the Port of Anchorage Expansion project.
- NMFS. 2001. Guidelines for salmonid passage at stream crossings. Southwest Region, Santa Rosa, CA. 14 pp. (<http://swr.nmfs.noaa.gov/hcd/NMFSSCG.PDF>).
- National Oceanic and Atmospheric Administration (NOAA) Marine Debris Program. Project Title: Temporal and Spatial Distribution of Marine Debris on Select Beaches in the Gulf of Alaska.

Reporting Period: December 1 – February 28, 2009. Date: March 15, 2009. P.I. : Jacek Maselko.

- NOAA. 1991. National Status and Trends Program for marine environmental quality. Progress report on secondary summary of data on chemical contaminants in sediments from the National Status and Trends Program. Tech. Mem. NOS OMA 59. NOAA, NOS, Silver Spring, MD. 29 pp.
- National Research Council. 2003. Oil in the sea III: inputs, fates and effects. Washington (DC): National Academy Press.
- North Pacific Fisheries Management Council. 1999. Environmental Assessment for Amendment 55 to the Fishery Management Plan for the Groundfish Fishery of the Bering Sea and Aleutian Islands Area; Amendment 55 to the Fishery Management Plan for Groundfish of the Gulf of Alaska; Amendment 8 to the Fishery Management Plan for the King and Tanner Crab Fisheries in the Bering Sea/Aleutian Islands; Amendment 5 to the Fishery Management Plan for Scallop Fisheries off Alaska; Amendment 5 to the Fishery Management Plan for the Salmon Fisheries in the EEZ off the Coast of Alaska, Essential Fish Habitat. 605 West 4th Ave, Suite 306, Anchorage, AK 99501-2252. 20 January.
- Nelson S.M., and Roline R.A. 1999. Relationships between metals and hyporheic invertebrate community structure in a river recovering from metals contamination. *Hydrobiologia*. 397:211–2
- Nelson, R.L., M. McHenry, and W.S. Platts. 1991. Mining. Influences of forest and rangeland management in salmonid fishes and their habitats. pp. 425-457. *In*: Meehan, W. ed. Influences of forest and range management on salmonid fishes and their habitats. AFS Special Publication 19. Bethesda, MD.
- North Pacific Fisheries Management Council (Council). 1999. Environmental Assessment for Amendment 55 to the Fishery Management Plan for the Groundfish Fishery of the Bering Sea and Aleutian Islands Area; Amendment 55 to the Fishery Management Plan for Groundfish of the Gulf of Alaska; Amendment 8 to the Fishery Management Plan for the King and Tanner Crab Fisheries in the Bering Sea/Aleutian Islands; Amendment 5 to the Fishery Management Plan for Scallop Fisheries off Alaska; Amendment 5 to the Fishery Management Plan for the Salmon Fisheries in the EEZ off the Coast of Alaska, Essential Fish Habitat. 605 West 4th Ave, Suite 306, Anchorage, AK 99501-2252. 20 January.
- O'Hara, T. 2001. *Evaluating Environmental Contaminant Trends in Arctic Alaska Marine Mammals: Biological and Experimental Design Considerations*. Workshop to Assess Contaminant Impacts on Steller Sea Lions in Alaska. Anchorage, AK, September 5-6, 2001. Sponsored by Auke Bay Laboratory.
- O'Keefe, T.C., Edwards, R.T. Evidence for Hyporheic Transfer and removal of Marine- Derived Nutrients in a Sockeye Stream in Southwest Alaska. American Fisheries Society Symposium 33:99–107, 2002
- Oil and Gas Technologies for the Arctic and Deepwater. 1985. U.S. Congress, Office of Technology Assessment, OTA-O-270, May 1985. Library of Congress Catalog Card Number 85-600528. U.S. Government Printing Office, Washington, DC 20402.

