Endangered Species Act

Section 7 Consultation - Biological Opinion

Agency:	National Marine Fisheries Service
Activities Considered:	Authorization of BSAI groundfish fisheries based on TAC specifications recommended by the North Pacific Fishery Management Council for 1999; and Authorization of GOA groundfish fisheries based on TAC specifications recommended by the North Pacific Fishery Management Council for 1999.
Consultation By:	NMFS - Alaska Region

Issued: ____

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1.0 PURPOSE AND CONSULTATION HISTORY

Section 7(a)(2) of the Endangered Species Act, 16 U.S.C. § 1531 et seq., requires that each Federal agency shall insure that any action authorized, funded, or carried out by such agency is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such species. When the action of a Federal agency may adversely affect a protected species, that agency is required to consult with either the National Marine Fisheries Service or the U.S. Fish and Wildlife Service, depending upon the protected species that may be affected. For the actions described in this document, the “action” agency is the Sustainable Fisheries Division of the National Marine Fisheries Service. The consulting agency is the Office of Protected Resources, also of the National Marine Fisheries Service. Section 7(b) of the Act requires that the consultation be summarized in a biological opinion detailing how the action may affect protected species.

This opinion fulfills the section 7 requirements for consultation on (1) authorization of groundfish fisheries in 1999 under the Bering Sea and Aleutian Islands (BSAI) groundfish fishery management plan and based on 1999 TAC specifications, and (2) authorization of groundfish fisheries in 1999 under the Gulf of Alaska (GOA) groundfish fishery management plan and based on 1999 TAC specifications. Section 7 regulations allow a formal consultation to encompass a number of similar actions within a given geographic area or a segment of a comprehensive plan (50 CFR 402.14). Consistent with this regulatory provision and for purposes of efficiency, these two actions are being summarized in a single biological opinion.

Much of this opinion focuses on the potential effects of these fisheries on the endangered western population of Steller sea lions. The Steller sea lion was listed as threatened in 1990. On April 18, 1991, the National Marine Fisheries Service (NMFS) issued two biological opinions on the groundfish fisheries off Alaska pursuant to section 7 of the Endangered Species Act, as amended. The first biological opinion was prepared on the effects of the Fishery Management Plan (FMP) for the BSAI Management Area, and the second opinion was prepared on the effects of the FMP for the GOA groundfish fisheries. Both opinions concluded that the fisheries were not likely to jeopardize the continued existence and recovery of the Steller sea lion.

Between 1991 and 1996, NMFS evaluated the effects of various changes to both the BSAI and GOA groundfish fisheries (Table 1), and collected additional data on the fisheries. During this period, the western population of sea lions continued to decline. In 1993, critical habitat was designated for the species and, in 1995, NMFS issued a proposed rule to list the western population as endangered.

In 1995, NMFS reinitiated formal consultation on the effects on the Steller sea lion of the BSAI and the GOA groundfish fisheries as managed under the FMPs, and the proposed 1996 total allowable catch (TAC) specifications. Consultation was reinitiated because of 1) new information on the fisheries and their management, and 2) continued decline of the sea lion. On January 26, 1996, NMFS issued two new biological opinions, both of which concluded that the respective FMPs, the fisheries, and the 1996 TAC specifications were not likely to jeopardize the continued existence of Steller sea lions or to result in the destruction or adverse modification of their critical habitat.

On January 17, 1997, NMFS issued a Decision Memorandum on the 1997 BSAI and GOA TAC specifications and the need for section 7 consultation. NMFS determined that the groundfish fisheries were not likely to affect Steller sea lions in a way or to an extent not already considered in previous section 7 consultations on this fishery and reinitiation of formal consultation was not required.

On September 10, 1997, NMFS issued an environmental assessment/regulatory impact review (EA/RIR) on a proposed action to remove blue and black rockfish species from the GOA FMP (amendment 46) and allow the State of Alaska to assume management of these species. NMFS also determined that this action 1) was not likely to adversely affect those threatened and endangered species under its jurisdiction, and 2) was also not likely to result in the adverse modification of any designated critical habitats of these species.

On February 26, 1998, NMFS determined that the 1996 biological opinion on the effects of the BSAI groundfish fishery on Steller sea lions remained valid for the 1998 BSAI groundfish fishery.

On March 2, 1998, NMFS issued a biological opinion that concluded that the 1998 GOA groundfish fishery was not likely to jeopardize the continued existence and recovery of Steller sea lions or to adversely modify critical habitat. NMFS noted that the biological opinion only addressed the 1998 fishery, not the continued implementation of the GOA FMP beyond 1998. The Alaska Region would need to reinitiate section 7 consultation for the fishery in 1999 and beyond.

In June 1998, the North Pacific Fishery Management Council (NPFMC) adopted a precautionary approach in approving a regulatory amendment to reduce the probability of localized depletion of Atka mackerel in critical habitat for Steller sea lions. The amendment would allocate the Atka mackerel TAC on a seasonal basis and shift the spatial allocation of the TAC over the next four years until 40% is taken within critical habitat and 60% is taken outside of critical habitat.

In June 1998, the NPFMC also approved an FMP amendment to alter the allocation of BSAI pollock to inshore and offshore sectors of the fishery from 35%:65% (respectively) to 39%:61% (respectively). On October 21, 1998, the President signed into law the American Fisheries Act (AFA), which changed the allocation scheme for pollock in the BSAI beginning in 1999.

On December 3, 1998, the NMFS completed a biological opinion on the BSAI Atka mackerel fishery and the BSAI and GOA pollock fisheries. This opinion concluded that the pollock fisheries were likely to jeopardize the continued existence of the endangered western population of Steller sea lions and adversely modify its designated critical habitat. Principles for a reasonable and prudent alternative were developed in the opinion and NMFS, in cooperation with the NPFMC, is in the process developing and implementing the changes required to satisfy those principles and thereby avoid jeopardy and adverse modification.

2.0 DESCRIPTION OF THE PROPOSED ACTIONS

The purpose of this section is to describe the proposed actions that are the subject of this consultation and opinion and thereby provide the background information needed to analyze their potential effects on protected species and, in particular, the western population of Steller sea lions. The actions being considered in this Biological Opinion are:

- *Authorization of 1999 BSAI groundfish fisheries under the BSAI groundfish FMP, based on 1999 TAC specifications.* Consultation on these fisheries was initiated because of new information on TAC specifications.

- *Authorization of 1999 GOA groundfish fisheries under the GOA groundfish FMP, based on 1999 TAC specifications.* Consultation on these fisheries was initiated because of new information on TAC specifications.

These two actions are separate actions that would be taken by NMFS and are each separately subject to consultation pursuant to section 7 of the ESA. They have been grouped into this single Biological Opinion for efficiency and in compliance with the regulatory language of section 7, which allows NMFS to group a number of similar, individual actions within a given geographic area or segment of a comprehensive plan (50 CFR 402.14(b)).

2.1 Groundfish and their management

For FMP managed stocks, the Council may split or combine species groups for purposes of establishing individual TAC specifications based on commercial importance of a species or species group and whether sufficient biological information is available to manage a species or species group on its own biological merits. Groundfish target species fall under the umbrella of Federal fisheries management or, by omission, not under management according to the approved FMPs and amendments thereto NPFMC 1994, 1995).

The status of each species or species group is assessed annually based upon the best available scientific information. Assessments are prepared by NMFS scientists, and compiled by the plan teams into annual Stock Assessment and Fishery Evaluation (SAFE) reports. The SAFE reports contain information on historical catch trends, biomass estimates, preliminary estimates of Acceptable Biological Catch (ABC), assessments of harvest impacts and alternative harvesting strategies. Most of the assessments are based primarily on trawl and longline surveys conducted by NMFS. Data are also collected from commercial fisheries through the observer program. In addition to determining total catch of each species, these data provide information on removal of fish by age and improve estimates of stock structure and year-class strength (Witherell and Ianelli 1997).

2.1.1 Derivation of Acceptable Biological Catch and Overfishing

Acceptable Biological Catch (ABC) recommendations are developed according to definitions of ABC and the overfishing level (OFL) contained in the groundfish FMPs (NPFMC 1996). The definitions of ABC and overfishing implemented in 1997 are shown below:

Acceptable Biological Catch is a preliminary description of the acceptable harvest (or range of harvests) for a given stock or stock complex. Its derivation focuses on the status and dynamics of the stock, environmental conditions, other ecological factors, and prevailing technological characteristics of the fishery. The fishing mortality rate used to calculate ABC is capped as described under "overfishing" below.

Overfishing is defined as any amount of fishing in excess of a prescribed maximum allowable rate. This maximum allowable rate is prescribed through a set of six tiers which are listed below in descending order of preference, corresponding to descending order of information availability. The Council's Scientific and Statistical Committee (SSC) has final authority for determining whether a given item of information is "reliable" for the purpose of this definition, and may use either objective or subjective criteria in making such determinations. For tier (1), a "pdf" refers to a probability density function. For tiers (1-2), MSY refers to maximum sustainable yield, which is the largest catch which the stock can withstand, on average, over a long period of time (given current environmental conditions). For tiers (1-3), the coefficient a is set at a default value of 0.05, with the understanding that the SSC may establish a different value for a specific stock or stock complex as merited by the best available scientific information. For tiers (2-4), a designation of the form "$F_{X\%}$" refers to the fishing mortality (F) associated with an equilibrium level of spawning per recruit (SPR) equal to X% of the equilibrium level of spawning per recruit in the absence of any fishing. If reliable information sufficient to characterize the entire maturity schedule of a species is not available, the SSC may choose to view SPR calculations based on a knife-edge maturity assumption as reliable. For tier (3), the term $B_{40\%}$ refers to the long-term average biomass that would be expected under average recruitment and $F=F_{40\%}$.

1) Information available: Reliable point estimates of B and BMSY and reliable pdf of FMSY.
   - 1a) Stock status: $B/B_{MSY} > 1$
     - $F_{OFL} = m_A$, the arithmetic mean of the pdf
     - $F_{ABC} \leq m_H$, the harmonic mean of the pdf
   - 1b) Stock status: $a < B/B_{MSY} \leq 1$
     - $F_{OFL} = m_A \times (B/B_{MSY} - a)/(1 - a)$
     - $F_{ABC} \leq mH \times (B/B_{MSY} - a)/(1 - a)$
   - 1c) Stock status: $B/B_{MSY} \leq a$
     - $F_{OFL} = 0$
     - $F_{ABC} = 0$

2) Information available: Reliable point estimates of B, B_{MSY} , F_{MSY} , $F_{30\%}$, and $F_{40\%}$..
   - 2a) Stock status: $B/B_{MSY} > 1$
     - $F_{OFL} = F_{MSY} \times (F_{30\%} /F_{40\%})$
     - $F_{ABC} \leq F_{MSY}$
   - 2b) Stock status: $a < B/B_{MSY} \leq 1$
     - $F_{OFL} = F_{MSY} \times (F_{30\%} /F_{40\%}) \times (B/B_{MSY} - a)/(1 - a)$

$F_{ABC} \leq F_{MSY} \times (B/B_{MSY} - a)/(1 - a)$

2c) Stock status: $B/B_{MSY} \leq a$

$F_{OFL} = 0$

$F_{ABC} = 0$

3) Information available: Reliable point estimates of B, B40% , F30% , and F40%.

3a) Stock status: $B/B_{40\%} > 1$

$F_{OFL} = F_{30\%}$

$F_{ABC} \leq F_{40\%}$

3b) Stock status: $a < B/B_{40\%} \leq 1$

$F_{OFL} = F_{30\%} \times (B/B_{40\%} - a)/(1 - a)$

$F_{ABC} \leq F_{40\%} \times (B/B_{40\%} - a)/(1 - a)$

3c) Stock status: $B/B_{40\%} \leq a$

$F_{OFL} = 0$

$F_{ABC} = 0$

4) Information available: Reliable point estimates of B, $F_{30\%}$, and $F_{40\%}$.

$F_{OFL} = F_{30\%}$

$F_{ABC} \leq F_{40\%}$

5) Information available: Reliable point estimates of B and natural mortality rate M.

$F_{OFL} = M$

$F_{ABC} \leq 0.75 \times M$

6) Information available: Reliable catch history from 1978 through 1995.

OFL = the average catch from 1978 through 1995, unless an alternative value is established by the SSC on the basis of the best available scientific information

$ABC \leq 0.75 \times OFL$

When enough information is available and if the stock is healthy, the exploitation rate corresponding to the fishing mortality rate that provides maximum sustainable yield (F_{MSY}) would be used for harvest recommendations. However, estimation of F_{MSY} is often difficult, because it is determined by unknown density dependent mechanisms. In an age-structured assessment, for example, estimation of F_{MSY} requires a reliable estimate of the stock-recruitment relationship. Surrogate exploitation rates were developed with the intent of achieving the same practical effect as fishing at the F_{MSY} level, that is, providing a yield close to MSY with a low probability of reducing the stock to dangerously low levels (Clark 1991, 1993). The surrogate rates are determined entirely by life history parameters, and based upon levels of spawning biomass per recruit. Clark (1993) suggested that maintaining a target level of spawning biomass per recruit around 40% of the equilibrium unfished level substantially reduced the frequency of episodes of low spawning biomass (which he defined as less than 20% of the equilibrium unfished level), given the presence of random variation in recruitment. The fishing mortality rate that reduces the spawning biomass per recruit to about 40% of the equilibrium unfished level is denoted $F_{40\%}$ (Clark 1993).

The analysis from which the $F_{40\%}$ exploitation rate was derived was an expansion of an earlier analysis (Clark 1991) that considered a range of life history parameters typical of North Pacific groundfish stocks and a set of spawner-recruit relationships that encompassed a reasonable range of density dependence. Deterministic yield computations over the range of life history parameters and spawner-recruit relationships showed that fishing at the rate that reduced spawning biomass to 35% of the equilibrium unfished value ($F_{35\%}$) was a robust strategy. Results further showed that yield would be at least 75% of MSY. Clark (1993) showed through stochastic trials that, in the presence of random variation in recruitment, the target level of spawning biomass per recruit was slightly higher, around 40%. This was particularly evident when the recruitment deviations had a high degree of serial correlation. Clark (1993) notes that fishing at rates higher than $F_{35\%}$ runs the risk of fishing less resilient stocks down to very low levels and consequently low yields.

Tiers (1-2) also rely on estimation of F_{MSY} to determine the overfishing level. Thompson (1993) recommended 30% of the unfished level of spawning biomass per recruit ($F_{30\%}$) as a minimum sustainable level. In cases where insufficient information exists to estimate F_{MSY}, but sufficient life history information to estimate spawning biomass per recruit levels, $F_{30\%}$ is the overfishing level. In cases where information is even more limited (Tier 5), the fishing mortality rate corresponding to the overfishing level is equal to the natural mortality rate, and the maximum allowable F_{ABC} is 75% of the natural mortality rate. Deriso (1982) showed that M often exceeds F_{MSY}, and Thompson (1993) showed that M can exceed even $F_{30\%}$. According to Thompson (1993) capping the harvest rate at 75% of M should generally keep the fishing mortality level below $F_{30\%}$.

2.1.2 Derivation of Total Allowable Catch

Annually at its September meeting, the Council, its Advisory Panel, and its Scientific and Statistical Committee review the Draft SAFE reports. Again at its December meeting, the Council, Advisory Panel, and Scientific and Statistical Committee review the Final SAFE reports. Using that information, the Council makes both ABC and TAC recommendations. The NMFS packages the recommendations into specification documents and forwards them to the Secretary of Commerce for approval. Secretarial approval usually occurs by March for the subject fishing year. Because some of the fisheries are underway before approval, the Secretary implements one-fourth of the preliminary TAC specifications and apportionments thereof toward fisheries occurring in the first quarter of the calendar year (§ 679.20(c)(2)). Upon approval, the new TAC specifications replace the preliminary TAC specifications (§ 679.20(c)(3)).

The TAC specifications define upper harvest limits, or fishery removals, for the next fishing year. Catch specifications are made for each managed species or species group, and in some cases, by species and sub-area. The sum of the TAC specifications is important because the fishery management plans specify upper and lower ceilings for total TAC in each management area. In the BSAI, the lower limit is 1.4 million mt and upper limit is 2 million mt (§ 679.20(a)(1)(I)). In the Gulf of Alaska the lower limit is 116,000 mt and the upper limit is 800,000 mt (§ 679.20(a)(1)(ii)).

Sub-allocations of TAC are made for biological and socio-economic reasons according to percentage formulas established through FMP amendments. For particular target fisheries, TAC specifications are further allocated within management areas (eastern, central, western Aleutian Islands; Bering Sea; western, central, and eastern Gulf of Alaska) among management programs (open access or community development quota program), processing components (inshore or offshore), specific gear types (trawl, non-trawl, hook-and-line, pot, jig), and seasons according to regulations § 679.20, § 679.23, and § 679.31.

Promulgation of the fisheries is the term for sub-allocations of TAC to the various gear groups, management areas, and seasons according to pre-determined regulatory actions and for regulatory announcements by the NMFS management authorities opening and closing the fisheries accordingly. The entire TAC amount is available to the domestic fishery. The gear authorized in the Federally managed groundfish fisheries off Alaska includes trawl, hook-and-line, longline pot, pot, and jig (50 CFR 679.2).

Fishing areas correspond to the defined regulatory areas within the fishery management units. The BSAI is divided into nineteen reporting areas (Fig. 1), some of which are combined for TAC specifications purposes. The Aleutian Islands group comprises regulatory Areas 541, 542, and 543. When the Aleutian Islands are referred to individually, 541 represents the eastern Aleutian Islands, 542 the central Aleutian Islands, and 543 the western Aleutian Islands. The GOA is divided into eight reporting areas (Fig. 2). The western GOA is Area 610, the central GOA includes Areas 620 and 630, and the eastern GOA includes Areas 640 and 650. State waters in Prince William Sound comprise Area 649. State waters in southeast Alaska comprise Area 659.

The fishing year coincides with the calendar year, January 1 to December 31 (§ 679.2 and 679.23). Depending on the target species' spatial allocation (detailed below), additional specifications are made to particular seasons (quarters of the year or combinations of quarters) within the year. Fisheries are opened and closed by regulatory announcement. Closures are made when inseason information indicates the apportioned TAC or available prohibited species catch (PSC) has been or will soon be reached, or at the end of the specified season, if the particular TAC has not been taken.

Catch accounting in the U.S. groundfish fisheries is divided into species that must be discarded (§ 679.20(d)(2) and 679.21(b)) and those that may be or are required to be retained (§ 679.20(e) and (f) and 679.27). Of the total TAC, 10% of the allowable catch for all species is first allocated to the Community Development Quota program in the BSAI (§ 679.31(a) and (b)(1)(iii)). The rest of the TAC is then apportioned to directed fishery or bycatch reserve according to spatial and temporal management measures that apply. These measures are detailed below, beginning with the BSAI and noting differences in the GOA, if any. Unless specified otherwise, in both FMP areas, trawl gear may only fish from January 20 though December 31 (§ 679.23(c)). The remaining gear types may start fishing January 1 (§ 679.23 (a)).