- Olsen, D.A., Young, R.G. 2009. Significance of River Aquifer Interactions for reach Scale Thermal Patterns and Trout Growth potential in the Motueka River, New Zealand. *Hydrogeology Journal*. Vol 17, p 175-183.
- Olsen, D.A., C.R. Townsend. 2003. Hyporheic community composition in a gravel-bed stream: influence of vertical hydrological exchange, sediment structure and physicochemistry. *Freshwater Biology*. Vol 48, pp 1363–1378.
- O'Reilly JE. 1994. Nutrient loading and eutrophication. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 25-30.
- Paul, J.F., K.J. Scott, A.F. Holland, S.B. Weisberg, J.K. Summers, and A. Robertson. 1992. "The estuarine component of the U.S. EPA's Environmental Monitoring and Assessment Program." Papers from the First International Ocean Pollution Symposium, 28th April 1991-2nd May 1991. University of Puerto Rico, Puerto Rico, (Part Two). *Chem. Ecol.* 7 (1-4): 93-116.
- Peddicord, R.K. and J. B. Herbich, ed. 1979. Impacts of open-water dredged material discharge. Proceedings of the eleventh dredging seminar. Published by TAMU, College Station, TX (USA). Oct 1979. pp. 24-40. Rep. Texas A&M University Sea Grant Program.
- Pezeshki, S.R., R.D. Delaune, and W.H. Patrick, Jr. 1987. "Response of the freshwater marsh species, *Panicum hemitomon* Schult., to increased salinity." *Freshwater Biology*. 17:195-200.
- Pickett, G.D., D.R. Eaton, R.M.H. Seaby, and G.P. Arnold. 1994. Results of bass tagging in Poole Bay, England during 1992. Laboratory Leaflet No. 74. British Ministry of Agriculture, Fisheries and Food.
- Pinay, G., O'Keefe, T.C., Edwards, R.T., Naiman, R.J., Nitrate Removal in the Hyporheic Zone of a Salmon River in Alaska. *River Research and Applications*. Vol 25, Issue 4, Pg 367 – 375, 12 June 2008
- Platts, W.S. 1991. Livestock grazing. pp. 389-424. In Meehan, W.R, ed. Influences of forest and rangeland management on salmonid fishes and their habitats. Special Publication 19. American Fisheries Society, Bethesda, MD.
- Raco-Rands, V.E. 1996. Characteristics of effluents from power generating stations in 1994. In Allen, M.J, ed. Southern California Coastal Water Research Project, Annual Report 1994-95. SCCWRP, Westminster, CA. pp. 29-36.
- Railsback, S. 2000. Instream Flow Assessment Methods: Guidance for evaluating instream flow needs in hydropower licensing, EPRI report 1000554, Palo Alto, CA: 2000.
- Reinijders, P.J.H. 1986. "Reproductive failure in common seals feeding on fish from polluted coastal waters." *Nature*. 324:456-457
- Reiser and Bjornn. 1979. Influence of forest and rangeland management on anadromous fish habitat in the Western United States and Canada. Meehan, W.R. ed. USDA Forest Service General

Technical Report PNW-96. U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. Portland, OR.

- RestoreTheGulf.gov. November 24, 2010. NOAA Closes 4,200 Square Miles of Gulf Waters to Royal Red Shrimping. <http://www.restorethegulf.gov/release/2010/11/24/noaa-closes-4200-square-miles-gulf-waters-royal-red-shrimping> Contact: Karrie Carnes 305-304-0179 (cell).
- Rice, S.D., D.A. Moles, J.F. Karinen, S. Korn, M.G. Carls, C.C. Brodersen, J.A. Gharrett, and M.M. Babcock. 1984. Effects of petroleum hydrocarbons on Alaskan aquatic organisms: A comprehensive review of all oil-effects research on Alaskan fish and invertebrates conducted by the Auke Bay Laboratory, 1970 - 81. U.S. Department of Commerce, NOAA Technical Memorandum NMFS F/NWC-67. 128 pp.
- Rich Passage Wave Action Study Team. 2001. Rich Passage Wave Action Study Final Report, WAC 197-11-970. Prepared for Washington State Ferries. August 27.
- Riedman, M. 1990. *The Pinnipeds*. University of California Press. Berkeley, California. 439 pp.
- Rozengurt, M.A., I. Haydock, and B.P. Anderson. 1994. Running on entropy: The effect of water diversion on the coastal zone. 37th Conference of the International Association for Great Lakes Research and Estuarine Research Federation: Program and Abstracts., Buffalo, NY (USA). 166 pp.
- Ruiz, G.M., Fofonoff, P.W., Carlton, J.T., Wonham, M.J., Hines, A.H., 2000. Invasion of coastal marine communities in North America: apparent patterns, processes, and biases. *Ann. Rev. Ecol. Syst.* 31, 481-531.
- Ruus, A., K.I. Ugland, and J.U. Skaare. 2002. "Influence of trophic position on organochlorine concentrations and compositional patterns in a marine food web." *Env. Tox. Chem.* 21(11):2356- 2364.
- Sadler, R., Delamont, C., White, P., Connell, D., 1999. Contaminants in soil as a result of leaching from Asphalt. *Toxicological and Environmental Chemistry*. Vol. 68, no. 1-2, pp. 71-81.
- Schafer, W.M. and Lewis, M., 1998. Evaluating the environmental risk of water quality Impacts at mining sites. Society for Mining, Metallurgy, and Exploration, Inc. Preprint 98-182, 9 pp.
- Schaumburg, F.D. 1970. The influence of log handling on water quality, annual report 1969-1970, Department of Civil Engineering, Oregon State University. Corvallis, Oregon.
- Schueler, T. 1994. The importance of imperiousness. *Watershed Protection Techniques* 2(4):100-111.
- Schult, D.T. and D.J. McGreer 2001. Effects of forest harvesting and roads on streamflow processes and application to watersheds of Southeast Alaska. Summary of Monitoring Studies of the Effectiveness of Practices under the Alaska Forest and Resources Practices Act 1990-2002. Compiled by Alison Arians, DNR Division of Forestry, April 2003. A report funded by the Alaska Coastal Management Program, Office of the Governor, pursuant to NOAA Award No. NA17OZ1113.
- Science Applications International Corporation. 2001. Information Collection Request for National Pollutant Discharge Elimination System (NPDES) and Sewage Sludge Monitoring Reports.

Prepared by the Science Applications International Corporation, 11251 Roger Bacon Drive, Reston, VA 20190, for Tetra Tech, Inc., Fairfax, VA, for the U.S. Environmental Protection Agency, Office of Wastewater Management, Washington, D.C. EPA ICR# 0229.15. p. 11.

- Scott G.I., M.H. Fulton, D.W. Moore, E.F. Wirth, G.T. Chandler, P.B. Key, J.W. Daugomah, E.D. Strozier, J. Devane, J.R. Clark, M.A. Lewis, D.B. Finley, W. Ellenberg, and K.J. Karnaky. 1999. "Assessment of risk reduction strategies for the management of agricultural nonpoint source pesticide runoff in estuarine ecosystems." *Toxicology and Industrial Health*. 15:200-213.
- Sea Grant. 2002. National Coastal Ecosystem Restoration Manual. Sea Grant Communications, Oregon State University, Corvallis, OR. Pacific Northwest:
<http://seagrant.oregonstate.edu/hot/exotics.html>.
- Sedell, J.R., F.N. Leone, and W.S. Duvall. 1991. Water transportation and storage of logs. In Meehan, W.R., ed. Influences of Forest and Rangeland Management on Salmonid Fishes and their Habitats. American Fisheries Society Special Publication. 19:325-368.
- Shafer, D.J. 2002. Recommendations to minimize potential impacts to seagrasses from single-family residential dock structures in the Pacific Northwest. U.S. Army Corps of Engineers, Seattle, WA. 28 pp.
- Sheavly, S.B. 2007. "National Marine Debris Monitoring Program: Final Program Report, Data Analysis and Summary." Prepared for U.S. Environmental Protection Agency by Ocean Conservancy, Grant Number X83053401-02. 76 pp.
- Simenstad, C.A., B.J. Nightingale, R.M. Thom, and D.K. Shreffler. 1999. Impacts of Ferry Terminal on Juvenile Salmon Migrating along Puget Sound Shorelines Phase I: Synthesis of State of Knowledge.
- Simenstad, C.A. 1994. pp. 11-19. In Wyllie-Echeverria, S., A.M. Olson, and M.J. Hershman, eds. Seagrass science and policy in the Pacific Northwest: proceedings of a seminar series (SMA 94-1) EPA 910/R-94-004. 63 pp.
- Simenstad, C.A., C.D. Tanner, F. Weinmann, and M. Rylko. 1991. The estuarine habitat assessment protocol. Puget Sound Notes. No. 25. June 1991.
- Soil Conservation Service, U.S. Department of Agriculture, Forest Service, and Economic Research Service. 1984. Southeast Washington cooperative river basin study. U.S. Department of Agriculture, Washington, D.C.
- State of North Carolina. 2009. Water efficiency manual for commercial, industrial, and institutional facilities. A joint publication of the Division of Pollution Prevention and Environmental Assistance and Division of Water Resources of the N.C. Department of Environment and Natural Resources, and Land-of-Sky Regional Council.
<http://www.p2pays.org/ref/01/00692.pdf>
- Stein, J., T. Hom, T. Collier, D. Brown, and U. Varanasi. 1995. "Contaminant exposure and biochemical effects in outmigrant juvenile chinook salmon from urban estuaries of Puget Sound, WA." *Environ. Toxicol. Chem.* 14:1019-1029.