Pollock is allocated between inshore and offshore components of the fishery and further distributed within seasons. On October 21, 1998, the President signed into law the American Fisheries Act (AFA), which changed the allocation scheme for pollock in the BSAI beginning in 1999. Under the AFA, 10% of the pollock TAC is allocated to the CDQ program and the remaining 90 percent of the TAC, after subtraction of an allowance for incidental catch in other fisheries, is allocated 50% to vessels delivering to the inshore sector, 40% to catcher processors and catcher vessels delivering to catcher processors, and 10% to catcher vessels delivering to motherships. These new allocation percentages mandated by the AFA represent a shift of 15% of the TAC from the offshore to the inshore sectors.

The AFA also contains a number of additional measures that affect the BSAI pollock and Atka mackerel fisheries:

! The AFA increases the US ownership requirement to 75% for vessels with US fisheries endorsements and prohibits new fisheries endorsements for vessels greater than 165 ft, LOA, greater than 750 gross registered tons, or with engines capable of producing greater than 3,000 shaft horsepower.

! Under the provisions of a $90 million buyout, nine factory trawlers will be lose their US fisheries endorsements on January 1, 1999 and eight of these vessels will be scrapped.

! Vessels and processors eligible to participate in the offshore, mothership, and inshore sectors are identified in the AFA creating a closed class of vessels eligible to participate in the BSAI pollock fishery.

! Vessels catching pollock for the offshore, mothership and inshore sectors are authorized to form harvesters cooperatives under which the various participants may agree to divide up the TAC among themselves.

! The AFA establishes various limits on the ability of BSAI pollock vessels and processors to participate in other fisheries. These limits are designed to prevent pollock vessels and processors from using the flexibility of a cooperative to increase their level of participation in other fisheries.

Pending emergency rule-making procedures, the BSAI and GOA pollock fisheries will be split into four seasons, beginning January 20, February 20, August 1, and September 15 in the BSAI fishery and January 20, June 1, September 1, and no later than October 1 but no sooner than 5 days after the close of the September season in the GOA fishery.

Pacific cod is allocated between trawl, 'fixed' gear and jig gear in the BSAI (§ 679.20(a)(7)). Within trawl gear, Pacific cod is further allocated between trawlers that catch and process Pacific cod and those that catch and deliver Pacific cod to a mothership or shore based processor (§ 679.20(a)(7)(I)(B)). In the GOA, Pacific cod is allocated between the processing components, 90% to inshore and 10% to offshore (§ 679.20(a)(6)(iii)).

Sablefish are allocated between trawl and hook-and-line (longline) gear in both the BSAI and GOA (§ 679.20(a)(4)). In the eastern regulatory Area, trawl gear may only retain sablefish as bycatch in other trawl fisheries (§ 679.20(a)(4)(I)). The hook-and-line allocation is utilized entirely by an individual quota program (IFQ). Each year the Regional Administrator determines the opening and closing dates of the IFQ sablefish fishery, taking into account the opening date of the Pacific halibut fishery so that they may be concurrent (§ 679.23(g)(1)). Since the beginning of the IFQ management program, the open season for hook-and-line gear has been from March 15 through November 15 each fishing year in both FMP areas. The IFQ season for longline pot gear in the BSAI is from March 15 through May 30 and from June 30 through November 15 (§ 679.24(c)(4)(ii)).

Atka mackerel in the eastern Aleutian and Bering Sea may be allocated up to 2% of the initial TAC to jig gear (§ 679.20(a)(8)). No open season is set for Atka mackerel in the GOA (§ 679.20 (d)(1)(ii)).

Flatfish in both the BSAI and GOA are not allocated to gear or subject to seasonal apportionments except for arrowtooth flounder and Greenland turbot in the BSAI, for which directed fishing is open from May 1 through December 31 (§ 679.23(e)(1)). It should, however, be noted that the harvest of these targets is severely constrained by prohibited species catch limits which are specified by season, area, and gear type, as discussed below.

Rockfish fisheries open July 1 for trawl gear and January 1 for other gear types and close December 31 in both FMP areas (§ 679.23(d)(1) and § 679.21(e)(3)(I)) if the NMFS determines the TACs available are large enough to manage the fishery. BSAI Plan Amendment 53 allocated 70% of the shortraker and rougheye rockfish TAC in the Aleutian Islands subarea to trawl gear and 30% to non-trawl gear (63 FR 40190). For several rockfish targets the Regional Administrator has established a directed fishery allowance of 0 mt after considering the amount of incidental catch expected in other directed fisheries (§ 679.20(d)(1)(ii)). These actions have effectively closed directed fishing for rockfish throughout the year in all, or portions of, the BSAI and GOA. Examples include: Pacific ocean perch, and other red rockfish in the BSAI (shortraker/rougheye, “other”, northern rockfish, and thornyheads in the GOA).

Other species in the BSAI consist of sculpins, skates, sharks, and octopus; a separate ABC and TAC is established for squid. In the GOA, the "other species" assemblage includes sculpins, skates, sharks, squid, and octopus. The GOA FMP specifies that the annual TAC for these species is 5% of the sum of the combined TACs for other groundfish targets.

In some situations, if the TAC is not taken during its first available season, it can be reapportioned to a later season (§ 679.20(a)(5)(ii)(B)(1) and (a)(7)(iv)(C)). Also in some situations, if a TAC allocation cannot be fully utilized by the component or gear type it was first allocated to, it may, by management action, be reallocated to a different component or gear type (§ 679.20(a)(6)(v) and (a)(7)(ii)).

2.1.3 1999 TAC recommendations

Recommended TACs for 1999 groundfish fisheries in the BSAI region are listed in Table 2. Recommended TACs for 1999 groundfish fisheries in the GOA region are listed in Table 3.

2.1.4 Life History and Stock Status Descriptions of Target Species

This section presents descriptions of major target species summarizing important life history traits, prey base, stock status, and overview of scientific management information about the stocks.

2.1.4.1 Walleye pollock

Stock Description and Life History

Walleye pollock (*Theragra chalcogramma*, hereafter referred to as pollock) is the most abundant species within the eastern Bering Sea (EBS) and the second most abundant groundfish stock in the GOA. Pollock is widely distributed throughout the North Pacific in temperate and subarctic waters (Wolotira *et al*. 1993). Pollock is a semidemersal schooling fish, which becomes increasingly demersal with age. Approximately 50% of female pollock reach maturity at age four at a length of approximately 40 cm. Pollock spawning is pelagic and takes place in the early spring on the outer continental shelf. In the EBS the largest concentrations occur in the southeastern portion of the EBS (north of Unimak Pass). In the GOA, the largest spawning concentrations in Shelikof Strait and the Shumagin Islands (Kendall *et al*. 1996). Juvenile pollock are pelagic and feed primarily on copepods and euphausiids. As they age, pollock become increasingly piscivorous and can be highly cannibalistic, with smaller pollock being a major food item (Livingston 1991b). Pollock are comparatively short-lived, with fairly high natural mortality rate estimated at 0.3 (Hollowed *et al*. 1997, Wespestad and Terry 1984) and maximum recorded age of around 22 years.

Although stock structure of Bering Sea pollock is not well defined (Wespestad 1993), three stocks of pollock are recognized in the BSAI for management purposes; eastern Bering Sea, Aleutian Islands and Aleutian Basin (Wespestad *et al*. 1997). Pollock in the GOA are thought to be a single stock (Alton and Megrey 1986) originating from springtime spawning in Shelikof Strait (Brodeur and Wilson 1996).

Fishery

Pollock supports the largest fishery in Alaskan waters. In the BSAI, pollock comprise 75-80% of the catch. In the Gulf, pollock constitute 25-50% of the catch. Most pollock (91%) is taken with pelagic trawl gear, the remainder with bottom trawl gear.

The directed fishery for BSAI pollock is prosecuted by catcher-processor and catcher vessels using pelagic and bottom trawl gear. The season is broken into two parts, a roe season during early winter, and a surimi/filet season during the second half of the year. The TAC is usually divided 45:55 between these two seasons. Observed pollock fishery trawl locations in the BSAI in 1995-1997 are shown by season in Figures 3 and 4. BSAI pollock are caught as bycatch in other directed fisheries but because they occur primarily in well defined aggregations, the impact of this bycatch is typically minimal. Most discard of pollock occurs in the non-directed pollock trawl fisheries (72% of all discards in 1996). Recent discard rates (discards/retained catch) of pollock in the directed fishery have been about 7% (Wespestad *et al*. 1997). Pollock are caught as bycatch in the trawl Pacific cod, rock sole, and yellowfin sole fisheries. In 1996, 21,000 mt of pollock were discarded in the directed fishery compared to 55,200 mt discarded in all other fisheries (Wespestad *et al*. 1997). Starting in 1998, discarding of pollock is prohibited except in the fisheries where pollock are in bycatch only status.

In the GOA, major exploitable concentrations are found primarily in the central and western regulatory areas (147° - 170° W). Pollock from this region are managed as a single stock that is separate from the Bering Sea and Aleutian Island pollock stocks (Alton and Megrey 1986). The pattern of the fishery generally the broad spatial distribution of pollock throughout the central and western regions of the GOA. Shifts in the location of fishable concentrations of pollock reflect the seasonal migrations to spawning locations. The fishery generally occurs at depths between 100 and 200 m (Hollowed *et al*. 1997). Observed pollock fishery trawl locations in the GOA in 1995-1997 are shown by season in Figures 5, 6, and 7. Important pollock fishery locations include Shelikof Strait, the canyon regions of the eastside of Kodiak Island, and Shumagin Canyon.

Megrey (1989) documented the historical expansion of the pollock fishery in the GOA. He identified four phases of expansion, beginning with a developmental phase between 1964-1971 when the fishery was dominated by foreign trawlers that captured pollock incidentally in mixed species catches. The second phase occurred between 1972 and 1980 when directed pollock harvests were initiated by foreign and joint venture fisheries. Floating freezer-surimi trawlers were active in the GOA during the second phase of fishery development. The third phase of development occurred between 1981- 1985. This phase was characterized by joint venture operations. During this period the Shelikof Strait spawning concentrations were discovered. Surimi production and roe harvest were emphasized during this phase of development. In more recent years, foreign vessels have been eliminated from the pollock fishery. This final phase was marked by the passage of the in-shore off-shore amendment which mandated that 100% of pollock catch would be processed at shoreside plants. During this period the fishing community moved from a bottom trawl fishery to a mid-water fishery due to management measures established to control bycatch of prohibited species. Pacific halibut taken in the pollock fishery are added to the total for the shallow water complex halibut mortality cap. When the halibut cap is reached for the shallow water complex, trawling for species in the complex is prohibited except for vessels using pelagic trawls.

Trophic Interactions

The diet of pollock in the eastern Bering Sea has been studied extensively (Dwyer 1984, Lang and Livingston 1996, Livingston 1991b, Livingston and DeReynier 1996, Livingston *et al*. 1993). These studies have shown that juvenile pollock is the dominant fish prey in the eastern Bering Sea; other fish are also consumed by pollock including juveniles of Pacific herring, Pacific cod, arrowtooth flounder, flathead sole, rock sole, yellowfin sole, Greenland turbot, Pacific halibut and Alaska plaice. On the shelf area of the EBS, the contribution of these other fish prey to the diet of pollock tends to be very low (i.e., usually less than 2% by weight of the diet; (Livingston 1991b, Livingston and DeReynier 1996, Livingston *et al*. 1993). However, in the deeper slope waters, deep-sea fish (myctophids and bathylagids) are a relatively important diet component (12% by weight), along with euphausiids, pollock, pandalid shrimp and squid (Lang and Livingston 1996).

The cannibalistic nature of pollock, particularly adults feeding on juveniles, is well-documented by field studies in the eastern Bering Sea (Bailey 1989a, Dwyer *et al*. 1987, Livingston 1989b, 1991b, Livingston and DeReynier 1996, Livingston and Lang 1997, Livingston *et al*. 1993). As mentioned previously, cannibalism by pollock in the Aleutian Islands region has not yet been documented (Yang 1996).

Cannibalism rates in the eastern Bering Sea vary depending on year, season, area, and predator size (Dwyer *et al*. 1987, Livingston 1989b, Livingston and Lang 1997). Cannibalism rates are highest in autumn, next highest in summer, and lowest in spring. Cannibalism rates by pollock larger than 40cm are higher than those by pollock less than 40cm. Most pollock cannibalized are age-0 and age-1 fish, with most age-1 pollock being consumed northwest of the Pribilof Islands where most age-1 pollock are found. Pollock larger than 50 cm tend to consume most of the age-1 fish. Smaller pollock consume mostly age-0 fish. Although age-2 and age-3 pollock are sometimes cannibalized, the frequency of occurrence of these age groups in the stomach contents is quite low. Laboratory studies have shown the possibility of cannibalism among age-0 pollock (Sogard and Olla 1993). Field samples have confirmed this interaction, but so far this interaction appears not to be very important.

Field and laboratory studies on juvenile pollock have examined behavioral and physical factors that may influence vulnerability of juveniles to cannibalism (Bailey 1989a, Olla *et al*. 1995, Sogard and Olla 1993, 1996). Although it had previously been hypothesized that cannibalism occurred only in areas with no thermal stratification, these recent studies show that age-0 pollock do move below the thermocline into waters inhabited by adults. Larger age-0 fish tend to move below the thermocline during the day, and all age-0 fish tend to inhabit surface waters at night for feeding. Most cannibalism may occur during the day. If food availability is high, all sizes tend to stay above the thermocline, but when food resources are low then even small age-0 fish do move towards the colder waters as an energy-conserving mechanism. Thus, prediction of cannibalism rates may require knowledge of the thermal gradient and food availability to juveniles in an area.

Various studies have modeled pollock cannibalism in either a static or dynamic fashion (Dwyer 1984, Honkalehto 1989, Knechtel and Bledsoe 1981, 1983, Laevastu and Larkins 1981, Livingston 1991a, 1994, Livingston *et al*. 1993). The Knechtel and Bledsoe (1983) size-structured simulations produced several conclusions regarding cannibalism. Under conditions simulating the current fishing mortality rate ($F=0.3yr^{-1}$) the population tended toward equilibrium. They also found that cannibalism is a stabilizing influence, with the population showing less variation compared to simulations in which cannibalism was not included. Zooplankton populations were also simulated in the model, and Knechtel and Bledsoe concluded that food was limiting, particularly for adult pollock. Maximization of average catch occurred at an extremely high F value ($F=3.0\ yr^{-1}$) that is about ten times higher than the actual fishing mortality rates in the eastern Bering Sea. However, the interannual variation in catches under this hypothetical scenario were extremely large.

The trend in more recent modeling efforts (Honkalehto 1989, Livingston 1993, 1994) has been to examine cannibalism using more standard stock assessment procedures such as virtual population analysis or integrated catch-age models such as Methot's (1990) synthesis model. The purpose is to obtain better estimates of juvenile pollock abundance and mortality rates, which can improve our knowledge of factors affecting recruitment of pollock into the commercial fishery at age 3. Results from Livingston (1993, 1994) highlight several points with regard to cannibalism. In the current state of the eastern Bering Sea, cannibalism appears to be the most important source of predation mortality for age-0 and age-1 pollock. Predation mortality rates for juvenile pollock are not constant, as assumed in most population assessment models, but vary across time mainly due to changes in predator abundance but perhaps also due to predators feeding more heavily on more abundant year classes. The decline in pollock recruitment observed at high pollock spawning biomasses appears to be due to cannibalism. There also appears to be an environmental component to juvenile pollock survival (Wespestad *et al*. 1997), wherein surface currents during the first 3 months of life may transport larvae to areas more favorable to survival (e.g., away from adult predators or in areas more favorable for feeding). Estimates of total amount of pollock consumed by important groundfish predators show that cannibalism is the largest source of removal of juvenile pollock by groundfish predation (Livingston 1991a, Livingston and DeReynier 1996, Livingston *et al*. 1993).

Other groundfish predators of pollock include Greenland turbot, arrowtooth flounder, Pacific cod, Pacific halibut, and flathead sole (Livingston 1991a, Livingston and DeReynier 1996, Livingston *et al*. 1986, 1993). These species are some of the more abundant groundfish in the eastern Bering Sea, and pollock constitutes a large proportion of the diet for many of them. Other less abundant species that consume pollock include Alaska skate, sablefish, Pacific sandfish, and various sculpins (Livingston 1989a, Livingston and DeReynier 1996). Small amounts of juvenile pollock are even eaten by small-mouthed flounders such as yellowfin sole and rock sole (Livingston 1991a, Livingston and DeReynier 1996, Livingston *et al*. 1993). Age-0 and age-1 pollock are the targets of most of these groundfish predators, with the exception of Pacific cod, Pacific halibut, and Alaska skate, which may consume pollock ranging in age from age 0 to greater than age 6 depending on predator size.

Pollock is a significant prey item of marine mammals and birds in the eastern Bering Sea and has been the focus of many studies. Studies suggest that pollock is a primary prey item of northern fur seals when feeding on the shelf during summer (Sinclair *et al*. 1997, 1994). Squid and other small pelagic fish are also eaten in slope areas or in other seasons. The main sizes of pollock consumed by fur seals range from 3-20 cm or age-0 and age-1 fish. Older age classes of pollock may appear in the diet, during years of lower abundances of young pollock (Sinclair *et al*. 1997). Pollock has been noted as a prey item for other marine mammals including northern sea lion, harbor seal, fin whales, minke whales, and humpback whales but stomach samples from these species in the eastern Bering Sea have been very limited so the importance of pollock in the diets has not been well-defined (Kajimura and Fowler 1984). Pollock are one of the most common prey in the diet of spotted seals and ribbon seals, which feed on pollock in the winter and spring in the areas of drifting ice (Lowry *et al*. 1997).

Essentially five species of piscivorus birds are dominant in the avifauna of the eastern Bering Sea: northern fulmar, red-legged kittiwake, black-legged kittiwake, common murre, and thick-billed murre (Kajimura and Fowler 1984, Schneider and Shuntov 1993). Pollock is sometimes the dominant component in the diets of northern fulmar, black-legged kittiwake, common murre and thick-billed murre while red-legged kittiwakes tend to rely more heavily on myctophids (Hunt *et al*. 1981, Kajimura and Fowler 1984, Springer *et al*. 1986). Age-0 and age-1 pollock are consumed by these bird species, and the dominance of a particular pollock age-class in the diet varies by year and season. Fluctuations in chick production by kittiwakes have been linked to the availability of fatty fishes such as myctophids, capelin and sandlance (Hunt *et al*. 1995). Changes in the availability of prey, including pollock, to surface-feeding seabirds may be due to changes in sea surface temperatures and the locations of oceanographic features such as fronts which could influence the horizontal or vertical distribution of prey (Decker *et al*. 1995, Springer 1992).