- Steward, C. 1983. Salmonoid populations in an urban environment - Kelsy Creek, Washington. M.S. Thesis, University of Washington.
- Stone, R.P. and S.W. Johnson. 1998. "Prolonged exposure to mine tailings and survival and reproductive success of ovigerous Tanner crabs (*Chionoecetes bairdi*).” Bull. Environ. Contam. Toxicol. 61: 548-556.
- Stull, J.K. and C.I. Haydock. 1989. Discharges and environmental responses: the Palos Verdes case. *In* Managing inflows in California's bays and estuaries. The Bay Institute, Sausalito, Calif. pp. 44-49.
- Sundberg, K.A., 1981. Marine biology and circulation investigations in Sitka Sound, Alaska, Marine/Coastal Habitat Management, Habitat Protection Section, ADF&G, Anchorage, AK.
- TAPS (Trans-Alaska Pipeline System) Draft Environmental Impact Statement. 2002. Renewal of the Federal Grant for the Trans-Alaska Pipeline System (TAPS) Right-of-Way. U.S. Dept. of the Interior, Bureau of Land Management. 4.3: 50.
- Thayer, G.W., ed. 1992. Restoring the Nation's Marine Environment. Publication UM- SG-TS-92-06. Maryland Sea Grant College, College Park, MD, 716 pp.
- Thayer, G.W., W.J. Kenworthy, and M.S. Fonseca. 1984. The ecology of eelgrass meadows of the Atlantic coast: a community profile. U.S. Fish and Wildlife Service FWS/OBS-84/02. 147 pp.
- Thorsteinson, F.V. and L.K. Thorsteinson. 1982. Finfish Resources. Chapter 6. *In* Hameedi, M.J., ed. The St. George Basin Environment and Possible Consequences of Planned Offshore Oil and Gas Development. Proceedings of a Synthesis Meeting. U.S. Department of Commerce, NOAA, Office of Marine Pollution Assessment.
- Toft, J., J. Cordell, C. Simenstad, L. Stamatiou. 2004. Fish Distribution, abundance and behavior at nearshore habitats along City of Seattle marine shorelines, with an emphasis on juvenile salmonids. Prepared for Seattle Public Utilities, City of Seattle. Wetland Ecosystem Team, School of Aquatic and Fishery Sciences, University of Washington SAFS-US-0401 March 2004. 52p.
- Trasky, L., 2008. Analysis of the Potential Impacts of Copper Sulfide Mining on the Salmon Resources of the Nushagak and Kvichak Watersheds. Sections 2 & 3 p17-41
- Turek, J.G., T.E. Bigford, and J.S. Nichols. 1987. Influence of freshwater inflows on estuarine productivity. NOAA Tech. Memo. NMFS-F/NEC-46. 26 pp.
- U.S. Army Corps of Engineers (USACE), Alaska District. 1999. Final Environmental Impact Statement. Beaufort Sea Oil and Gas Development/Northstar Project. P.O. Box 898, Anchorage, Alaska. February 1999.
- USDA. 2008a. Tongass Monitoring and Evaluation Report – Appendix B
http://www.fs.fed.us/r10/tongass/projects/tlmp/2008_monitoring_report/index2008.shtml
- USDA. 2008b. Tongass National Forest Land and Resource Management Plan. R10-MB-603b.
http://tongass-fpadjust.net/Documents/2008_Forest_Plan.pdf

- USDA. 2003. Tongass Best Management Practice Implementation Monitoring Report.
- USDA. 2002. Southern Intertie Project Final Environmental Impact Statement. U.S. Dept. of Agriculture. Rural Utilities Service. Washington D.C.
- USDA. 2000. Tongass National Forest Draft Annual Monitoring Report.
- USDA. 1989. The second RCA appraisal: Soil, water, and related resources on nonfederal land in the United States, analysis of conditions and trends. Washington, D.C. 280 pp.
- USEPA. 2000. Scoping Document for the Proposed Pogo Mine Site. U.S. EPA, Region 10, 1200 Sixth Ave., Seattle, WA 98101. 11 August. (<http://www.pogomineeis.com/documents/ScopingDraft.pdf>).
- USEPA. 1997. Office of Water. Guidance specifying management measures for sources of nonpoint pollution in coastal waters. Chapter 5: Management measure for marinas and recreational boating. (<http://www.p2pays.org/ref/04/03686/index-5.html>).
- USEPA Estuaries, 1992, Technical Guidance Manual for Performing Waste Load Allocations Book III: Estuaries, US EPA, 1992.
- USEPA. 1992. Turning the Tide on Trash: Marine Debris Curriculum. A Learning Guide on Marine Debris. EPA842-B-92-003 (<http://www.epa.gov/owow/OCPD/Marine/contents.html>)
- USEPA 1991, Technical Support Document for Water-Quality Based Toxics Control (TSD), Document No. EPA/505/2-90-001. March 1991.
- USEPA. 1975. Development document for effluent limitations guidelines and new source performance standards for the fish meal, salmon, bottom fish, clam, oyster, sardine, scallop, herring, and abalone segment of the canned and preserved fish and seafood processing industry point source category. Effluent Guidelines Division, Office of Water and Hazardous Material, Washington, D.C. EPA 440/1-75/041a. 485 pp.
- USEPA. 1974. Development Document for Effluent Limitations Guidelines and Standards of Performance for the Catfish, Crab, Shrimp, and Tuna segments of the Canned and Preserved Seafood Processing Industry Point Source Category. Effluent Guidelines Division, Office of Water and Hazardous Material, Washington, D.C. EPA-440/1-74-020-a. 389 pp.
- USEPA, Office of Water (<http://www.epa.gov/water/>) and Office of Pesticide Programs (<http://www.epa.gov/pesticides/>).
- USEPA, Office of Wetlands, Oceans and Watersheds, Ocean and Coastal Protection Division, Marine Debris Abatement (<http://www.epa.gov/owow/oceans/debris/>)
- U.S. Fish and Wildlife Service (USFWS). 1987. Polycyclic Aromatic Hydrocarbons Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. Biological Report 85(1.11). Patuxent Wildlife Research Center, Laurel, MD, USA.
- USFWS. 1980. FWS/OBS-80/09. Gravel Removal Guidelines Manual for Arctic and Subarctic Floodplains. June 1980. Prepared by Woodward Clyde Consultants. Contract Number