The diet of pollock, particularly adults, in the GOA has not been studied as thoroughly as in the eastern Bering Sea. Larvae, 5-20 mm in length, consume larval and juvenile copepods and copepod eggs (Canino 1994, Kendall *et al*. 1987). Early juveniles (25-100 mm) of pollock in the GOA primarily eat juvenile and adult copepods, larvaceans, and euphausiids while late juveniles (100-150 mm) eat mostly euphausiids, chaetognaths, amphipods, and mysids (Brodeur and Wilson 1996, Grover 1990a, Krieger 1985, Livingston 1985, Merati and Brodeur 1997, Walline 1983). Juvenile and adult pollock in southeast Alaska rely heavily on euphausiids, mysids, shrimp and fish as prey (Clausen 1983). Euphausiids and mysids are important to smaller pollock and shrimp and fish are more important to larger pollock in that area. Copepods are not a dominant prey item of pollock in the embayments of southeast Alaska but appear mostly in the summer diet. Similarly, the summer diet of pollock in the central and western GOA does not contain much copepods (Yang 1993). Euphausiids are the dominant prey, constituting a relatively constant proportion of the diet by weight across pollock sizes groups. Shrimp and fish are the next two important prey items.

Fish prey become an increasing fraction of the pollock diet with increasing size in the GOA. Over 20 different species of fish have been identified in the stomach contents of pollock from this area but the dominant fish consumed is capelin (Yang 1993). A high diversity of prey fish were also found in pollock stomachs. Commercially important fish prey included: Pacific cod (*Gadus macrocephalus*), pollock, arrowtooth flounder (*Atheresthes stomias*), flathead sole (*Hippoglossoides elassodon*), Dover sole (*Microstomus pacificus*), and Greenland halibut (*Reinhardtius hippoglossoides*). Forage fish such as capelin (*Mallotus villosus*), eulachon (*Thaleichthys pacificus*) and Pacific sand lance (*Ammodytes hexapterus*), were also found in pollock stomach contents.

Dominant populations of groundfish in the GOA that prey on pollock include arrowtooth flounder, sablefish, Pacific cod, and Pacific halibut (Albers and Anderson 1985, Best and

St-Pierre 1986, Jewett 1978, Yang 1993). Pollock is one of the top five prey items (by weight) for Pacific cod, arrowtooth flounder, and Pacific halibut. Other prey fish of these species include Pacific herring and capelin (an osmerid fish). Other predators of pollock include great sculpins (Carlson 1995) and shortspined thornyheads (Yang 1993). As found in the eastern Bering Sea, Pacific halibut and Pacific cod tend to consume larger pollock, and arrowtooth flounder consumes pollock that are mostly less than age 3. Unlike the eastern Bering Sea, however, the main source of predation mortality on pollock at present appears to be from the arrowtooth flounder (Livingston 1994). Stock assessment authors have attempted to incorporate predation mortality by arrowtooth flounder, Pacific halibut, and sea lions in the stock assessment for pollock in the GOA (Hollowed *et al*. 1997).

Research on the diets of marine mammals and birds in the GOA was less intensive for the Bering Sea, but recently has been greatly accelerated (Brodeur and Wilson 1996, Calkins 1987, DeGange and Sanger 1986, Hatch and Sanger 1992, Lowry *et al*. 1989, Merrick and Calkins 1996, Pitcher 1980a, 1980b, 1981). Brodeur and Wilson's (1996) review summarized both bird and mammal predation on juvenile pollock. The main piscivorus birds that consume pollock in the GOA are black-legged kittiwakes, common murre, thick-billed murre, tufted puffin, horned puffin, and probably marbled murrelet. The diets of murres have been shown to contain around 5% to 15% age-0 pollock by weight depending on season. The tufted puffin diet is more diverse and tends to contain more pollock than that of the horned puffin (Hatch and Sanger 1992). Both horned puffins and tufted puffins consume age-0 pollock. The amount of pollock in the diet of tufted puffin varied by region in the years studied, with very low amounts in the north-central Gulf and Kodiak areas, intermediate (5-20%) amounts in the Semidi and Shumagin Islands, and large amounts (25-75%) in the Sandman Reefs and eastern Aleutians. The proportion of juvenile pollock in the diet of tufted puffin at the Semidi Islands varied by year and was related to pollock yearclass abundance.

Walleye pollock is a major prey of Steller sea lions and harbor seals in the GOA (Merrick and Calkins 1996, Pitcher 1980a, 1980b, 1981). Harbor seals tend to have a more diverse diet, and the occurrence of pollock in the diet is lower than in sea lions. Pollock is a major prey of both juvenile and adult Steller sea lions in the GOA. It appears that the proportion of animals consuming pollock increased from the 1970s to the 1980s, and this increase was most pronounced for juvenile Steller sea lions. Sizes of pollock consumed by Steller sea lions range from 5-56cm and the size composition of pollock consumed appears to be related to the size composition of the pollock population. However, juvenile sea lions consume smaller pollock on average than adults. Age-1 pollock was dominant in the diet of juvenile Steller sea lions in 1985, possibly a reflection of the abundant 1984 year class of pollock available to sea lions in that year.

Stock Assessment

Currently, information on pollock in the eastern Bering Sea comes from the NMFS observers aboard commercial fishing vessels, annual trawl surveys, and triennial echo integration (hydroacoustic) trawl surveys. In the Aleutian Islands, information comes from observer data and triennial bottom trawl surveys. In the GOA, stock assessment information is based on observer and port sampling data, annual hydroacoustic surveys in the Shelikof Straits area, and triennial bottom trawl surveys. These different data sets are analyzed simultaneously to obtain an overall view of each stock's condition. 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 not available to bottom trawls and much of the Aleutian Islands shelf is untrawlable due to rough bottom.

In the eastern Bering Sea walleye pollock are assessed with an age-structured model incorporating fishery and two types of survey catch data and age compositions. Bottom trawl surveys are conducted annually during June through August and provide a consistent time series of adult population abundance from 1982-1997. Echo-integrated trawl surveys are run every three years (typically) and provide an abundance index on more pelagic (typically younger) segments of the stock. Both surveys dispose their catches into their relative age compositions prior to analyses. Fishery data include estimates of the total catch by area/time strata and also the average body weight-at-age and relative age composition of the catch within each stratum. The results of the statistical model applied to these data are updated annually and presented in the BSAI pollock chapter of the NPFMC BSAI SAFE report. Also included are separate analyses on pollock stocks in the Aleutian Islands and Bogoslof areas. These analyses are constrained by data limitations and are presented relative to the status of the eastern Bering Sea (EBS) stock. This analysis focused specifically on the EBS stock with the view that extensions to these other areas are equally applicable. The stock assessment is reviewed by the NPFMC Plan Team, the Scientific and Statistical Committee, and presented to the Council.

The estimated 1998 age composition of EBS pollock from the stock assessment model is shown in Figure 8. Ages four through 15 represent the recruited population (Fig. 8 shows only to age 9). The age composition has been dominated by strong year classes—most recently there appears to be higher than average 1992 year class (age 6), and prior to that the 1989 (age 9) year class was very high. The abundance of these year classes is evident from the EIT and bottom trawl surveys in addition to the extensive fishery age-composition data that have been collected. The selectivity of the fishery has cumulative impacts on the age composition due to fishing mortality. The fishery has tended to exhibit variable selectivity over time, but generally targets fish aged 5 years and older.

Pollock in the GOA are also assessed with an age-structured model incorporating fishery and survey data. The data used in this analysis consist of estimates of total catch biomass, bottom trawl biomass estimates, Echo Integration Trawl (EIT) survey estimates of the spawning biomass in Shelikof Strait, egg production estimates of spawning biomass in Shelikof Strait, fisheries catch at age and survey size and age compositions. Fishery catch statistics (including discards) are estimated by the NMFS Alaska Regional Office. These estimates are based on the best blend of observer-reported catch and weekly production reports. Age composition data are obtained from several sources including catch at age aggregated over all seasons, nations, vessel classes and INPFC statistical areas for the years, and numbers at age from the spring EIT survey and the bottom trawl surveys. An additional estimate of the age composition of the population in 1973 was available from a bottom trawl survey of the GOA. Length frequency data collected from the EIT survey are also included in the model, as is historical information on pollock size composition obtained from the Japanese Pacific ocean perch fishery from the period 1964-1975 (Hollowed *et al*. 1991). Recent assessments have explored the impact of predation mortality by arrowtooth flounder, Pacific halibut and Steller sea lions by incorporating time series of estimated predator biomass, the age composition of pollock consumed by predators, and estimated consumption rates (Hollowed *et al*. 1997).

The current age and size distributions of GOA pollock are discussed in Hollowed *et al*. (1997). The estimated 1997 age composition of pollock from the stock assessment model is shown in Figure 9. Ages 3 through 15 represent the recruited population (the Figure only shows through age 10), although reliable estimates of abundance for ages 2 and above exist. The age composition is dominated by a recent strong 1994 year class; large numbers from the strong 1988 year class are still in the population. The estimated mean age of the recruited portion of the population in 1997 was 4 years.

Over the last 15 years, NOAA's Fisheries Oceanography Coordinated Investigations (FOCI) targeted much of their research on understanding processes influencing recruitment of pollock in the GOA. These investigations led to the development of a conceptual model of factors influencing pollock recruitment (for complete review collection of papers (Kendall *et al*. 1996)). Bailey *et al*. (1996) reviewed 10 years of data for evidence of density dependent mortality at early life stages. Their study revealed evidence of density dependent mortality only at the late larval to early juvenile stages of development. Bailey *et al*. (1996) hypothesize that pollock recruitment levels can be established at any early life stage (egg, larval or juvenile) depending on sufficient supply from prior stages. He labeled this hypothesis the supply dependent multiple life stage control model. In a parallel study, Megrey *et al*. (1996) reviewed data from FOCI studies and identified several events that are important to survival of pollock during the early life history period. These events are climatic events (Hollowed and Wooster 1995, Stabeno *et al*. 1995), preconditioning of the environment prior to spawning (Hermann *et al*. 1996), the ability of the physical environment to retain the planktonic life stages of pollock on the continental shelf (Bograd *et al*. 1994, Schumacher *et al*. 1993), and the abundance and distribution of prey and predators on the shelf (Bailey and Macklin 1994, Canino 1994, Theilacker *et al*. 1996). Thus, the best available data suggest that pollock year-class strength is controlled by sequences of biotic and abiotic events and that population density is only one of several factors influencing pollock production.

In both the BSAI and GOA, cumulative impacts of fishing mortality on the age composition are influenced by the selectivity of the fishery. The current age compositions of the stocks reflect a fished population with a long catch history. In any given year, the age composition of the stock is influenced by previous year class strength. The reproductive potential of the stock in a given year is dependent on the biomass of spawners as modified by abiotic and biotic conditions. Thus, it is likely that the average age of unfished populations would have varied inter-annually due to the history of oceanic and climate conditions. The NMFS's Fisheries Oceanography Coordinated Investigations (FOCI) and the Coastal Ocean Program's Southeast Bering Sea Carrying Capacity (SEBSCC) regional study focus research on improving our understanding of mechanisms underlying annual production of pollock stocks in the GOA and EBS. NOAA's long-term goal is to improve our ability to assess quantitatively the long term impact of commercial removals of adult pollock on future recruitment by combining the findings of process-oriented research programs such as FOCI and SEBSCC with NMFS's on-going studies of species interactions, fish distributions, and abundance trends. In this supplemental environmental impact statement, we did not seek to evaluate the range of mean ages that could have occurred in the absence of fishing.

ABC as Recommended in the Most Recent Stock Assessments

The general impacts of fishing mortality within the ABC/OFL definitions are discussed in the beginning of the section and apply to walleye pollock. Specifically, EBS pollock fell into tier 3a of the ABC/OFL definitions in 1997, which require reliable estimates of biomass, $B_{40\%}$, $F_{30\%}$, and $F_{40\%}$. Under the definitions and current stock conditions, the overfishing fishing mortality rate is the $F_{30\%}$ rate which is 0.65 for pollock and equates to a yield of 2.3 million mt (Wespestad *et al*. 1997). The maximum allowable fishing mortality rate for ABC (F_{ABC}) is the $F_{40\%}$ rate which is 0.36 for pollock and translates to a yield of 1.49 million mt. The current ABC recommendation for pollock from the stock assessment is 1.1 million mt, well below the maximum rate prescribed under tier 3a. This lower level has been adjusted downwards to provide a risk-averse harvest rate which more accurately reflects the degree of uncertainty.

In 1997, GOA pollock fell into tier 3 of the ABC/OFL definitions, which require reliable estimates of biomass, $B_{40\%}$, $F_{30\%}$, and $F_{40\%}$. Under the definitions and current stock conditions, the overfishing rate is the fishing mortality rate that reduces the spawner stock biomass to 30% of its unfished level (the $F_{30\%}$ rate). In 1997, the full recruitment fishing mortality $F_{30\%}$ rate was 0.517 for pollock and equated to a yield of 170,500 mt for the Central and Western GOA (Hollowed *et al*. 1997). The projected 1998 spawner stock biomass fell below $B_{40\%}$, therefore the maximum allowable fishing mortality rate for ABC (F_{ABC}) was the adjusted $F_{40\%}$ rate 0.341 (Hollowed *et al*. 1997). This FABC translated to a yield projection of 120,800 mt in 1998 for the western and central regions. The 1998 Council ABC level was 120,800 mt for the western and central regions, which was equivalent to the recommended stock assessment ABC, and equivalent to the TAC. Current harvest rates were set to ensure a healthy spawning stock of sufficient size to ensure successful recruitment over long time periods and recruitment variations.

2.1.4.2 Pacific Cod

Stock Description and Life History

Pacific cod is a demersal species that occurs on the continental shelf and upper slope from Santa Monica Bay, California through the GOA, Aleutian Islands, and eastern Bering Sea to Norton Sound (Bakkala 1984). The Bering Sea represents the center of greatest abundance, although Pacific cod are also abundant in the GOA and Aleutian Islands (Outer Continental Shelf Environmental Assessment Program 1987). Gulf of Alaska, Bering Sea, and Aleutian Islands cod stocks are genetically indistinguishable (Grant *et al*. 1987), and tagging studies show that cod migrate seasonally over large areas (Shimada and Kimura 1994).

In the late winter, Pacific cod converge in large spawning masses over relatively small areas. Major aggregations occur between Unalaska and Unimak Islands, southwest of the Pribilof Islands and near the Shumagin group in the western Gulf (Shimada and Kimura 1994). Spawning takes place in the sublittoral-bathyal zone (40-290 m) near the bottom. The eggs sink to the bottom and are somewhat adhesive (Hirschberger and Smith 1983).

Pacific cod reach a maximum recorded age of 19. Estimates of natural mortality vary widely and range from 0.29 (Thompson and Shimada 1990) to 0.83-0.99 (Ketchen 1964). For stock assessment purposes, a value of 0.37 is used in both the BSAI (Thompson *et al*. 1997) and the Gulf (Thompson and Dorn 1997). In the BSAI, 50% of Pacific cod are estimated to reach maturity by 5.7 years at a length of 67 cm (Thompson *et al*. 1997).

Trophic Interactions

Pacific cod are omnivorous. Livingston (1991b) characterized the diet of Pacific cod in the BSAI and GOA as follows: In terms of percent occurrence, the most important items were polychaetes, amphipods, and crangonid shrimp; in terms of numbers of individual organisms consumed, the most important items were euphausiids, miscellaneous fishes, and amphipods; and in terms of weight of organisms consumed, the most important items were pollock, fishery offal, and yellowfin sole. Small Pacific cod were found to 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 (Westrheim 1996).

Fishery

The Pacific cod fishery is the second largest Alaskan groundfish fishery. In 1997, Pacific cod constituted 13% of groundfish catch in the BSAI and 30% of the groundfish catch in the GOA. The fishery for Pacific cod is conducted with bottom trawl, longline, pot, and jig gear. Of these, the fishery conducted with jig gear is by far the smallest. More than 100 vessels participate in each of the three larger fisheries. The age at 50% recruitment varies between regions. For trawl, longline, and pot gear, the age at 50% recruitment is 4 years in the EBS (Thompson and Dorn 1997) and 5 years in the GOA (Thompson *et al*. 1997). The trawl fishery is typically concentrated during the first few months of the year, whereas fixed-gear fisheries may sometimes run essentially year-round. Bycatch of crab and halibut often causes the Pacific cod fisheries to close prior to reaching the TAC. In the EBS, 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 Shumagins. Pacific cod is also taken as bycatch in a number of trawl fisheries. In the EBS, Pacific cod is taken as bycatch in the trawl fisheries for pollock, yellowfin sole, and rock sole. In the Aleutian Islands region, Pacific cod is taken as bycatch in the trawl fishery for Atka mackerel. In the GOA, Pacific cod is taken as bycatch in the trawl fisheries for shallow-water flatfish, arrowtooth flounder, and flathead sole. In each of the above-mentioned fisheries, annual discards of Pacific cod have comprised at least 1% of the total Pacific cod catch from all fisheries in the area. Pacific cod is also discarded in its own directed fisheries (specifically, the directed trawl fisheries in all three areas and the directed longline fisheries in the EBS and Aleutian Islands region). Starting in 1998, discarding is prohibited except in the fisheries where Pacific cod are in bycatch only status.

Stock Assessment

Beginning with the 1993 BSAI SAFE report (Thompson and Methot 1993) and the 1994 GOA SAFE report (Thompson and Zenger 1994), a length-based Synthesis model (Methot 1990) has formed the primary analytical tool used to assess Pacific cod (*Gadus macrocephalus*). Although the Pacific cod stocks in the EBS and GOA are modeled separately, the model structures in recent years have been identical (Thompson and Dorn 1997, Thompson *et al*. 1997). No formal assessment model exists for the Aleutian Islands portion of the BSAI stock. Instead, results from the EBS assessment are inflated proportionally to account for Aleutian Islands fish.

Annual trawl surveys in the eastern Bering Sea and triennial trawl surveys in the Aleutian Islands and Gulf are the primary fishery-independent sources of data for Pacific cod stock assessments (Thompson and Dorn 1997, Thompson *et al*. 1997). For the most recent assessments, fishery size compositions were available, by gear, for the years 1978 through the first part of 1997. The catch history was divided into two portions determined by the relative importance of the domestic fishery. A “pre-domestic” portion was defined as those years in which the domestic fishery took less than half the catch, and a “domestic” portion was defined as those years in which the domestic fishery took at least half the catch. Within each year (in both portions of the time series), catches were divided according to three time periods: January-May, June-August, and September-December. This particular division, which was suggested by participants in the EBS fishery, is intended to reflect actual intra-annual differences in fleet operation (e.g., fishing operations during the spawning period may be different than at other times of year). Four fishery size composition components were included in the likelihood functions used to estimate model parameters: the period 1 trawl fishery, the periods 2-3 trawl fishery, the longline fishery, and the pot fishery. In addition to the fishery size composition components, likelihood components for the size composition and biomass trend from the bottom trawl surveys were included in the model. All components were weighted equally.

Quantities estimated in the most recent stock assessments include parameters governing the selectivity schedules for each fishery and survey in each portion of the time series, parameters governing the length-at-age relationship, population numbers at age for the initial year in the time series, and recruitments in each year of the time series. Given these quantities, plus parameters governing natural mortality, survey catchability, the maturity schedule, the weight-at-length relationship, and the amount of spread surrounding the length-at-age relationship, the stock assessments reconstruct the time series of numbers at age and the population biomass trends (measured in terms of both total and spawning biomass). The model around which the most recent Pacific cod assessments are structured uses an assumed survey catchability of 1.0 and an assumed natural mortality rate of 0.37. Other outputs of the assessments include projections of biomass and harvest under a variety of reference fishing mortality rates. Based on these projections, the scientists responsible for conducting the assessments recommend a pair of ABC values for the coming year (one value for the BSAI and one for the GOA).

Pacific cod is currently managed under tier 3 of the Council's ABC and OFL definitions (Amendment 44 to each of the respective FMPs). Management under tier 3 requires reliable estimates of projected biomass, $B_{40\%}$, $F_{40\%}$ (for ABC), and $F_{30\%}$ (for OFL).

ABC as Recommended in the Most Recent Stock Assessments

Under tier 3 of Amendment 44 to the groundfish FMPs, the $F_{40\%}$ rate is the highest harvest rate permissible for stocks projected to be above the $B_{40\%}$ level in the coming year. For the BSAI, the base model in the 1997 assessment projected a 1998 ABC of 255,000 mt under an $F_{40\%}$ harvest strategy (Thompson and Dorn 1997). For the GOA, the base model in the 1997 assessment projected a 1998 ABC of 96,700 mt under an $F_{40\%}$ harvest strategy (Thompson *et al*. 1997). Because the yield corresponding to an $F_{40\%}$ harvest strategy is only the upper limit on ABC under tier 3a, the 1997 assessments considered whether reasons might exist to adopt lower ABC values. In this context, each assessment presented a decision-theoretic analysis of the statistical uncertainty surrounding the respective model's projected $F_{40\%}$ catch level, specifically the uncertainty associated with the assumed values of the natural mortality rate (M=0.37) and survey catch ability coefficient (q=1.0). These analyses resulted in a recommended 1998 ABC of 210,000 mt for the BSAI region and 77,900 mt for the GOA region.

2.1.4.3 Flathead Sole

Flathead sole (*Hippoglossoides elassodon*) is distributed from northern California northward throughout Alaska (Wolotira *et al*. 1993). In the northern part of its range, it overlaps with the related and very similar Bering flounder (*Hippoglossoides robustus*) (Hart 1973). Because it is difficult to separate these two species at sea, they are currently managed as a single stock (Walters and Wilderbuer 1997). Adults are benthic and occupy separate winter spawning and summer feeding distributions. From overwintering grounds near the continental shelf margin, adults begin a migration onto the mid and outer continental shelf in April or May. The spawning period occurs in the spring, primarily in deeper waters near the margins of the continental shelf (Walters and Wilderbuer 1997). Eggs are large and pelagic. Upon hatching, the larvae are planktonic and usually inhabit shallow areas (Waldron and Vinter 1978). Exact age and size at maturity are unknown, but recruitment to the fishery begins at age 3. The maximum age for flathead sole is approximately 20 years. An estimated natural mortality rate of .20 is used for stock assessment (Turnock *et al*. 1997a, Waldron and Vinter 1978). Flathead sole feed primarily on invertebrates (amphipods and decapods). In the eastern Bering Sea, other fish species represented 5-25% of the diet (Livingston *et al*. 1993). Flathead sole are taken in bottom trawls both as a directed fishery and in pursuit of other bottom dwelling species.

In the Bering Sea, flathead sole and Bering flounder are managed as a single unit. The following information is available to assess the unit stock condition:

Data Component	Years of Data
Fishery catch	1977 to 1997
Foreign fishery size composition data	1977 to 1989
Domestic fishery size composition data	1990 to 1996
NMFS trawl survey biomass estimates	1982 to 1997
NMFS trawl survey size composition data	1982 to 1997
NMFS trawl survey age composition data	1980, 1982, 1985, 1992, 1995

Annual trawl survey biomass results have been the primary data component used to assess stock level since 1982, although all the above information was also input into a length-based stock assessment model for the first time in the 1997 stock assessment (Walters and Wilderbuer 1997). The outputs include estimates of abundance, spawning biomass, fishery and survey selectivity, exploitation trends, and projections of future biomass. The model also estimates reference fishing mortality rates in terms of the ratio of female spawning biomass to unfished levels which are used to calculate ABC. The stock assessment is updated annually at the conclusion of the summer trawl survey and is incorporated into the Bering Sea and Aleutian Islands SAFE document.

For information on flathead sole assessment in the GOA see Section 2.1.4.8.

2.1.4.4 Rock Sole

Rock sole are distributed from southern California northward through Alaska (Wolotira *et al*. 1993). Two species of rock sole occur in the North Pacific ocean, a northern rock sole (*Lepidopsetta* sp. cf. *bilineata*) and a southern rock sole (*L. bileneata*). These species have an overlapping distribution in the GOA, but the northern species primarily comprise the BSAI populations where they are managed as a single stock. The distribution of the species overlap in the GOA while the northern species dominates the BSAI (Wilderbuer and Walters 1997b). Adults are benthic and, in the eastern Bering

Sea, occupy separate winter (spawning) and summertime feeding distributions on the continental shelf. Spawning takes place during the late winter-early spring, near the edge of the continental shelf at depths of 125 to 250 m. Eggs are demersal and adhesive (Forrester 1964). The estimated age at 50% maturity for female rock sole is 9-10 years at a length of 35 cm (Wilderbuer and Walters 1997b). The best estimate for natural mortality is 0.18 for the BSAI (Wilderbuer and Walters 1992) and 0.20 for the GOA (Turnock *et al*. 1997a). Rock sole are important as the target of a high value roe fishery occurring in February and March, which accounts for the majority of the BSAI catch. Although female rock sole are highly desirable when in spawning condition, large amounts are discarded in other trawl fisheries during the rest of the year. Commercial harvest occurs primarily on the eastern Bering Sea continental shelf and in lesser amounts in the Aleutian Islands region.

Northern and Southern Rock sole (*Lepidopsetta bilineata*) are managed as a single unit in the BSAI. Rock sole are abundant on the eastern Bering Sea shelf and to a lesser extent in the Aleutian Islands. This species represents a "data-rich" case where the following information is available.

Data Component	Years of Data
Trawl Fishery catch at age	1980 to 1996
Trawl survey population age composition	1975, 1979 to 1996
Catch weight	1975 to 1997
Trawl survey biomass estimates and Standard Error.	1982 to 1997
Maturity Schedule	1993 to 1994
Mean weight at age	1985 to 88

The time-series of fishery and survey age compositions allows the use of an age-based stock assessment model (Wilderbuer and Walters 1997b). The outputs include estimates of abundance, spawning biomass, fishery and survey selectivity, exploitation trends, and projections of future biomass. The model also estimates reference fishing mortality rates in terms of the ratio of female spawning biomass to unfished levels which are used to calculate ABC. The stock assessment is updated annually at the conclusion of the summer trawl survey and is incorporated into the Bering Sea and Aleutian Islands SAFE document.

For information on rock sole assessment in the GOA see Section 2.1.4.8.

2.1.4.5 Greenland Turbot

Greenland turbot (*Reinhardtius hippoglossoides*) are distributed from Baja California northward throughout Alaska. It is rare south of Alaska and is primarily distributed in the eastern BSAI region (Hubbs and Wilimovsky 1964). Juveniles are believed to spend the first three or four years of life on the continental shelf and then move to the continental slope as adults (Alton *et al*. 1988, Templeman 1973). Greenland turbot are demersal to semi-pelagic. Unlike most flatfish, the migrating eye of Greenland turbot does not move completely to one side, but stops at the top of the head, which presumably results in a greater field of vision and helps to explain this species' tendency to feed off the sea bottom (de Groot 1970). Spawning occurs in winter and may be protracted, starting as early as September and continuing until March (Bulatov 1983). The eggs are benthypelagic (suspended in the water column near the bottom)(D'yakov 1982). Juveniles are absent in the Aleutian Islands region, suggesting that populations in that area originate from elsewhere (Alton *et al*. 1988). Greenland turbot are a moderately long-lived species, with a maximum recorded age of 21 years (Ianelli and Wilderbuer 1995) and an estimated natural mortality rate of 0.18 (Ianelli *et al*. 1997b). Pelagic fish are the main prey of Greenland turbot, with pollock often a major species in the diet (Livingston 1991b). Greenland turbot also feed on squid, euphausiids and shrimp.

Abundance of juvenile Greenland turbot is estimated in the eastern Bering Sea by the annual trawl survey and in the Aleutian Islands by the triennial trawl survey. Abundance of adults has been estimated by trawl slope surveys conducted cooperatively by the U.S. and Japan. In the Gulf, abundance is estimated by the triennial trawl survey. A lack of deepwater samples, however, creates a high degree of uncertainty for these estimates (Turnock *et al*. 1997b). The biomass of Greenland turbot in the BSAI increased during the 1970s and is currently estimated to be about half of the unfished level. A lack of recruitment success during recent years has led to extra caution in setting harvest levels. Greenland turbot is a relatively valuable species, however, because of low ABC and TAC amounts, it is primarily a bycatch only fishery.

The resource in the BSAI is managed as a single stock. The following information is available to assess the stock condition of Greenland turbot in the BSAI.

Data Component	Years of Data
Trawl survey size-at-age	1975, 1979 to 1982
Shelf survey size composition and biomass	1979 to 1997
Slope survey size composition and biomass	1979, 1981, 1982, 1985, 1988, 1991
Longline survey size comp and abundance index	1984 to 1993
Total fishery catch data	1960 to 1997
Trawl fishery CPUE index	1978 to 1984
Trawl fishery size compositions	1977 to 1987,1989 to 1991, 1993 to 1996
Longline catch size composition	1977, 1979 to 1985, 1992 to 1996

The time-series of fishery and survey length compositions allows the use of a length-based stock assessment model (Ianelli *et al*. 1997b). The outputs include estimates of abundance, spawning biomass, fishery and survey selectivity, exploitation trends, and projections of future biomass. The model also estimates reference fishing mortality rates in terms of the ratio of female spawning biomass to unfished levels which are used to calculate ABC. The stock assessment is updated annually at the conclusion of the summer trawl survey and is incorporated into the BSAI SAFE document.

For information on the Greenland turbot assessment in the GOA see Section 2.1.4.8.

2.1.4.6 Yellowfin Sole

Yellowfin sole (*Limanda aspera*) is distributed from British Columbia to the Chukchi Sea (Hart 1973). In the Bering Sea, it is one of the most abundant flatfish species and is the target of the largest flatfish fishery in the United States. While also found in the Aleutian Islands and GOA, the stock is of negligible size in those areas. Adults are benthic and occupy separate winter spawning and summer feeding grounds. Adults overwinter near the shelf-slope break at approximately 200 m and move into nearshore spawning areas as the shelf ice recedes (Nichol 1997). Spawning is protracted and variable, it begins as early as May and continues through August, occurring primarily in shallow water at depths less than 30 m (Wilderbuer *et al*. 1992). Eggs, larvae and juveniles are pelagic and usually are found in shallow areas (Nichol 1994). The estimated age at 50% maturity is 10.5 years at a length of approximately 29 cm (Nichol 1994). The natural mortality rate likely falls within the range of 0.12 to 0.16, with a maximum recorded age of 33 years (Wilderbuer 1997). Yellowfin sole feed primarily on benthic invertebrates, with polychaetes, amphipods, decapods and clams dominating the diet in the eastern Bering Sea (Livingston 1993).

Yellowfin sole stocks were over-exploited by foreign fisheries in 1959-1962. Since that time, indices of relative abundance have shown major increases in abundance during the late 1970s. Since 1981, abundance has fluctuated widely but biomass estimates indicate that the yellowfin sole population remains at a high, stable level. Information on yellowfin sole stock conditions in the BSAI comes primarily from the annual eastern Bering Sea trawl survey. Estimates of yellowfin sole biomass derived from these surveys have been more variable than would be expected for a comparatively long-lived and lightly exploited species (Wilderbuer 1997). The reason for this variability is not known. However, Nichol (1997) hypothesized that much of the yellowfin sole resource is found at depths less than 30 m during the summer when bottom trawl surveys are conducted. This would probably cause the survey to underestimate the abundance of yellowfin sole.

Yellowfin sole is the most abundant flatfish species in the eastern Bering Sea and is the target of the largest flatfish fishery in the United States. They inhabit the Bering Sea shelf and are considered one stock. This species represents a “data-rich” case where the following information is available.

Data Component	Years of Data
Trawl Fishery catch-at-age	1964 to 1996
Trawl survey population age composition	1975, 1979 to 1996
Catch weight	1954 to 1997

Trawl survey biomass estimates and S.E..	1982 to 1997
Maturity schedule	1992 to 1993
Mean weight at age	1979 to 1990

The time-series of fishery and survey age compositions allows the use of an age-based stock assessment model (Wilderbuer 1997). The outputs include estimates of abundance, spawning biomass, fishery and survey selectivity, exploitation trends, and projections of future biomass. The model also estimates reference fishing mortality rates in terms of the ratio of female spawning biomass to unfished levels which are used to calculate ABC. The stock assessment is updated annually at the conclusion of the summer trawl survey and is incorporated into the BSAI SAFE document.

For information on the GOA yellowfin sole assessment see Section 2.1.4.8.

2.1.4.7 Arrowtooth Flounder

Arrowtooth flounder (*Atheresthes stomias*) is common from Oregon through the eastern Bering Sea (Allen and Smith 1988). The very similar Kamchatka flounder (*Atheresthes evermanni*) also occurs in the Bering Sea. Because it is not usually distinguished from arrowtooth flounder in commercial catches, both species are managed as a group. Arrowtooth flounder is a relatively large flatfish that occupies continental shelf waters almost exclusively until age 4, but at older ages occupies both shelf and slope waters, with concentrations at depths between 100 and 200 m (Martin and Clausen 1995). Spawning is protracted and variable and probably occurs from September through March (Zimmermann 1997). For female arrowtooth flounder collected off the Washington coast, the estimated age at 50% maturity was 5 years with an average length of 37 cm. Males matured at 4 years and 28 cm (Rickey 1995). The maximum reported age is 15 years in the Bering Sea and 21 years in the GOA, with a natural mortality rate used for assessment purposes of 0.2 (Turnock *et al*. 1997b, Wilderbuer and Sample 1997). Arrowtooth flounder are important as a large and abundant predator of other groundfish species. Adults are almost exclusively piscivorous and over half their diet can consist of pollock (Livingston 1991b). The species has a low perceived commercial value because the flesh softens soon after capture, possibly owing to an enzyme released by a parasite (Greene and Babbitt 1990). It is primarily taken by bottom trawls as bycatch in other high value fisheries. Stocks are lightly exploited and appear to be increasing in both the GOA and the BSAI. Information on arrowtooth flounder stock conditions in the BSAI comes from the annual eastern Bering Sea trawl survey, the triennial slope survey and catch in the commercial fishery.

Information on Bering Sea arrowtooth flounder is available from the following sources:

Data Component	Years of Data
Fishery catch	1970 to 1997
Shelf survey biomass and Southeast	1982 to 1997
Slope survey biomass and Southeast	1981,82,85,88,91

Shelf survey size composition (by sex)	1979 to 1997
Slope survey size composition (by sex)	1981,82,85,88,91
Fishery length-frequencies from observers	1978 to 1991

The time-series of fishery and survey size compositions allows the use of an size-based stock assessment model (Wilderbuer and Sample 1997). The outputs include estimates of sex-specific abundance, spawning biomass, fishery and survey selectivity, exploitation trends, and projections of future biomass. The model also estimates reference fishing mortality rates in terms of the ratio of female spawning biomass to unfished levels which are used to calculate ABC. The stock assessment is updated annually at the conclusion of the summer trawl survey and is incorporated into the BSAI SAFE document.

The reference fishing mortality rate and ABC for arrowtooth flounder are determined by the amount of population information available (Amendment 44 of the FMP for the groundfish fishery of the BSAI) (NMFS 1996). Arrowtooth flounder fell into tier 3 of the ABC/OFL definition, because equilibrium recruitment could be approximated by the average recruitment from the time-series estimated in the stock assessment, and $B_{40\%}$, $F_{40\%}$, and $F_{30\%}$ could be estimated. In 1997, Bcurrent>$B_{40\%}$ for arrowtooth flounder, and ABC was based on the F40% fishing mortality rate because reliable estimates of F_{MSY} and B_{MSY} were unavailable. The 1998 Council TAC of 16,000 mt was well below the ABC of 147,000 mt recommended from the stock assessment.

Information on GOA arrowtooth flounder used for stock assessments is available from the following sources:

Data Component	Years of Data
Fishery catch	1960 to 1996
IPHC trawl survey biomass and S.E.	1961 to 1962
NMFS exploratory research trawl survey biomass and S.E.	1973 to 1976
NMFS triennial trawl survey biomass and S.E.	1984, 1987, 1990, 1993, 1996
Fishery size compositions	1977 to 1981, 1984 to 1993,1995to 1996
NMFS triennial trawl survey size compositions	1984, 1987, 1990, 1993, 1996
NMFS GOA groundfish surveys length-at-age data	1975, 1977 to 1978, 1980 to 1983
NMFS triennial trawl survey length-at-age data	1984

The time-series of fishery and survey size compositions allows the use of a size-based stock assessment model (Turnock *et al*. 1997b). The outputs include estimates of sex-specific abundance, spawning biomass, fishery and survey selectivity, exploitation trends, and projections of future biomass. The model also estimates reference fishing mortality rates in terms of the ratio of female spawning biomass to unfished levels which are used to calculate ABC. The stock assessment is updated annually and incorporated into the GOA SAFE document.