- FWS-14-16-0008-970. Performed for the Water Resources Analysis Project, Office of Biological Services. U.S. Department of the Interior, Washington, D.C. 20240.
- U.S. Geologic Survey (USGS). 1999. The quality of our nation's waters: Nutrients and pesticides. pp. 33-55. USGS, Reston, VA.
- USGS. Toxic Substances Hydrology Program: Watershed Contamination from Hard Rock Mines. <http://toxics.usgs.gov/regional/mining/index.html>
- Van Dolah, R.E., P.P. Maier, M.H. Fulton, and G.I. Scott. 1997. "Comparison of azinphomethyl toxicity to juvenile red drum (*Scianops ocellatus*) and the mummichog (*Fundulus heteroclitus*)."
Environmental Toxicology and Chemistry. 16:1488-1493.
- Vernberg F.J., W.B. Vernberg. 2001. The Coastal Zone. Past, Present, and Future. University of South Carolina.
- Vetter, E.W. 1995. "Detritus based patches of high secondary production in the nearshore benthos."
Mar. Ecol. Prog. Ser. 120:251-262.
- Vuorinen, P.J., R. Parmanne, T. Vartiainen, M. Keinanen, H. Kiviranta, O. Kotovuori, and F. Hallig. 2002. "PCDD, PCF, PCB and thiamin in Baltic herring (*Clupea harengus* L.) and sprat (*Sprattus sprattus* L.) as a background to the M74 syndrome of Baltic salmon (*Salmo salar* L.)." *ICES J. Mar. Sci.* 59:480-496.
- Waisley, S.L. 1998. Projections for U.S. and Global Supply and Demand for 2010 and 2020. presented at U.S. and China Oil and Gas Industrial Forum, Beijing, People's Republic of China, November 2-4, 1998. Office of Natural Gas and Petroleum Technology, U.S. DOE, Washington, D.C. (http://www.fe.doe.gov/oil_gas/china_forum/cl04000.html).
- Wania, F. and D. Mackay. 1999. "Global chemical fate of hexachlorocyclohexane. 2. Use of a global distribution model for mass balancing, source apportionment, and trend prediction." *Environ Toxicol Chem.* 18: 1400B1407.
- Washington State Department of Ecology, Water Quality Program, Sand & Gravel General Permit (<http://www.ecy.wa.gov/programs/wq/sand/escp.html>).
- Washington Department of Fish and Wildlife. 1998. Gold and fish. Rules and regulations for mineral prospecting and mining in Washington State. Draft, February 1998. Olympia, WA.
- Wemple, B.C., F.J. Swanson, and J.A. Jones. 2001. "Forest roads and geomorphic process interactions, Cascade Range, Oregon." *Earth Surface Processes and Landforms*. 26:191-204.
- Wemple, B.C., J.A. Jones, and G.E. Grant. 1996. "Channel network extension by logging roads in two basins, western Cascades, Oregon." *Water Resources Bulletin*. 32:1195-1207.
- Wertheimer, A.C., R.A. Heintz, J.F. Thedinga, J.M. Maselko, and S.D. Rice. 2000. Straying of adult pink salmon from their natal stream following exposure as embryos to weathered Exxon Valdez crude oil. *Trans. Amer. Fish. Soc.* 129: 989-1004.
- Wicker, K.M., R.E. Emmer, D. Roberts, and J. van Beek. 1989. Pipelines, navigation channels, and facilities in sensitive coastal habitats: an analysis of Outer Continental Shelf impacts, Coastal

Gulf of Mexico. Volume I: technical narrative. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Report MMS 89-0051.