The reference fishing mortality rate and ABC for arrowtooth flounder are determined by the amount of population information available. Assuming that equilibrium recruitment can be approximated by the average recruitment from the time-series estimated in the stock assessment, $B_{40\%}$, $F_{40\%}$, and $F_{30\%}$ are known and because Bcurrent>B0.40, arrowtooth flounder reference fishing mortality is defined in tier 3a of the ABC/OFL definition in 1997. The current stock assessment ABC is based on the $F_{40\%}$ fishing mortality rate because reliable estimates of F_{MSY} and B_{MSY} are unavailable. The 1998 Council TAC of 35,000 mt is well below the ABC of 208,337 mt recommended from the stock assessment to limit the bycatch of halibut.

2.1.4.8 Other Flatfish

In the Bering Sea, eight other flatfish species are managed under the FMPs (Alaska plaice (*Pleuronectes quadriterculatus*), rex sole (*Glyptocephalus zachirus*), Dover sole (*Microstomus pacificus*), starry flounder (*Platichthys stellatus*), English sole *(Parophrys vetulus*), butter sole (*Isopsetta isolepis*), sand sole (*Psettichthys melanostictus*) and deep sea sole (*Embassichthys bathybius*). Adults of all species are benthic and occupy separate winter spawning and summer feeding grounds. Adults overwinter in deeper water and move into nearshore spawning areas in the late winter and spring. Spawning takes place as early as November for Dover Sole (Hagerman 1952) but occurs from February through April for most species (Hart 1973). All flatfish eggs are pelagic and sink to the bottom shortly before hatching (Alderdice and Forrester 1968, Hagerman 1952, Orcutt 1950, Zhang 1987), except for butter sole, which has demersal eggs (Levings 1968).

In the Bering Sea, Alaska plaice is the most abundant and commercially important of the other flatfish species. It is a comparatively long-lived species, and has frequently been aged as high as 25 years. For stock assessment purposes, a natural mortality rate of 0.25 is used (Wilderbuer and Walters 1997b). Alaska plaice appear to feed primarily on polychaetes, marine worms and other benthic invertebrates (Livingston and DeReynier 1996, Livingston *et al*. 1993).

In general, other flatfish are taken as bycatch in bottom trawl fisheries for other groundfish. Alaska plaice are also taken in directed bottom trawl fisheries in the eastern Bering Sea. Because other flatfish are generally not targeted, commercial catch data is of limited use for stock assessment purposes. The principal source of information for evaluating the condition of other flatfish stocks in the BSAI is the annual eastern Bering Sea trawl survey.

A moderate amount of information is available for Alaska plaice in the Bering Sea and is summarized below.

Data Component	Years of Data
Catch number at age	1971-79, 1988, 1995
Total catch weight	1971 to 1996
Age-specific estimates of proportion of mature females	1971 to 1996
Weight-at-age (from survey) and estimate of M (0.2)	
Survey age composition	1979, 1981, 1982, 1988, 1992 to 1995

The time series of fishery and survey age compositions allows the use of an age-based stock assessment model (Wilderbuer and Walters 1997a). The outputs include estimates of abundance, spawning biomass, fishery and survey selectivity, exploitation trends, and projections of future biomass. The model also estimates reference fishing mortality rates in terms of the ratio of female spawning biomass to unfished levels which are used to calculate ABC. For the rest of the species of the "other flatfish" management group, annual trawl survey biomass estimates are considered the best information available to determine the stock biomass. The stock assessment is updated annually at the conclusion of the summer trawl survey and is incorporated into the BSAI SAFE document.

The other flatfish species complex in the GOA is currently managed as four categories with separate ABCs: shallow-water flatfish, deep-water flatfish, flathead sole (*Hippoglossoides elassodon*) and rex sole (*Glyptocephalus zachirus*). The shallow-water flatfish consists of Alaska plaice (*Pleuronectes quadriterculatus*), starry flounder (*Platichthys stellatus*), yellowfin sole (*Pleuronectes asper*), English sole (*Parophrys vetulus*), butter sole (*Isopsetta isolepis*), northern rock sole (*Lepidopsetta perarcuata*) and southern rock sole (*Pleuronectes bilineatus*). Deep-water flatfish are: Dover sole (*Microstomus pacificus*), Greenland turbot (*Reinhardtius hippoglossoides*) and deepsea sole (*Embassichthys bathybius*). The shallow water category catch in 1997 was about 66% rock sole (southern and northern combined), 25% butter sole, 6% starry flounder, 1% English sole, and the remaining 2%, yellowfin sole, Alaska plaice and sand sole. The deep water catch is practically all Dover sole (over 99% in 1997).

The classification into the shallow-water and deep-water groups was due to significant differences in halibut bycatch rates in directed fisheries targeting on shallow and deep water flatfish species. Flathead sole were assigned a separate ABC due to their overlap in depth distribution of the shallow and deep water groups. In 1993 rex sole was split out of the deep-water management category because of concerns regarding the Pacific ocean perch bycatch in the rex sole target fishery. The information available for each species varies.

Data Component	Years of Data
Age composition from surveys-not all species	Various years

Triennial bottom trawl survey biomass and S.E.	1984, 1987, 1990, 1993, 1996
Total fishery catch weight by management category	Various years
Survey size composition	1984, 1987, 1990, 1993, 1996

Stock assessment models were not used for any of the species here due to the lack of available information (Turnock *et al*. 1997a). Triennial trawl survey biomass estimates from 1984, 1987, 1990, 1993 and 1996 are considered the best information available to determine the stock biomass for all of the "other flatfish" species.

The reference fishing mortality rate and ABC for the flatfish management groups are determined by the amount of population information available. Rock sole, for which maturity information from Bering sea rock sole is deemed adequate, are in tier 4 of the ABC and overfishing definitions, where $F_{ABC} = F_{40\%}$ and $F_{OFL} = F_{30\%}$. ABCs for all flatfish except rock sole, deep-sea sole and Greenland turbot were calculated using $F_{ABC} = 0.75$ M and $F_{OFL} = M$ (tier 5), because maturity information was not available. Natural mortality was assumed to be 0.2 for all flatfish species except Dover sole where M is 0.1. Greenland turbot and Deep-sea sole are in tier 6 because no reliable biomass estimates exist, where ABC = 0.75 OFL and the overfishing level (OFL) = the average catch from 1978 to 1995.

The TAC is well below the ABC for shallow-water group and Flathead sole. The ABC, TAC, and catch are summarized below. The TAC is essentially the same as the ABC for the deep-water group and rex sole. The flatfish fishery in the GOA mainly targets rock sole, rex sole, and Dover sole. The catch of flatfish is limited by the bycatch of halibut and does not reach the TAC for any species group.

Management group	1997 ABC	1997 TAC	1996 Catch
Shallow-water	43,144	18,630	9,350
Deep-water	7,162	7,170	2,193
Flathead sole	26,114	9,040	3,107
Rex sole	9,155	9,150	5,874

2.1.4.9 Sablefish

Sablefish is found from northern Mexico to the GOA, westward to the Aleutian Islands, and in gullies and deep fjords, generally at depths greater than 200 m. Sablefish observed from a manned submersible were found on or within 1 m of the bottom (Krieger 1997). Several studies have shown sablefish to be highly migratory for at least part of their life cycle (Heifetz and Clausen 1991, Maloney and Heifetz 1997), and substantial movement between the BSAI and the GOA has been documented (Heifetz and Clausen 1991). Thus sablefish in Alaskan waters are assessed as a single stock

(Sigler *et al*. 1997a). Adults reach maturity at 4 to 5 years and a length of 51 to 54 cm (McFarlane and Beamish 1990). Spawning is pelagic at depths of 300-500 m near the edges of the continental slope (McFarlane and Nagata 1988). Juveniles are pelagic and appear to move into comparatively shallow near-shore areas where they spend the first 1 to 2 years (Rutecki and Varosi 1997). Sablefish are long-lived, with a maximum recorded age in Alaska of 62 years (Sigler *et al*. 1997b). For stock assessments, a natural mortality rate of 0.10 is used (Sigler *et al*. 1997a). It appears that sablefish are opportunistic feeders. Feeding studies conducted in Oregon and California, found that fish made up 76% of the diet (Laidig *et al*. 1997). Other studies, however, have found a diet dominated by euphausiids (Tanasichuk 1997).

Alaskan sablefish are considered a single stock and assessed in a combined area (Bering Sea, Aleutian Islands, and GOA) with an age-structured model incorporating fishery and survey catch data and age and length compositions. Survey data come from annual sablefish longline surveys in the GOA, and biennial longline survey in the Aleutian Islands and the Bering Sea. These surveys indicate that the stock size peaked in the mid-1980s because of a series of strong year classes, and has been declining since.

The stock assessment includes catch history, fishery description, assessment methods, abundance and exploitation trends, and projected catch and abundance. Sablefish fall into tier 3 of the ABC/OFL definitions, which requires reliable estimates of biomass, $B_{40\%}$, $F_{30\%}$, and $F_{40\%}$. Under the definitions and projected stock conditions in 1998, the overfishing fishing mortality rate was the adjusted $F_{30\%}$ rate which was 0.145 for sablefish and equated to a combined stock yield of 27,900 mt. Projections for 1998 showed that the maximum allowable fishing mortality rate for ABC (F_{ABC}) was the adjusted $F_{40\%}$ rate (0.096) and translated to a combined stock yield of 19,000 mt. The 1998 ABC recommendation was set below the maximum rate prescribed under tier 3b. The stock assessment F_{ABC} was 0.085 which translated to a yield of 16,800 mt. An ABC recommendation lower than $F_{40\%}$ was prescribed because the yield from an adjusted $F_{40\%}$ strategy represented an increase over recent ABCs. Increasing ABC was inconsistent with a predicted spawning biomass trend that was projected to fall near the observed low by year 2000. Rather than increasing 1998 ABC and reducing ABCs thereafter toward the predicted short-term equilibrium, it was recommended that current catch or ABC be incrementally adjusted toward the short-term equilibrium yield. The same rationale was used for setting the ABC the previous year. The current Council ABC level is equivalent to the recommended stock assessment ABC and equivalent to the TAC.

Recent important year classes are 1995 and 1990 (Fig. 10), although the abundance estimate for the 1995 cohort is uncertain because it is based on only one year of data. The large pooled age group, 16+, is due to strong year classes from the later 1970s. Abundance has fallen in recent years because recent recruitment is insufficient to replace these older, strong year-classes which are dying off. The estimated mean age of the recruited portion of the population is at least eight years (pooling of the older age groups prevents computation of the exact value). The dominating factor determining the age composition is the magnitude of the recruiting year classes. The selectivity of the fishery has cumulative impacts on the age composition due to fishing mortality, and the current composition is also the result of a fished population with a several-decade catch history. How the current age composition of the population compares with the unfished population is unknown. The directed fishery for sablefish is prosecuted by longliners. Trawlers also catch sablefish as bycatch in other fisheries. A tiny amount of sablefish is caught by pot boats. By gear, the catches in 1996 were longlines (88%), trawls (12%) and pots (<1%). The directed fishery occurs on the upper continental slope and a few deepwater gullies, the areas inhabited by adult sablefish. Sablefish discards were 1,005 mt in 1996, equal to 6% of the total catch of 17,410 mt. The largest amount of sablefish discard occurred in trawl fishing not directed towards sablefish (553 mt in 1996). Most of these discards (91%) were due to flatfish and rockfish trawl fisheries in the GOA; the discard rate (discards/total catch) of sablefish was 27%. The second largest amount of sablefish discard occurred in the directed longline fishery (341 mt in 1996), but the discard rate was low (2%) because of the large amount of sablefish retained. The third largest amount of sablefish occurred in longline fishing not directed towards sablefish (109 mt in 1996). Most of these discards (98%) were due to Greenland turbot and Pacific cod longline fisheries in the Bering Sea; the discard rate of sablefish was 21%. The least amount of sablefish discard occurred in trawl sets directed towards sablefish. The amount discarded and the discard rate were small, 3 mt and 2%.

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). The older demersal juveniles and adults appear to be opportunistic feeders, with food ranging from variety of benthic invertebrates, benthic fishes, as well as squid, mesopelagic fishes, jellyfish, and fishery discards. Gadid fish (mainly pollock) comprise a large part of the sablefish diet. Nearshore residence during their second year provides the opportunity to feed on salmon fry and smolts during the summer months. Young-of-the-year sablefish are commonly found in the stomachs of salmon taken in the southeast troll fishery during the late summer.

2.1.4.10 Rockfish

At least 32 rockfish species of the genus *Sebastes* and *Sebastolobus* have been reported to occur in the GOA and BSAI (Eschmeyer *et al*. 1984), and several are of commercial importance. Pacific ocean perch (*S. alutus*) has historically been the most abundant rockfish species in the region and has contributed most to the commercial rockfish catch. Other species such as northern rockfish (*S. polyspinis*), rougheye rockfish (*S. aleutianus*), shortraker rockfish (*S. borealis*), shortspine thornyheads (*S. alascanus*), yelloweye rockfish (*S. ruberrimus*), and dusky rockfish (*S. ciliatus*) are also important to the overall rockfish catches. The TAC levels for these and all other rockfish species are determined on an annual basis by the NPFMC. Among the main inputs needed for making this determination are the ABC and OFL recommendations from annual stock assessments conducted for each species and/or species assemblage.

Rockfish in the GOA is currently managed as four assemblages: 1) slope rockfish, 2) pelagic shelf rockfish, 3) demersal shelf rockfish, and 4) thornyheads. Separate ABCs, OFLs, and TACs are set for each assemblage except for slope rockfish which is further subdivided into four subgroups with separate ABCs, OFLs, and TACs: 1) Pacific ocean perch, 2) shortraker and rougheye rockfish, 3) northern rockfish, and 4) “other slope rockfish”.

Rockfish in the Bering Sea and Aleutian Islands are currently managed as two assemblages; 1) Pacific ocean perch complex and 2) other rockfish. The Pacific ocean perch complex includes Pacific ocean perch, rougheye rockfish, shortraker rockfish, sharpchin rockfish, and northern rockfish. For the Eastern Bering Sea region the Pacific ocean complex is divided into two subgroups with: 1) Pacific ocean perch, and 2) shortraker, rougheye, sharpchin, and northern rockfish combined. For the Aleutian Island region, the Pacific ocean perch complex is divided into three subgroups: 1) Pacific ocean perch, 2) shortraker and rougheye rockfish, and 3) sharpchin and northern rockfish. Separate ABC, and TAC, and OFLs are assigned to each subgroup. Other rockfish includes all Sebastes and Sebastolobus species in the BSAI region other than the Pacific ocean perch complex. Shortspine thornyheads account for most of the estimated biomass and commercial catch of the other rockfish assemblage in the BSAI.

Rockfish are assessed with either an age structured model or trawl survey based model, depending on the management group. Pacific ocean perch are assessed with an age-structured model incorporating fishery and survey catch and age composition data. Most other species of rockfish are assessed based on trawl survey catch data. Survey data are from the NMFS triennial trawl surveys. The stock assessments provide the best available information. For all rockfish management groups the assessment includes catch history, characterizations of the fishery, assessment methodology, and abundance and exploitation trends. The results of the analyses, which are updated annually, are presented in the GOA and BSAI stock assessment report, which is incorporated into the NPFMC SAFE reports.

Pacific ocean perch

Pacific ocean perch is primarily a demersal species which inhabits the outer continental shelf and slope regions of the North Pacific and Bering Sea, from southern California to Japan (Allen and Smith 1988). As adults, they live on or near the sea floor, generally in areas with smooth bottoms (Krieger 1993), generally at depths ranging from 180 to 420 m. The diet of Pacific ocean perch appears to consist primarily of plankton (Brodeur and Percy 1984); euphausiids are the single most important prey item (Yang 1996).

Though more is known about the life history of Pacific ocean perch than about other rockfish species (Kendall and Lenarz 1986), much uncertainty still exists about its life history. Pacific ocean perch are viviparous, with internal fertilization and the release of live young (Hart 1973). Insemination occurs in the fall, and release of larvae occurs in April or May. Pacific ocean perch larvae are thought to be pelagic and drift with the current. Juveniles seem to inhabit rockier, higher relief areas than adults (Carlson and Straty 1981, Krieger 1993). Pacific ocean perch is a slow growing species that, in the GOA, reaches maturity at approximately 10 years, or 36 cm in length (Heifetz *et al*. 1997) and has a maximum life span of 90 years (Chilton and Beamish 1982). The natural mortality rate likely is between 0.02 and 0.08 (Archibald *et al*. 1981, Chilton and Beamish 1982).

Pacific ocean perch is the most commercially important rockfish in Alaska's fisheries and is taken almost exclusively with bottom trawls. The species is highly valued and supported large Japanese and Soviet trawl fisheries throughout the 1960s. Apparently, stocks were not productive enough to support the large removals that took place, and they declined throughout the 1960s and 1970s, reaching their lowest levels in the early 1980s. Since that time, stocks have stabilized in the EBS, and increased in the Aleutian Islands and GOA.

A time series of fishery and survey age compositions allows the use of an age-based stock assessment model for Pacific ocean perch. The outputs include estimates of abundance, spawning biomass, fishery and survey selectivity, exploitation trends, and projections of future biomass. The model also estimates reference fishing mortality rates in terms of the ratio of female spawning biomass to unfished levels which are used to calculate ABC. The stock assessment is updated annually.

In the GOA, Pacific ocean perch fall into tier 3b of the ABC/OFL definitions, which requires reliable estimates of biomass, $B_{40\%}$, $F_{30\%}$, and $F_{40\%}$. Under the definitions and current stock conditions, the overfishing fishing mortality rate for Pacific ocean perch is the $F_{30\%}$ adjusted rate which is 0.079 for Pacific ocean perch rockfish and equates to a yield of 18,090 mt. The maximum allowable fishing mortality rate for ABC (F_{ABC}) defined by tier 3b is the $F_{40\%}$ adjusted rate which is 0.055 for Pacific ocean perch and translates to a yield of 12,820 mt. The stock assessment fishing mortality rate for ABC is equivalent to the maximum allowable fishing mortality rate. The current Council ABC level is equivalent to the recommended stock assessment ABC and is greater than the TAC which is 10,776 mt.

The current age and size distributions of Pacific ocean perch in the GOA are discussed in Heifetz *et al*. 1997 (Heifetz *et al*. 1997). The age composition estimated from the stock assessment model is dominated by recent strong 1992, 1986, and 1984 year classes, and considerable numbers from the strong 1980 and 1976 year classes are still in the population. The dominating factor determining the age composition is the magnitude of the recruiting year classes which are highly variable. The selectivity of the fishery has cumulative impacts on the age composition due to fishing mortality, and the current composition is also the result of a fished population with a 37-year catch history. It is not certain how the current age composition of the population compares with the unfished population.