- Williams, J.E., C.A. Wood, and M.P. Dombeck, eds. 1997. Watershed Restoration: Principles and Practices. American Fisheries Society, Bethesda, MD. 561 pp.
- Williams, R.N., L.D. Calvin, C.C. Coutant, M.W. Erho Jr., J.A. Lichatowich, W.J. Liss, W.E. McConaha, P.R. Mundy, J.A. Stanford, R.R. Whitney, D.L. Bottom, and C.A. Frissell. 1996. Return to the river: restoration of salmonid fishes in the Columbia River ecosystem. Development of an alternative conceptual foundation and review and synthesis of science underlying the Columbia River Basin fish and wildlife program of the northwest power planning council by the independent scientific group. Northwest Power Planning Council, Portland, Oregon. 584 pp.
- Wolkersdorfer, C. and Howell, R. 2005. Contemporary Reviews of Mine Water Studies in Europe. Mine Water and the Environment 24: Supplementary Material © Springer Verlag.
- Woltemade, C.J. 2000. "Ability of restored wetlands to reduce nitrogen and phosphorus concentrations in agricultural drainage water." J. Soil and Water Cons. 55: 303.
- Yang, J., D. Shin, S. Park, Y. Chang, D. Kim, and M.G. Ikononou. 2002. "PCDDs, PCDFs and PCBs concentrations in breast milk from two areas in Korea: body burden of mothers and implications for feeding infants." Chemosphere. 46(3):419-28.
- Ylitalo, G.M. C.O. Matkin, J. Buzitis, M.M. Krahn, L.L. Jones, T. Rowles, and J.E. Stein. 2001a. "Influence of life-history parameters on organochlorine concentrations in free-ranging killer whales (*Orcinus orca*) from Prince William Sound, AK." Sci. Tot. Env. 281:183-203.
- Ylitalo, G.M., J.W. Bickham, J. Buzitis, G.K. Yanagida, J.E. Stein, and M.M. Krahn. 2001b. *Contaminant Bioaccumulation and Feeding ecology of Steller Sea Lions from Alaska*. Workshop to Assess Contaminant Impacts on Steller Sea Lions in Alaska. Anchorage, AK, September 5-6, 2001. Sponsored by Auke Bay Laboratory.
- York, A.E., R.L. Merrick, and T.R. Loughlin. 1996. An analysis of the Steller sea lion metapopulation in Alaska. In McCullough, D., ed. Metapopulations and wildlife conservation and management. Island Press, Covelo, CA. pp. 259-292.
- Young, K.A. 2000. "Riparian zone management in the Pacific Northwest: who's cutting what?" Environmental Management. 26, 131-44.
- Younger P.L., Banwart S.A., and Hedin R.S. 2004. Mine water: hydrology, pollution, remediation. London: Kluwer Academic Publishers; 442 pp.
- Youngson, A.F., Malcolm, I.A. Thorley, P.J., Bacon, P.J., Soulsby, C., 2004. Long Residence Groundwater Effects on Incubating Salmonid Eggs: Low Hyporheic Oxygen Impairs Embryo Development. Canadian Journal of Fisheries and Aquatic Sciences. Vol 61(12) p 2278-2287
- Zedler, J.B., C.S. Nordby, and B.E. Kus. 1992. The ecology of the Tijuana Estuary, California: A National Estuarine and Research Reserve. NOAA Office of Coastal Resource Management, Sanctuaries and Reserves Division, Washington, D.C.

- Zenteno-Savin, T., M. Castellini, L.D. Rea, and B.S. Fadely. 1997. "Plasma haptoglobin in threatened Alaskan pinniped populations." *J. Wildlife Dis.* 33:64-71.
- Zeppelin, T.K., K.A. Call, D.J. Tollit, T.J. Orchard, and C.J. Gudmundson. 2003. Estimating the size of walleye pollock and Atka mackerel consumed by the western stock of Steller sea lions. Marine Science in the Northeast Pacific. Sponsored by Exxon Valdez Oil Spill Trustee Council, GLOBEC-Northeast Pacific Program, Steller Sea Lion Investigations, North Pacific Reesarch Board, North Pacific Marine Research Institute and Pollock Conservation Cooperative. Anchorage, Alaska. January 13-17.
- Zielger, A.D., R.A. Sutherland, and T.W. Gaimbelluca. 2001. "Interstorm surface preparation and sediment detachment by vehicle traffic on unpaved mountain roads." *Earth Surface Processes and Landforms.* 26:235-250.