In the GOA, the directed fishery for Pacific ocean perch is prosecuted by catcher-processor and catcher bottom trawlers. The fishery generally occurs at depths between 150 and 300 m along the outer continental shelf, the upper continental slope and at the mouth of gullies. Important Pacific ocean perch fishery locations include: in the Eastern GOA, the gully and slope southwest of Yakutat Bay and off Cape Omaney; in the Central GOA, the shelf, slope and gullies off of Kodiak Island south of Portlock Bank and near Albatross Bank; and in the western GOA, the shelf and slope south of Unimak and Umnak Islands.

In the GOA, Pacific ocean perch are caught as bycatch (not necessarily discarded) in other directed fisheries aimed mostly at other species of rockfish. Heifetz and Ackley (1997) analyzed bycatch in rockfish fisheries of the GOA. Bycatch rates of Pacific ocean perch are highest in the pelagic shelf rockfish, "other slope rockfish", and shortspine thornyhead fisheries. Information on bycatch in non-rockfish fisheries has not been analyzed. Recent discard rates (discards/total catch) of Pacific ocean perch have been about 15% (Heifetz *et al*. 1997). In 1997, about 1,360 mt of Pacific ocean perch were discarded compared to a total catch of 9,500 mt.

The diets of commercially important groundfish species in the GOA during the summer of 1990 were analyzed by Yang (1993). About 98% of the total stomach content weight of Pacific ocean perch in the study was made up of invertebrates and 2% of fish. Euphausiids (mainly *Thysanoessa inermis*) were the most important prey item. Euphausiids comprised 87% by weight of the total stomach contents. Calanoid copepods, amphipods, arrow worms, and shrimp were frequently eaten by Pacific ocean perch. Documented predators of Pacific ocean perch include Pacific halibut and sablefish, and it 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 demersal fish.

In the BSAI, Pacific ocean perch are assessed with an age-structured model incorporating fishery and survey catch data and age compositions. Survey data are from the NMFS triennial trawl groundfish surveys and the fishery data comes from the observer program. The stock assessment is based on the best available information. It includes catch history, characterizations of the fishery, assessment methodology, abundance and exploitation trends, and projected catch and abundance trends for a range of fishing mortalities and recruitment assumptions (Ito and Ianelli 1997). The assessments for the other species in the POP complex and for the "other rockfish" management category are based on substantially less information (Ito 1997, Ito and Ianelli 1997).

The current spawning biomass for Pacific ocean perch in the Aleutian Islands is about 10,700 mt below its long-term average under an $F_{44\%}$ (=0.066) harvest strategy. Our current estimate of spawning biomass for this stock is about 129,000 mt, whereas, the long-term equilibrium spawning biomass is about 139,700 mt. Based on the guidelines established under tier 3b, the adjusted F_{ABC} was calculated as 0.0552, which equates to an ABC estimate of approximately 12,100 mt. The total Aleutian Islands ABC was then apportioned among Aleutian Islands subareas based on survey distribution, as follows: western AI=5,580 mt, central AI=3,450 mt, and eastern AI=3,070 mt. This was done to better distribute fishing effort over a wider area, thereby reducing the chance for localized depletion. The OFL was determined using an estimated $F_{30\%}$ rate of 0.096 which translates to an OFL of 20,700 mt.

For the EBS stock of Pacific ocean perch, the estimate of current spawning biomass is also below its long-term average. The current estimate of spawning biomass for this stock is about 23,900 mt and its long-term equilibrium spawning biomass is 37,900 mt, placing true POP in sub-tier "b" of tier 3. The same adjustment procedure used for the Aleutian Islands $F_{44\%}$ rate was also applied to the EBS $F_{44\%}$ estimate. This procedure produced an F_{ABC} of 0.0304 and an ABC estimate for the EBS of approximately 1,400 mt. The overfishing mortality level (F_{OFL}) was given as an adjusted $F_{30\%}$, based on guidelines set forth under tier 3b. The estimate of F_{OFL} for the EBS stock is 0.056 which translates to an OFL of about 3,300 mt.

Shortraker and rougheye rockfish

Shortraker and rougheye rockfish inhabit the outer continental shelf of the north Pacific from the eastern Bering Sea as far south as southern California (Kramer and O'Connell 1988). Adults of both species are semi-demersal and are usually found in deeper waters (from 50 to 800 m) and over rougher bottoms (Krieger and Ito *in prep*) than Pacific ocean perch. Little is known about the biology and life history of these species, but they appear to be long-lived, with late maturation and slow growth. Shortraker rockfish have been estimated to reach ages in excess of 120 years and rougheye rockfish in excess of 140 years. Natural mortality rates have been estimated by Heifetz and Clausen (1991) at 0.025 for rougheye rockfish and 0.030 for shortraker rockfish. Like other members of the genus Sebastes, they are viviparous (bear live young) and parturition occurs in the early spring through summer (McDermott 1994). Food habit studies conducted by Yang (1993) indicate that the diet of rougheye rockfish is dominated by shrimp. The diet of shortraker rockfish is not well known, based on a small number of samples, the diet appears to be dominated by squid. Because shortraker rockfish have large mouths and short gill rakers, it is possible that they are potential predators of other fish species (Yang 1993). Though shortraker/rougheye are highly valued, amounts available to the commercial fisheries are limited by relatively small TAC and ABC amounts that are fully needed to support bycatch needs in other groundfish fisheries. As a result, the directed fishery for these species typically is closed at the beginning of the fishing year.

The primary methods of harvest for shortraker and rougheye rockfishes are bottom trawl and longline gears. The bulk of the commercial harvest usually occurs at depths between 200 and 500 m along the upper continental slope. Both species are associated with a variety of habitats from soft to rocky habitats, although boulders and sloping terrain appear also to be desirable habitat. Age at recruitment is uncertain, but is probably on the order of 20+ years for both species. Length at 50% sexual maturity is about 45 cm for shortraker rockfish and about 44 cm for rougheye rockfish (McDermott 1994).

A sufficient time series of fishery and survey age compositions is not available to construct an age-based stock assessment model for shortraker and rougheye rockfish. Thus assessment is based mostly on biomass estimates provided by trawl surveys. Life history information allows estimates of reference fishing mortality rates which are used to calculate ABC. The stock assessment is updated annually.

In the GOA, shortraker rockfish falls into tier 5, and rougheye rockfish falls into tier 4 of the ABC/OFL definitions. Under these definitions, the overfishing fishing mortality rate for shortraker rockfish is the F=M rate of 0.03, and the overfishing fishing mortality rate for rougheye rockfish is the $F_{30\%}$ rate of 0.046. These overfishing fishing mortality rates translate into a yield of 2,740 mt for the shortraker and rougheye management group. The maximum allowable fishing mortality rate for ABC (F_{ABC}) defined by tier 5 for shortraker rockfish is the F=0.75M rate which is 0.023. The maximum allowable fishing mortality rate for ABC (F_{ABC}) for rougheye rockfish defined by tier 4 is $F_{40\%}$ which is 0.032. These maximum allowable F_{ABC} rates translate to a yield of 1,930 mt for the shortraker and rougheye management group. The stock assessment F_{ABC} is set lower than the maximum allowable fishing mortality rate for ABC because in the stock assessment the F_{ABC} for rougheye rockfish is set equal to the natural mortality M of 0.025. This results in the stock assessment ABC of 1,590 mt for shortraker and rougheye rockfish. The current Council ABC level is equivalent to the recommended stock assessment ABC, and is equal to the TAC. Because the shortraker and rougheye rockfish ABC and TAC are set more conservatively than the maximum prescribed under the definitions, less of a risk of the F_{ABC} rate being an overly aggressive harvest rate for shortraker and rougheye rockfish exists. This affords more protection to the stocks given the variability and uncertainty associated with the abundance. Furthermore, a larger buffer exists between the fishing mortality rates associated with ABC and OFL, which lowers the risk of overfishing the stock.

For shortraker and rougheye rockfish, Aleutian stock, the assessment is based on catch and survey data. The biomass estimates from all Aleutian bottom trawl surveys are averaged over all years to obtain the best estimate of biomass for the species in this subcomplex. In 1997, this procedure produced a biomass estimate of 46,500 mt. By species, the biomass estimates are as follows: rougheye rockfish, 21,600 mt and shortraker rockfish, 24,900 mt. In 1996, the SSC determined that reliable estimates of the natural mortality rate (M) existed for the species in this subcomplex, and that shortraker and rougheye rockfish in the Aleutian Islands therefore qualified for management under tier 5 of Amendment 44. The accepted estimates of M for these species in the Aleutian Islands are as follows: rougheye rockfish (0.025) and shortraker rockfish (0.030). The Plan Team recommends setting F_{ABC} at the maximum value allowable under tier 5, which is 75% of M. On a species-specific basis, this translates into the following F_{ABC} values: rougheye rockfish (0.019) and shortraker rockfish (0.023). Multiplying these rates by the best estimates of species-specific biomass and summing across species gives a 1998 ABC of 965 mt. The Plan Team's OFL was determined from the tier 5 formula, where setting F_{OFL}=M for each species gives a combined OFL of 1,290 mt.

In recent years a directed fishery for shortraker and rougheye rockfish has not been allowed, because TACs are small. Shortraker and rougheye rockfishes are often caught as bycatch and retained in the sablefish and halibut longline fisheries and fisheries targeting other species of rockfish. Heifetz and Ackley (1997) analyzed bycatch (not necessarily discarded) in rockfish fisheries of the GOA. Bycatch rates of shortraker and rougheye rockfish are highest in the shortspine thornyhead and Pacific ocean perch fisheries. An analysis of bycatch rates in non-rockfish fisheries has not been conducted. Discard rates (discards/total catch) of shortraker and rougheye rockfish during 1996 to 1997 have been about 22% (Heifetz and Ackley 1997). In 1997, about 430 mt of shortraker and rougheye rockfish were discarded compared to a total catch of 1,600 mt.

Northern rockfish

Northern rockfish inhabit the outer continental shelf from the eastern Bering Sea, throughout the Aleutian Islands and the GOA (Kramer and O'Connell 1988). This species is semi-demersal and is usually found in comparatively shallower waters of the outer continental slope (from 50 to 600 m). Little is known about the biology and life history of northern rockfish. However, they appear to be long lived, with late maturation and slow growth. Heifetz and Clausen (1991) estimated the natural mortality rate for northern rockfish to be 0.060. Like other members of the genus Sebastes, they bear live young, and parturition occurs in the early spring through summer (McDermott 1994). Food habit studies conducted by Yang (1993) indicate that the diet of northern rockfish is dominated by euphausiids. Although northern rockfish are lower in value than Pacific ocean perch, they still support a valuable directed trawl fishery, especially in the GOA.

In the GOA, northern rockfish falls into tier 4 of the ABC/OFL definitions. Under these definitions, the overfishing fishing mortality rate for northern rockfish is the $F_{30\%}$ rate of 0.113 which translates into a yield of 9,420 mt. The maximum allowable fishing mortality rate for ABC (F_{ABC}) defined by tier 4 is the $F_{40\%}$ rate which is 0.075 for northern rockfish and translates to a yield of 6,250 mt. The stock assessment F_{ABC} is set lower than the maximum allowable fishing mortality rate for ABC. The stock assessment F_{ABC} is set equal to the natural mortality rate M of 0.060 which translates to a yield of 5,000 mt. The current Council ABC level is equivalent to the recommended stock assessment ABC, and is equal to the TAC. Because the northern rockfish ABC and TAC are more conservative than the maximum prescribed under the definitions, less risk exists of the F_{ABC} rate being an overly aggressive harvest rate for this species. This affords more protection to the stocks given the variability and uncertainty associated with the abundance. Under this harvest strategy, a larger buffer exists between the fishing mortality rates associated with ABC and OFL, which lowers the risk of overfishing the stock.

The age and size distributions of northern rockfish are discussed in Heifetz *et al*. (1997). The most recent age-composition information for northern rockfish is from the 1993 trawl survey. The age composition is dominated by recent strong 1984 and 1982 year classes and, considerable numbers from strong 1977 and 1970-1968 year classes are still in the population. The dominating factor determining the age composition is the magnitude of the recruiting year classes, which is highly variable. The selectivity of the fishery has cumulative impacts on the age composition due to fishing mortality. It is not certain how the current age composition of the population compares with the unfished population.

The directed fishery for northern rockfish is prosecuted by catcher-processor and catcher bottom trawlers. The patterns of the fishery generally reflect the distribution of the species. The fishery is concentrated at discrete, relatively shallow offshore banks of the outer continental shelf at depths between 75 and 125 m. Important northern rockfish fishery locations include Portlock Bank and Albatross Bank south of Kodiak Island, Shumagin Bank south of the Shumagin Islands, and Davidson Bank south of Unimak Island.

Heifetz and Ackley (1997) analyzed bycatch (not necessarily discarded) in rockfish fisheries of the GOA. Bycatch rates of northern rockfish are highest in the pelagic shelf rockfish, "other slope rockfish", and Pacific ocean perch fisheries. Information on bycatch of northern rockfish in non-rockfish fisheries has not been analyzed. Discard rates (discards/total catch) of northern rockfish during 1996 to 1997 have been about 22% (Heifetz and Ackley 1997). In 1997, about 820 mt of northern rockfish were discarded compared to a total catch of 2,900 mt.

Northern rockfish are generally planktivorous with euphausiids being the predominant prey item (Yang 1993). Copepods, hermit crabs, and shrimp have also been noted as prey items in much smaller quantities. Predators of northern rockfish are not well documented but likely include larger fish such as Pacific halibut that are known to prey on other rockfish species.

In the Aleutian Islands, northern rockfish are managed together with sharpchin rockfish (*S. zacentrus*). Because sharpchin rockfish are found only rarely in the Aleutian Islands, northern rockfish are for all practical purposes the only species in this subcomplex. The 1997 assessment of northern and sharpchin rockfish was a straightforward update of the 1996 assessment, incorporating new catch and survey data. Traditionally, the biomass estimates from all Aleutian Islands bottom trawl surveys are averaged over all years to obtain the best estimate of northern rockfish biomass. This procedure produced a biomass estimate of 94,000 mt, down 3% from the 1996 estimate. Northern rockfish in the Aleutian Islands are managed under tier 5 of Amendment 44. The accepted estimate of M for northern rockfish in the Aleutian Islands is 0.06. ABC was based on maximum allowable F_{ABC} under tier 5, which is 75% of M, or 0.045. Multiplying this rate by the best estimate of biomass gave a 1998 ABC of 4,230 mt. The Plan Team's OFL was determined from the tier 5 formula, where setting F_{OFL}=M gives a 1998 OFL of 5,640 mt.

Pelagic shelf rockfish

In the GOA, pelagic shelf rockfish are assessed with a trawl survey-based model, with survey data coming from the NMFS GOA triennial trawl surveys. The stock assessments provide the best available information for pelagic shelf rockfish, and include discussions of catch history, characterizations of the fishery, assessment methodology, and abundance and exploitation trends. The results of the analyses, which are updated annually, are presented in the GOA pelagic shelf rockfish stock assessment which is incorporated into the GOA SAFE report.

Dusky rockfish is by far the most important species in the group, both in terms of abundance and commercial value, although black rockfish has also been of some importance. As of April 1998, however, black rockfish were removed from both the pelagic shelf group and the GOA groundfish FMP. Consequently, black rockfish are not discussed in this report, and the focus is on dusky rockfish.

Pelagic shelf rockfish fall into tier 4 of the current ABC/OFL definitions, because the only population dynamics parameters known for the assemblage are biomass, $F_{30\%}$, and $F_{40\%}$. Biomass estimates come from the triennial trawl surveys, and estimates of $F_{30\%}$ and $F_{40\%}$ are derived using life history parameters for dusky rockfish. According to the definitions for tier 4, the maximum allowable fishing mortality rate for ABC (F_{ABC}) is the $F_{40\%}$ rate, which is 0.101 for pelagic shelf rockfish and translates to a Gulfwide yield of 5,614 mt. The actual stock assessment F_{ABC} for pelagic shelf rockfish, however, is set to a more conservative value, F=M, in which F_{ABC} equals the natural mortality of dusky rockfish, 0.090. Hence, the corresponding yield is 5,002 mt, which is the recommended ABC value in the stock assessment for 1998. The Council has adopted this ABC for 1998, and has also set an equivalent TAC of 5,000 mt for pelagic shelf rockfish in the GOA. Because the pelagic shelf rockfish ABC and TAC are more conservative than the maximum prescribed under the definitions for tier 4, the status quo impacts of fishing mortality can be further characterized as follow: 1) Less of a risk of the FABC rate being an overly aggressive harvest rate for pelagic shelf rockfish exists. This affords more protection to the stocks given the variability and uncertainty associated with the abundance estimates of dusky rockfish from the trawl surveys. 2) A larger buffer exists between the fishing mortality rates associated with ABC and OFL, which lowers the risk of overfishing the stock.

Age and size distributions of dusky rockfish are based on results of the 5 triennial trawl surveys from 1984 to 1996, and are discussed in Clausen and Heifetz (1997). Age results are only available from the 1987, 1990, and 1993 surveys, and these show that substantial recruitment of dusky rockfish appears to be a relatively infrequent event. Strong year classes are only seen for 1976 to 1977, 1979 to 1980, and 1986. Mean age of the population in 1993 was 12 years. Likewise, the size compositions from each of the 5 surveys indicate that recruitment of small fish to the survey occurred only in 1993, corresponding to the 1986 year class. The effects of fishing on the age and size compositions are unknown, as no age or size data are available from either the fishery, or the unfished population prior to the beginning of the fishery.

Dusky rockfish are caught almost exclusively with bottom trawls. Factory trawlers dominated the directed fishery from 1988 to 1995. Since 1996, some of catch has also been taken by shore-based trawlers for delivery to plants in Kodiak. 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. Catch distribution by depth has not been summarized, but most of the fish are apparently taken at depths of 75-200 m.

Dusky rockfish often co-occur with northern rockfish, and they are caught as bycatch in the northern rockfish and "other slope rockfish" fisheries (Heifetz and Ackley 1997). To a lesser extent, they are also taken as bycatch in the Pacific ocean perch fishery. Overall discard rates (discards/total catch) of dusky rockfish in recent years have been quite low, generally 10% or less (Clausen and Heifetz 1997).

Trophic interactions of dusky rockfish are not well known. Food habits information is available from just one study with a relatively small sample size for dusky rockfish (Yang 1993). This study indicated that adult dusky rockfish consume primarily euphausiids, followed by larvaceans, cephalopods, and pandalid shrimp. 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 founder.

Demersal Shelf rockfish

Demersal Shelf Rockfish (DSR) include seven species of nearshore, bottom-dwelling rockfish: canary rockfish (*S. pinniger*), China rockfish (*S. nebulosus*), copper rockfish (*S. caurinus*), quillback rockfish (*S. maliger*), rosethorn rockfish (*S. helvomaculatus*), tiger rockfish (*S. nigrocinctus*), and yelloweye rockfish (*S. ruberrimus*). DSR are managed under the NPFMC as a distinct assemblage only off southeast Alaska east of 140°W long. Yelloweye rockfish comprise 90% of the catch and will be the focus of this section.

Yelloweye rockfish occur on the continental shelf from northern Baja California to the Eastern Bering Sea, commonly in depths less than 200 m (Kramer and O'Connell 1988). They are long-lived, slow growing, and late maturing. Yelloweye have been estimated to reach 118 years and their natural mortality rate is estimated at 0.20 (O'Connell and Funk 1987). They are viviparous with parturition occurring primarily in late spring through mid-summer (O'Connell 1987). Yelloweye inhabit areas of rugged, rocky relief and adults appear to prefer complex bottoms with the presence of "refuge spaces" (O'Connell and Carlile 1993). DSR are highly valued and a directed longline fishery is held for these species. However, yelloweye are the primary bycatch in the halibut fishery and therefore a large portion of the TAC and ABC are set aside for bycatch.

Traditional abundance estimation methods (e.g., area-swept trawl surveys, mark recapture) are not considered useful for these fishes given their distribution, life history, and physiology. However, ADF&G is continuing research to develop and improve a stock assessment approach for them. As part of that research a manned submersible, Delta, is used to conduct line transects (Buckland *et al*. 1993, Burnham *et al*. 1980). Density estimates are limited to adult yelloweye, because it is the principal species targeted and caught in the fishery, and therefore ABC/TAC recommendations for the entire assemblage are keyed to adult yelloweye abundance. Total yelloweye rockfish biomass is estimated for each management subdistrict as the product of density, mean weight of adult yelloweye, and areal estimates of DSR habitat (O'Connell and Carlile 1993). For estimating variability in yelloweye biomass, log-based confidence limits are used because the distribution of density tends to be positively skewed and density is assumed to be log-normal (Buckland *et al*. 1993). Estimation of both line length for the transects and total area of rocky habitat are difficult and result in some uncertainty in the biomass estimates. During the 1997 survey, the area estimate of rock habitat in the East Yakutat management area was reduced by 60% compared to past assessments, resulting in a similar reduction in the biomass estimate for this area. The sum of the lower 90% confidence limits of biomass, by area, is the reference number for setting ABC because of the continued uncertainty in yelloweye biomass estimation. This resulted in a biomass estimate of 25,031 mt for 1998.

DSR falls into tier 4 of the ABC/OFL definitions. Under these definitions, the overfishing (OFL) mortality rate is $F_{30\%}$=0.038 (951 mt), and the maximum allowable fishing mortality rate for ABC is the $F_{40\%}$=0.025. However, a more conservative approach has been taken for setting ABC and TAC. By applying F=M=0.02 to yelloweye rockfish biomass and adjusting for the 10% of other DSR species, the recommended 1998 ABC is 560 mt. Continued conservatism in managing this fishery is warranted given the life history of the species and the uncertainty of the biomass estimates.

The age and size distributions of yelloweye rockfish are discussed in O'Connell *et al*. (1997) and O'Connell and Funk (1987). Estimated length and age at 50% maturity for yelloweye collected in Central Southeast Outside (CSEO) in 1988 are 45 cm and 21 years for females and 50 cm and 23 years for males. Age of first recruitment into the fishery is between 13 and 18 years. The most recent age data is from the 1996 commercial catch samples. Age frequency data from the commercial catch differs somewhat by management area. In CSEO, the area with the longest catch history, the 1996 distribution shows a strong mode at 27 years of age (1969 year class) with some younger recruitment. The older ages have declined in frequency over time and the average age continues to decline and remains the lowest of all areas. In Southern Southeast Outside (SSEO) the 1996 age data shows a pronounced mode at 43 years with smaller modes at 38, 27, and 20.

Some signs of younger recruitment are seen in this area, and although the older ages appear to be contributing less, the mean age remains stable at 41 years. In East Yakutat (EYKT), the 1996 age distribution is bimodal, the largest mode at 28 years and a second one at 39 years. Mean age of these samples is 38 years, somewhat lower than in past samples, and fish older than 60 are declining in frequency of occurrence. Unlike other areas, no sign of recruitment is seen here. The selectivity of the fishery has cumulative impacts on the age composition due to fishing mortality, and the current composition is also the result of a fished population with 20 years of directed catch in some areas, as well as many decades of bycatch. How the current age composition of the population compares with the unfished population is unknown.

The directed fishery for DSR is prosecuted by longliners. Yelloweye rockfish occur in areas of rugged, rocky bottom, commonly between 100 and 200 m. The lava fields off Cape Edgecumbe in CSEO and the offshore Fairweather Ground in EYKT are the most important fishing areas. A small amount of DSR are taken as bycatch in jig and troll fisheries. Trawling is prohibited in the eastern GOA. Yelloweye rockfish is the dominant bycatch species in the halibut longline fishery. The majority of the longline vessels in the eastern GOA are unobserved so it is difficult to get an accurate accounting of discard at sea. For the past several years we have estimated unreported mortality of DSR during the halibut fishery based on International Pacific Halibut Commission (IPHC) interview data. The 1993 interview data indicates a total mortality of DSR of 13% of the June halibut landings (by weight) and 18% of the September halibut landings. Unreported mortality data has been more difficult to collect under the halibut IFQ fishery and appears to be less reliable than previous data. The allowable bycatch limit of DSR during halibut fishing is 10% of the halibut weight. The total bycatch of DSR during the 1998 halibut fishery in the eastern GOA is estimated to be 300 mt, much of which is unreported. Catch statistics do not accurately reflect true mortality of DSR.

Yelloweye are a large, predatory fish that usually feeds close to the bottom. Food habit studies indicate that the diet of yelloweye rockfish is dominated by fish remains, which comprised 95%, by volume, of the stomachs analyzed. Herring (*Clupea harengus*), sandlance (*Ammodytes hexapterus*) and Puget Sound rockfish (*S. empheaus*) were particularly dominant. Shrimp are also an important prey item (Rosenthal *et al*. 1988).

Thornyheads

Thornyheads in Alaskan waters are comprised of two species, the shortspine thornyhead and the longspine thornyhead. Only the shortspine thornyhead is of commercial importance. It is a demersal species found in deep water from 93 to 1,460 m from the Bering Sea to Baja California. Little is known about thornyhead life history. Like other rockfish, they are long lived and slow growing. The maximum recorded age is probably in excess of 50 years, and females do not become sexually mature until an average age of 12 to 13 at a length of about 21 cm. Thornyheads spawn large masses of buoyant eggs during the late winter and early spring (Pearcy 1962). Juveniles are pelagic for the first year. Yang (1993, 1996) showed that shrimp were the top prey item for shortspine thornyheads in the GOA; while, cottids were the most important prey item in the Aleutian Islands region. Until recently, thornyheads were not targeted by the commercial fishery. However, they are now among the most valuable rockfish species and are harvested by trawl and longline gear. Most of the domestic harvest is exported to Japan. Thornyheads are taken with some frequency in the longline fishery for sablefish and cod and are often part of the bycatch of trawlers concentrating on pollock and other rockfish species.

In the GOA shortspine thornyheads are assessed with an age-structured model incorporating data from two fisheries (longline and trawl) and two types of survey data. Bottom trawl surveys are conducted every three years in the GOA during June through August and provide a limited time-series of abundance since 1977. Longline surveys occur annually and extend into the deeper waters (300 – 800 m) of shortspine thornyhead habitat. Both surveys provide estimates of the size distributions of their respective catches. These are used in the stock assessment model in place of age compositions because extensive age-determinations on this species are currently impractical given the difficulties in interpretation of their otoliths. Biologically, the biggest area of uncertainty for this species is in their longevity and natural mortality rate. Currently, NMFS scientists believe they are slow-growing and long-lived fish that are relatively sedentary on the ocean floor. Survey and fishery catch rates indicate that they are relatively evenly distributed within their habitat and do not tend to form dense aggregations like many other groundfish species. This distribution pattern is important in interpreting the survey results because the assumptions implied in “area-swept” methods for the bottom trawl gear are likely to be satisfied. Fishery data include estimates of the total catch and size distribution information by gear type. The results of the statistical model applied to these data are updated annually and presented in the GOA shortspine thornyheads chapter of the GOA SAFE report.

In the eastern Bering Sea and Aleutian Islands, thornyheads are managed as part of the “other rockfish” management assemblage. Shortspine thornyheads are the primary species in the “other rockfish” management assemblage. The assessment is based on the most recent catch and survey data. Traditionally, the biomass estimates (split according to management area) from all bottom trawl surveys (EBS shelf/slope and Aleutian Islands) are averaged over all years to obtain the best estimates of biomass for the species in this complex. In 1997, this procedure produced a biomass estimate of 7,030 mt in the EBS, and a biomass estimate of 13,000 mt in the Aleutian Islands. The great majority of this biomass is comprised of thornyhead rockfish. In 1996, the SSC determined that a reliable estimate of the natural mortality rate (M) existed for the species in this subcomplex, and that "other rockfish" in the EBS and Aleutian Islands therefore qualified for management under tier 5 of Amendment 44. The accepted estimate of M for these species in both areas is 0.07. F_{ABC} was set at the maximum value allowable under tier 5, which is 75% of M, or 0.053. Multiplying this rate by the best estimate of complex-wide biomass gives an ABC of 369 mt in the EBS and 685 mt in the Aleutian Islands. The Plan Team’s OFLs were determined from the tier 5 formula, where setting F_{OFL}=M gives an OFL of 492 mt in the EBS and 913 mt in the Aleutian Islands.

Other rockfish species

Numerous other rockfish species of the genus Sebastes have been reported in the GOA and BSAI (Eschmeyer *et al*. 1984), and several are of commercial importance. Most are demersal or semi-demersal with different species occupying different depth strata (Kramer and O'Connell 1988). All are viviparous and bear live young (Hart 1973). Life history attributes of most of these rockfish are poorly known or unknown. Because they are long lived and slow growing, natural mortality rates are probably low (less than 0.10). Species for which dietary information exists, the diet seems to consist primarily of planktonic invertebrates (Yang 1993, 1996). Other rockfish species are taken both in directed fisheries and as bycatch in trawl and longline fisheries.

In the GOA, although the “other slope rockfish” management group comprises 17 species, five species alone make up 95% of the catch and estimated abundance. These five species are sharpchin, redstripe, harlequin, silvergrey, and redbanded rockfish. Sharpchin rockfish falls into tier 4, and the remaining species fall into tier 5 of the ABC/OFL definitions. Under these definitions, the overfishing fishing mortality rate for sharpchin rockfish is the $F_{30\%}$ rate of 0.08. The overfishing fishing mortality rate for the other species is the F=M rate of 0.10 for redstripe rockfish, 0.04 for silvergrey rockfish, and 0.06 for all the other species. These overfishing fishing mortality rates translate into a yield of 7,560 mt for the “other slope rockfish” management group. The maximum allowable fishing mortality rate for ABC (F_{ABC}) defined by tier 4 for sharpchin rockfish is the $F_{40\%}$ rate which is 0.055. For the other species the maximum allowable fishing mortality rate for ABC is the F=0.75M rate which is 0.075 for redstripe rockfish, 0.030 for silvergrey rockfish, and 0.045 for the remaining species. These maximum allowable F_{ABC} rates translate to a yield of 5,470 mt for “other slope rockfish.” The stock assessment F_{ABC} is set lower than the maximum allowable fishing mortality rate for ABC because in the stock assessment the F_{ABC} for sharpchin rockfish is set equal to the natural mortality M of 0.050. This results in the stock assessment ABC of 5,260 mt for “other slope rockfish”. The current Council ABC level is equivalent to the recommended stock assessment ABC, and the TAC is set considerably lower than the ABC at 2,170 mt. Because the “other slope rockfish” ABC and TAC are more conservative than the maximum prescribed under the definitions, less risk exists of the F_{ABC} rate and TAC being an overly aggressive harvest rate for “other slope rockfish.” This affords more protection to the stocks given the variability and uncertainty associated with the abundance. Under this harvest strategy a larger buffer exists between the fishing mortality rates associated with ABC and OFL, which lowers the risk of overfishing the stock.

Heifetz and Ackley (1997) analyzed bycatch (not necessarily discarded) in rockfish fisheries of the GOA. Bycatch rates of “other slope rockfish” are highest in the pelagic shelf rockfish and Pacific ocean perch fisheries. Information on bycatch of “other slope rockfish” in non-rockfish fisheries has not been analyzed. Discard rates (discards/total catch) of “other slope rockfish” during 1996 to 1997 have been about 65% (Heifetz and Ackley 1997). In 1997, about 670 mt of “other slope rockfish” were discarded compared to a total catch of 1,210 mt. High discard rates are seen because many species of “other slope rockfish” are small in size and of low economic value, and fishermen have little incentive to retain these fish.

Prey of “other slope rockfish” is not documented for the GOA. Predators of “other slope rockfish” are also not well documented, but likely include larger fish such as Pacific halibut that are known to prey on other rockfish species.

2.1.4.11 Atka Mackerel

Atka Mackerel - Bering Sea/Aleutian Islands

Atka mackerel are distributed from the east coast of the Kamchatka peninsula, throughout the Aleutian Islands and the eastern Bering Sea, and eastward through the GOA to southeast Alaska (Wolotira *et al*. 1993). Their center of abundance is in the

Aleutian Islands, where they are one of the most abundant fish species (Lowe and Fritz 1997a). They are an important prey species for marine mammals and are the target of a directed trawl fishery. Adults are semi-pelagic and spend most of the year over the continental shelf in depths generally less than 200 m. Adults migrate annually to shallow coastal waters during spawning, forming dense aggregations near the bottom (Morris 1981, Musienko 1970). In Russian waters, spawning peaks in mid-June (Zolotov 1993) and in Alaskan waters in July through October (McDermott and Lowe 1997). Females deposit adhesive eggs in nests or rocky crevices. The nests are guarded by males until hatching occurs (Zolotov 1993). Genetic studies indicate that Atka mackerel form a single stock in Alaskan waters (Lowe *et al*. 1998). However, growth rates can vary extensively among different areas (Kimura and Ronholt 1988, Lowe *et al*. 1998, Lowe and Fritz 1997a). Age and size at 50% maturity has been estimated at 3.6 years and 33 to 38 cm, respectively (McDermott and Lowe 1997). Atka mackerel are a fairly short-lived species. A maximum age of 15 years has been noted, however most of the population is probably less than 10 years old. Natural mortality estimates vary extensively, and range from 0.12 to 0.74 as determined by various methods (Lowe and Fritz 1997a). For stock assessment purposes, a value of 0.3 is used (Lowe and Fritz 1997a). Atka mackerel feed primarily on plankton. Studies conducted in Alaskan waters (Yang 1996) show a diet dominated by euphausiids and copepods. Studies conducted in Russian waters, however, indicate that fish can form a significant part of the diet, especially for larger individuals (Orlov 1997).

Atka mackerel are a difficult species to survey because they do not have a swim bladder, and therefore are poor targets for hydroacoustic surveys. They prefer rough and rocky bottoms that are difficult to trawl, and their schooling behavior makes the species susceptible to large variances in catches. Complicating the difficulty in surveying Atka mackerel is the low probability of encountering schools in the GOA where the abundance is lower and their distribution is patchier relative to the BSAI. Because of this, it has not been possible to estimate trends in population for the species in the GOA. Stock assessment in the Aleutian Islands is based on the triennial trawl survey as well as total catch and catch at age data from the commercial fishery.

Bering Sea and Aleutian Islands Atka mackerel are assessed with an age-structured model incorporating fishery and survey catch data and age compositions. Survey data are from the NMFS Aleutian Islands triennial trawl groundfish surveys. Fishery catch statistics (including discards) are estimated by the NMFS Regional Office. These estimates are based on the best blend of observer reported catch and weekly production reports. The stock assessment includes catch history, characterizations of the fishery, assessment methodology, key life history parameterizations, survey and model estimated abundance trends, historical exploitation rates, reference fishing mortality rates, recommended harvest rates, projected catch and abundance trends for a range of fishing mortalities and recruitment assumptions, and recommended catch. The results of the analyses, which are updated annually, are presented in the BSAI Atka mackerel stock assessment which is incorporated into the BSAI SAFE report.

In 1997, Atka mackerel fell into tier 3a of the ABC/OFL definitions, which requires reliable estimates of biomass, $B_{40\%}$, $F_{30\%}$, and $F_{40\%}$. Under the definitions and current stock conditions, the overfishing fishing mortality rate is the $F_{30\%}$ rate which is 0.50 for Atka mackerel and equates to a yield of 133,600 mt (Lowe and Fritz 1997a). The maximum allowable fishing mortality rate for ABC (F_{ABC}) is the $F_{40\%}$ rate which was 0.34 for Atka mackerel in 1998, which would have translated to a yield of 97,100 mt (Lowe and Fritz 1997a). In 1997, the ABC recommendation for Atka mackerel from the stock assessment was below the maximum rate prescribed under tier 3a, to provide a more risk-averse harvest rate and to accommodate uncertainty. The stock assessment F_{ABC} is 0.225 which translates to a yield of 64,300 mt. A recommendation lower than $F_{40\%}$ was recommended in the 1997 stock assessment because: 1) stock size has been steeply declining since 1991 according to the age--structured analysis; 2) the 1997 Aleutian trawl survey biomass estimate was about 50% lower than the 1991 and 1994 survey estimates; 3) under an $F_{40\%}$ harvest strategy, female spawning biomass is projected to decline to almost 30% below $B_{40\%}$ within 5 years; and 4) estimated local Atka mackerel fishery harvest rates appear to have been much greater (on the order of 3-5 times) than the Aleutian-wide harvest rates estimated from the model (Lowe and Fritz 1997a). While this pattern of fishing apparently does not affect local fishing success from one year to the next, uncertainty exists about the long-term effects on the population and particularly on the spawning stock.

The 1997 age and size distributions of BSAI Atka mackerel are discussed in Lowe and Fritz (1997a). The estimated 1997 age composition of Atka mackerel from the stock assessment model is shown in Figure 11. Ages four through 15 represent the recruited population, for which reliable estimates of abundance exist. The age composition is dominated by a recent strong 1992 year class; large numbers from the strong 1988 year class are still in the population. The estimated mean age of the recruited portion of the population is seven years. The current fishery tends to select fish ages 4 to 11 years old (Lowe and Fritz 1997a). It is not known how the age composition of the population would look if it had not been fished.