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**Finding of No Significant Impact for Essential Fish Habitat Omnibus Amendments:
Amendment 98 to the Fishery Management Plan (FMP) for Groundfish of the
Bering Sea and Aleutian Islands Management Area; Amendment 90 to the FMP for
Groundfish of the Gulf of Alaska; Amendment 40 to the FMP for Bering
Sea/Aleutian Islands King and Tanner Crabs; Amendment 15 to the FMP for the
Scallop Fishery off Alaska; Amendment 1 to the FMP for Fish Resources of the
Arctic Management Area [RIN 0648-XA500]**

October 2012

National Oceanic and Atmospheric Administration Administrative Order 216-6 (NAO 216-6) (May 20, 1999) contains criteria for determining the significance of the impacts of a proposed action. In addition, the Council on Environmental Quality regulations at 40 CFR 1508.27 state that the significance of an action should be analyzed both in terms of “context” and “intensity.” Each criterion listed below is relevant in making a finding of no significant impact and has been considered individually, as well as in combination with the others. The significance of this action is analyzed based on the NAO 216-6 criteria and CEQ’s context and intensity criteria. These include:

1) Can the proposed action reasonably be expected to jeopardize the sustainability of any target species that may be affected by the action?

Response: No. The action will have no impact on the sustainability of the target species. Target species are those species managed under the BSAI Groundfish FMP; GOA Groundfish FMP; BSAI Crab FMP; Scallop FMP; and the Arctic FMP. As mentioned in Sections 4.3.2, 5.3.2, 6.3.2, and 7.3.2 of the EA, the preferred alternatives will result in relatively minor changes to the existing EFH descriptions for the target stocks, and the impact of the changes is not substantively different from that analyzed in the 2005 EFH EIS. Updated information on EFH for each FMP species would improve management.

2) Can the proposed action reasonably be expected to jeopardize the sustainability of any non-target species?

Response: No. The action will have no impact on the sustainability of the non-target species that are caught in the fisheries of the above-referenced FMPs. The action amends EFH information and will not affect the management of these species. The revisions to EFH text and maps are minor and the impact of the changes under these amendments is not substantively different from that analyzed in the 2005 EFH EIS.

3) Can the proposed action reasonably be expected to cause substantial damage to the ocean and coastal habitats and/or essential fish habitat as defined under the Magnuson-Stevens Act and identified in FMPs?

Response: No. The action will have no damaging effect on ocean and coastal habitats and/or essential fish habitat. The revisions to EFH text and maps are minor and the impact of the changes under these amendments is not substantively different from that analyzed in the 2005 EFH EIS. The inclusion of more up-to-date and accurate EFH information might have a slightly beneficial impact on ocean and coastal habitats and/or essential fish habitat compared to status quo by better informing fisheries management.

4) Can the proposed action be reasonably expected to have a substantial adverse impact on public health or safety?

Response: No, the action will have no impact on public health and safety. The revisions to EFH text and maps are minor. The impact of the changes under these amendments is not substantively different from that analyzed in the 2005 EFH EIS, and no changes are expected in fisheries activities that would lead to public health impacts or safety impacts.

5) Can the proposed action reasonably be expected to adversely affect endangered or threatened species, marine mammals, or critical habitat of these species?

Response: No, the action will not affect endangered or threatened species, marine mammals, or critical habitat of these species. The revisions to EFH text and maps are minor and the impact of the changes under these amendments is not substantively different from that analyzed in the 2005 EFH EIS. The inclusion of more up-to-date and accurate EFH information might have a slight beneficial impact on endangered or threatened species, marine mammals, or critical habitat compared to status quo by better informing fisheries management for managed fish species that may also be used by ESA-listed species or marine mammals.

6) Can the proposed action be expected to have a substantial impact on biodiversity and/or ecosystem function within the affected area (e.g., benthic productivity, predator-prey relationships, etc.)?

Response: No, the action is not expected to impact biodiversity and/or ecosystem function within the affected areas. The revisions to EFH text and maps are minor, and the impact of the changes under these amendments is not substantively different from that analyzed in the 2005 EFH EIS. Any adjustments to fisheries management based on the minor changes to the EFH descriptions are not expected to have ecosystem level impacts or impacts on biodiversity.

7) Are significant social or economic impacts interrelated with natural or physical environmental effects?

Response: No, there are no significant social or economic impacts interrelated with natural or physical environmental effects. The revisions to EFH text and maps are minor, and the impact of the changes under these amendments is not substantively different from that analyzed in the 2005 EFH EIS. No social or economic impacts are expected with the EFH description changes, as only minor shifts in fisheries management may occur and no overall changes in economic or social aspects of the fisheries are expected.

8) Are the effects on the quality of the human environment likely to be highly controversial?

Response: No, the effects on the quality of the human environment are not likely to be controversial. The revisions to EFH text and maps are minor and the impact of the changes under these amendments is not substantively different from that analyzed in the 2005 EFH EIS. The effects of describing EFH are not controversial as any changes to fisheries management due to the minor changes in the EFH descriptions are well understood and described in the 2005 EFH EIS; there is no new information that would lead to different effects conclusions.

9) Can the proposed action reasonably be expected to result in substantial impacts to unique areas, such as historic or cultural resources, park land, prime farmlands, wetlands, wild and scenic rivers or ecologically critical areas?

Response: No, the action is not expected to result in impacts to unique areas. EFH may include ecologically sensitive areas, but this action is only a description of EFH to use in consideration of fisheries management measures and EFH consultation. No substantial impacts on these areas are expected because the revisions to EFH text and maps are minor, and the impact of the changes under these amendments is not substantively different from that analyzed in the 2005 EFH EIS.

10) Are the effects on the human environment likely to be highly uncertain or involve unique or unknown risks?

Response: No, the effects on the human environment are not likely to be uncertain or involve unique or unknown risks. The revisions to EFH text and maps are minor, and the impact of the changes under these amendments is not substantively different from that analyzed in the 2005 EFH EIS. Impacts of describing EFH are well known as shown in the 2005 EFH EIS.

11) Is the proposed action related to other actions with individually insignificant, but cumulatively significant impacts?

Response: No, the action is not related to other actions with individually insignificant, but cumulative significant impacts. The revisions to EFH text and maps are minor, and the impact of the changes under these amendments is not substantively different from that analyzed in the 2005 EFH EIS. No additional past, present, or reasonably foreseeable future actions beyond those described in the cumulative effects analysis in the 2005 EFH EIS have been identified that would combine with the minor beneficial effects of improved EFH descriptions to result in significant cumulative effects.

12) Is the proposed action likely to adversely affect districts, sites, highways, structures, or objects listed in or eligible for listing in the National Register of Historic Places or may cause loss or destruction of significant scientific, cultural or historical resources?

Response: No, the action will not adversely affect districts, sites, highways, structures, or objects listed in or eligible for listing in the National Register of Historic Places or cause loss or destruction of significant scientific, cultural, or historical resources. This action occurs in the

exclusive economic zone off Alaska, which does not contain these types of sites. This action revises EFH text and maps and will result in the minor beneficial effect of improved fisheries management through more accurate EFH descriptions.

13) Can the proposed action reasonably be expected to result in the introduction or spread of a nonindigenous species?

Response: No, the action is not reasonably expected to result in the introduction or spread of a nonindigenous species as this action has no effect on the location or participation of fishing vessels in the fisheries that could result in the introduction of invasive species.

14) Is the proposed action likely to establish a precedent for future actions with significant effects or represents a decision in principle about a future consideration?

Response: No, the action is not likely to establish a precedent for future actions with significant effects or represent a decision in principle about a future consideration. The schedule for revisions to EFH descriptions are mandated by the Magnuson-Stevens Act and the FMPs for Alaska fisheries, as analyzed in the 2005 EFH EIS and implemented in 2006. The revisions to EFH text and maps are minor, and the impact of the changes under these amendments is not substantively different from that analyzed in the 2005 EFH EIS.

15) Can the proposed action reasonably be expected to threaten a violation of Federal, State, or local law or requirements imposed for the protection of the environment?

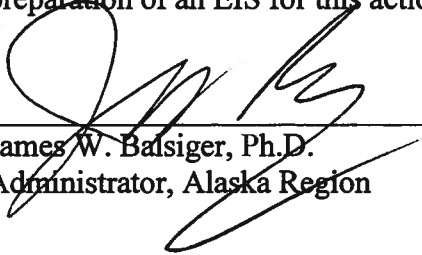
Response: No, the action is not expected to threaten a violation of federal, state, or local law or requirements imposed for the protection of the environment. The revisions to EFH text and maps are minor, and the impact of the changes under these amendments is not substantively different from that analyzed in the 2005 EFH EIS. The action is consistent with requirements of the Magnuson-Stevens Act established for the identification and conservation of EFH and does not conflict with any other laws for the protection of the environment.

16) Can the proposed action reasonably be expected to result in cumulative adverse effects that could have a substantial effect on the target species or non-target species?

Response: No, the action is not expected to result in cumulative adverse effects that could have a substantial effect on the target species or non-target species. The revisions to EFH text and maps are minor, and the impact of the changes under these amendments is not substantively different from that analyzed in the 2005 EFH EIS. No additional past, present, or reasonably foreseeable future actions beyond those described in the 2005 EFH EIS have been identified that would combine with the minor beneficial effects of improved EFH descriptions to result in significant cumulative effects on target or non-target species.

DETERMINATION

In view of the information presented in this document and the analysis contained in the supporting Environmental Assessment prepared for Essential Fish Habitat Omnibus Amendments, it is hereby determined that the Essential Fish Habitat Omnibus Amendments will not significantly impact the quality of the human environment as described above and in the supporting Environmental Assessment. In addition, all beneficial and adverse impacts of the action have been addressed to reach the conclusion of no significant impacts. Accordingly, preparation of an EIS for this action is not necessary.



James W. Balsiger, Ph.D.
Administrator, Alaska Region

10-18-12
Date