The directed fishery for Atka mackerel is prosecuted by catcher-processor bottom trawlers. The patterns of the fishery generally reflect the behavior of the species in that the fishery is highly localized, occurring in the same few locations each year, generally occurs at depths between 100 and 200 m (Lowe and Fritz 1997a). Observed Atka mackerel fishery trawl locations during 1993 to 1997 in the Aleutian Islands are shown in Figure 12. Important Atka mackerel fishery locations include Seguam Bank, Tanaga Pass, north of the Delarof Islands, Petrel Bank, south of Amchitka Island, east and west of Kiska Island, and on the seamounts and reefs near Buldir Island.

Atka mackerel are not caught as bycatch to a large extent in other directed fisheries. The largest amounts of discards of Atka mackerel occur in the directed Atka mackerel trawl fisheries. Recent discard rates (discards/retained catch) of Atka mackerel in the directed fishery have been about 20% (Lowe and Fritz 1997a).

Atka mackerel are also caught as bycatch in the trawl Pacific cod and rockfish (primarily Pacific ocean perch, sharpchin and northern rockfish) fisheries. It is difficult to discern the level of natural bycatch of Atka mackerel in the rockfish fisheries, as vessels may actually be targeting Atka mackerel in particular hauls, but overall they are designated as targeting rockfish on a particular trip. In 1996, 15,400 mt of Atka mackerel were discarded in the directed fishery as compared to 2,000 mt discarded in all other fisheries.

The diets of commercially important groundfish species in the Aleutian Islands during the summer of 1991 were analyzed by Yang (1996). More than 90% of the total stomach contents weight of Atka mackerel in the study was made up of invertebrates, with less than 10% made up of fish. Euphausiids (mainly *Thysanoessa inermis* and *Thysanoessa rachii*) were the most important prey item, followed by calanoid copepods. The two species of euphausiids comprised 55% by weight of the total stomach contents, and copepods comprised 17% of the total stomach contents weight. Larvaceans and hyperiid amphipods had high frequencies of occurrence (81% and 68%, respectively), but comprised less than 8% of the total stomach contents weight. Squid was another item in the diet of Atka mackerel; it had a frequency of occurrence of 31%, but only comprised 8% of the total stomach contents weight. Atka mackerel are known to eat their own eggs. Yang (1996) found that Atka mackerel eggs comprised 3% of the total stomach contents weight and occurred in 9% of the Atka mackerel stomachs analyzed. Walleye pollock were the second most important prey fish of Atka mackerel, comprising about 2% of the total stomach contents weight. Myctophids, bathylagids, zoarcids, cottids, stichaeids, and pleuronectids were minor components of the Atka mackerel diet; each category comprised less than 1% of the total stomach contents.

Atka mackerel are consumed by a variety of predators including groundfish, mainly arrowtooth flounder, Pacific halibut, and Pacific cod (Yang 1996); marine mammals, mainly northern fur seals and Steller sea lions (Kajimura 1984, NMFS 1995); and seabirds, mainly tufted puffins (Byrd *et al*. 1992). Atka mackerel are also components in the diets of the following marine mammals and seabirds: harbor seals, Dall's porpoise, thick-billed murre, and horned puffin (Yang 1996).

Atka Mackerel - Gulf of Alaska

No reliable estimate exists of current Atka mackerel biomass in the GOA. Atka mackerel have been uncommonly caught in each of the GOA triennial trawl surveys. It has been determined that the general GOA groundfish bottom trawl survey does not assess the GOA portion of the Atka mackerel stock well, and the resulting biomass estimates have little value as absolute estimates of abundance or as indices of trend (Lowe and Fritz 1997a). Because of this lack of fundamental abundance information, GOA Atka mackerel are not assessed with a model and the assessment does not utilize abundance estimates from the trawl survey. The stock assessment for GOA Atka mackerel consists of descriptions of catch history, length and age distributions from the fishery during 1990 to 1994, and length and age distributions from the trawl surveys (1990, 1993, and 1996). This information is presented in the GOA Atka mackerel stock assessment, which is incorporated into the GOA SAFE report.

Atka mackerel in the GOA fall into tier 6 of the ABC/OFL definitions, which defines the overfishing level as the average catch from 1978 to 1995, and that ABC cannot exceed 75% of the overfishing level. The average annual catch from 1978-95 is 6,200 mt; thus ABC cannot exceed 4,700 mt. The current ABC recommendation from the stock assessment is below the maximum prescribed under tier 6, to provide a very risk-averse harvest rate given the uncertainty about GOA Atka mackerel. The 1997 stock assessment recommended an ABC of 600 mt, with the intention of precluding a directed fishery, but providing for bycatch needs in other trawl fisheries. An ABC lower than the maximum prescribed under tier 6 was recommended because: 1) When past ABCs were lower than 4,700 mt (approximately 3,000 mt in 1994), it was shown that the fishery might have created localized depletions of Atka mackerel even at those catch levels (appendix in (Lowe and Fritz 1996)). This analysis indicated that the fishery was very efficient in removing fish from local areas and at rates which far surpassed the target harvest rate. 2) Analyses of local fishery CPUEs indicated that the Atka mackerel populations may have declined significantly between 1992 and 1994 (appendix in (Lowe and Fritz 1996)), reflecting the trend of the Aleutian Islands Atka mackerel population during that period, which has continued to decline since 1994 (Lowe and Fritz 1997b). 3) The GOA Atka mackerel population appears to be particularly vulnerable to fishing pressure because of sporadic movement of fish eastward from the Aleutian Islands.

Age and size distributions of GOA Atka mackerel are discussed in Lowe and Fritz (1997a). The most recent size and age distributions are from the 1996 and 1993 trawl surveys, respectively. Male and female size distributions had mean lengths of 45 and 47 cm, respectively. A mode of fish from 45 to 47 cm represented the 1988 year class. It appears as though little recent recruitment has occurred in the GOA population. Currently, no directed fishery for GOA Atka mackerel occurs. Atka mackerel are caught as bycatch, and the selectivity of Atka mackerel by the other fisheries is unknown.

Atka mackerel in the GOA are currently managed as a bycatch fishery. They are caught as bycatch in the pollock, Pacific cod, Pacific ocean perch, and northern rockfish fisheries. The low level of TAC likely precludes directed targeting of Atka mackerel on a haul by haul basis, and the catches of Atka mackerel in other directed fisheries may represent true bycatch of Atka mackerel.

The diets of commercially important groundfish species in the GOA during the summer of 1990 were analyzed by Yang (1993). Atka mackerel were not sampled as a predator species. However, it is probably a reasonable assumption that the major prey items of GOA Atka mackerel would likely be euphasiids and copepods as was found in Aleutian Islands Atka mackerel (Yang 1996). The abundance of Atka mackerel in the GOA is much lower compared to the Aleutian Islands. Atka mackerel only showed up as a minor component in the diet of arrowtooth flounder in the GOA (Yang 1993).

2.1.4.12 Squid

Squid are found throughout the Pacific Ocean. They are not currently the target of groundfish fisheries in the GOA or BSAI, though they are taken as bycatch in trawl fisheries for pollock and rockfish. The red, or magistrate, armhook squid (*Berryteuthis magister*) is probably the best known species found in Alaskan waters. It is abundant over continental slopes throughout the north Pacific from Oregon to southern Japan (Nesis 1987). It is the basis of fisheries in both Russian and Japanese waters. Little is known about the reproductive biology of squid. Fertilization is internal and juveniles have no larval stage. Eggs of inshore species are often enveloped in a gelatinous matrix attached to substrate, while the eggs of offshore species are extruded as drifting masses. The red armhook squid appears to spawn in the spring and to live as long as 4 years, though most die after spawning at one year to 16 months old (Arkhipkin *et al*. 1996). Perez (1990) estimated that squids comprise over 80% of the diet of some whales. Seabirds and some salmon species are also known to feed heavily on squid at certain times of the year.

In the Bering Sea and Aleutian Islands FMP squid are grouped in a "Squid and Other Species" groups made up of squids, which are considered separately; and sculpins, skates, sharks, and octopus, which comprise the true "other species" category. Because insufficient data exists to manage each of the other species groups separately, they are considered collectively. Neither squid nor any of the species in the other species category are currently targeted by the groundfish fisheries in the BSAI and GOA. As such, they are only caught as bycatch by fisheries targeting groundfish. Beginning in 1999, smelts have been removed from the other species category and been placed, along with a wide variety of other fish and crustaceans including euphausiids, Bathylagidae, and Myctophidae, in the forage fish category.

Assessment data are not available for squid from AFSC surveys because of their mainly pelagic distribution over deep water. Information on the distribution, abundance, and biology of squid stocks in the EBS and Aleutian Islands region is generally lacking. *Berryteuthis magister* predominates in commercial catches in the EBS and GOA, and *Onychoteuthis borealijaponicus* is the principal species encountered in the Aleutian Islands region.

Forty-one species of sculpins were identified in the EBS and 22 species in the Aleutian Islands region (Bakkala 1993, Bakkala *et al*. 1985, Ronholt *et al*. 1985). During these same surveys, 15 species of skates were identified but inadequate taxonomic keys for this family may have resulted in more species being identified than actually exist. Species that have been consistently identified during surveys are the Alaska skate (*Bathyraja parmifera*), big skate (*Raja binoculata*), longnose skate (*R. rhina*), starry skate (*R. stellulata*), and Aleutian skate (*B. aleutica*). Biomass estimates of sculpins and skates from demersal trawl surveys serve as valuable indices of their relative abundance.

While biomass estimates have been made for sharks and octopi, the AFSC bottom trawl surveys are not designed to adequately sample the realms they inhabit. Sharks are rarely taken during demersal trawl surveys in the Bering Sea; however, spiny dogfish (*Squalus acanthias*) is the species usually caught, and the Pacific sleeper shark (*Somniosus pacificus*) has been taken on occasion. Two species of octopus have been recorded, with

Octopus dofleini the principal species and *Opisthoteuthis california* appearing only intermittently.

Many species in the squid and other species assemblage are important as prey for marine mammals and birds as well as commercial groundfish species. Squid and octopus are consumed primarily by marine mammals, such as Steller sea lions ((Lowry *et al*. 1982), northern fur seals (Perez and Bigg 1986), harbor seals (Lowry *et al*. 1982, Pitcher 1980b), sperm whales (Kawakami 1980), Dall's porpoise (Crawford 1981), and Pacific white-sided dolphins (Morris *et al*. 1983) and beaked whales (Loughlin and Perez 1985)). Sculpins have also been found in the diet of harbor seals (Lowry *et al*. 1982).

Current Stock Assessment and OFL/ABC/TAC Determinations

No reliable biomass estimates for squid exist, and no stock assessment per se. Sobolevsky (1996) cites an estimate of 4 million tons for the entire Bering Sea made by squid biologists at TINRO (Shuntov *et al*. 1993), and an estimate of 2.3 million tons for the western and central Bering Sea (Radchenko 1992), but admits that squid stock abundance estimates have received little attention. AFSC bottom trawl surveys almost certainly underestimate squid abundance. Squid catches and ABCs are almost certainly a very small percentage of the total squid biomass in the EBS and GOA. BSAI squid ABC and OFL are set using criteria in tier 6 as described in Amendment 44 to the BSAI FMP given the lack of data on their population dynamics and biomass. Over fishing level is set equal to the average annual catch from 1978 to 1995 (2,624 mt), while ABC is capped at no greater than 75% of OFL (1,970 mt). As currently defined, BSAI squid ABC and OFL values would remain constant in the future, unless different methodologies were employed to assess squid abundance (e.g., analysis of fishery CPUE data). This methodology change could occur under any of the alternatives considered. The BSAI squid TAC has been set equal to the stock assessment recommended ABC by the Council.

Reliable biomass estimates exist for two (skates and sculpins) of the groups that comprise the bulk of the biomass and fishery catches in the other species category. Survey biomass estimates for sharks, smelts, and octopus, while not reliable, represent the best data available on the abundance of these species. A single estimate of M for this diverse assemblage, while not known, is conservatively estimated at 0.2. OFL for the other species assemblage is set using the criteria in tier 5 as described in Amendment 44, where F_{OFL}=M, and OFL=M x (total other species survey biomass). Using tier 5 criteria, ABC is capped at 75% of OFL. However, rather than use this method, the other species ABC has been calculated as the average annual catch since 1978 to avoid potentially 5-fold increases in other species catches that could occur if it were set at 75% of OFL. Bering Sea and Aleutian Islands area other species TAC has been set equal to the other species ABC by the Council. A 1998 ABC for the BSAI other species category set using this process represents an exploitation rate of about 4% of the best estimate of current biomass (669,263 mt). This estimate was obtained by averaging the three most recent EBS bottom trawl survey estimates of other species biomass (from 1995 to 1997:

620,564 mt), and adding the most recent Aleutian Islands bottom trawl estimate (from 1997: 48,699 mt).

The annual TAC for other species in the GOA (which includes squid) is set equal to 5% of the sum of all GOA groundfish TACs. Catches of other species in the GOA have ranged between 1,570 and 6,867 mt from 1990 to 1997.

2.1.5 Action areas for the groundfish fisheries

The action area for BSAI groundfish fisheries effectively covers all Bering Sea areas under U.S. jurisdiction, extending southward to include the waters south of the Aleutian Islands west of 170°W long. to the border of the U.S. Exclusive Economic Zone (Fig. 1). The pollock fishery occurs primarily over the southeastern Bering Sea shelf in winter months and extends northwestward along the shelf break in the summer/autumn season (Wespestad *et al*. 1997). The 1996 Pacific cod fishery occurred primarily in the eastern Bering Sea with an additional 10% (or less) of the annual catch from the Aleutian Islands subarea (Thompson and Dorn 1997). In 1996, the yellowfin sole fishery occurred in the southeastern Bering Sea, with a second area of concentration southwest of the mouth of Kuskokwim Bay and additional fishing dispersed along the shelf break as far northward as St. Matthew Island (Wilderbuer 1997). Trawling for Greenland turbot in 1996 was concentrated along the Aleutian Islands, with the highest catch per unit effort just west of 170°W long. The longline fishery for Greenland turbot was dispersed along the shelf break from the northern side of the Fox Islands to north of 60°N lat (east of St. Matthew Island; Ianelli *et al*. 1997b). The distribution of the 1996 catch of rock sole was similar to that of yellowfin sole (Wilderbuer and Walters 1997a). The 1996 catch of flathead sole was similar to that of yellowfin sole and rock sole, but less catch occurred to the southwest of Kuskokwim Bay and more to the west and northwest of the Pribilof Islands along the shelf break (Walters and Wilderbuer 1997). Alaska plaice were taken in 1996 in the southeastern Bering Sea east of the Pribilof Islands along 165°W long. (Wilderbuer and Walters 1997b). Sablefish are taken in small amounts (currently less than 1000 mt) in both the Aleutian Islands and eastern Bering Sea regions (Sigler *et al*. 1997a). Pacific ocean perch and other rockfish are taken primarily in the Aleutian Islands region, with some additional removal in the eastern Bering Sea (Ito and Ianelli 1997, Ito 1997). Atka mackerel are taken from Seguam Island and Pass westward along the Aleutians to Attu Island and, in some past years, Stalemate Bank (Lowe and Fritz 1997a). From 1996, skate and sculpin catches occurred from the shelf break eastward over the shelf and along the Aleutian Islands; octopus, squid, and shark catches were primarily along the shelf break, with some catch from the Aleutian Islands region; and smelt were taken primarily over the southeastern Bering Sea shelf (Fritz 1997).

In the GOA, the action area extends from 170°W long. (the western border of management area 610) to the U.S.-Canadian border and extends southward to all contingent waters of the U.S. Exclusive Economic Zone (Fig. 2). Pollock is taken primarily in the western (601) and central (620, and 630) regions, with concentrations of catch in Shelikof Strait, near Kodiak Island, in the Shumagin Islands, and Davidson Bank (Hollowed *et al*. 1997). In recent years, most Pacific Cod has been taken from the central region, with about half as much taken in the western region (Thompson *et al*. 1997). Deep-water flatfish are taken primarily from the central and eastern regions, whereas shallow-water flatfish are taken primarily from the western and central regions

(Turnock *et al*. 1997a). Arrowtooth flounder are taken primarily from the central region (Turnock *et al*. 1997b). Sablefish are taken primarily in the Kodiak region (630), W. Yakutat (640), and E. Yakutat and Southeast outside (SEO) region (650), with smaller amounts taken in the Shumagin (610) and Chirikof (620) regions (Sigler *et al*. 1997b). Slope rockfish are taken primarily in the central region (Heifitz *et al*. 1997), as are pelagic shelf rockfish (Clausen and Heifitz 1997). Demersal shelf rockfish are caught in the SEO region (O'Connell *et al*. 1997). Estimates of thornyhead biomass by surveys suggests thornyheads are found in greater abundance in the eastern and central regions, but removal by region can not yet be determined due to lack of observer coverage (Ianelli *et al*. 1997a). Atka mackerel are taken in the GOA in relatively small amounts (compared to the BSAI region), primarily from the western (610) management area (Lowe and Fritz 1997b).

2.1.6 Potential direct and indirect effects of the groundfish fisheries on Steller sea lions

The potential effects of the groundfish fisheries on Steller sea lions can be described as either operational or biological. Operational effects include gear interactions, incidental kill of sea lions, or entanglement in fishery-related debris. Biological interactions include competition for prey, changes in community composition secondary to fishery removals, changes in size structure of prey species, or changes in the temporal and spatial distribution of prey. Exploitative competition for prey may occur because both the groundfish fisheries and Steller sea lions consume similar prey. Interactive competition could occur if sea lions abandon primary foraging areas due, for example, to disturbance.

2.1.7 Conservation measures associated with the groundfish fisheries

Groundfish fisheries are managed by NMFS and the NPFMC in a manner intended to protect and conserve the integrity of these ecosystems. Fishery management tools include permits and limited entry, catch quotas (TACs), seasons, in-season adjustments, gear restrictions, closed waters, bycatch limits and rates, allocations, regulatory areas, record keeping and reporting requirements, and observer monitoring. Annual management efforts are detailed below in the section on Federal fishery management actions (in the section on the environmental baseline).

3.0 STATUS OF PROTECTED SPECIES

The following threatened and endangered species and designated critical habitat may be affected by the proposed actions:

Steller sea lion (western population)	*Eumetopias jubatus*	Endangered
Steller sea lion (eastern population)		Threatened
Northern right whale	*Balaena glacialis*	Endangered
Sei whale	*Balaenoptera borealis*	Endangered
Blue whale	*Balaenoptera musculus*	Endangered
Fin whale	*Balaenoptera physalus*	Endangered
Humpback whale	*Megaptera novaeangliae*	Endangered

Sperm whale	*Physeter macrocephalus*	Endangered
Chinook salmon (Snake River spring/summer)	*Oncorhynchus tshawytscha*	Threatened
Chinook salmon (Snake River fall)		Threatened
Sockeye salmon (Snake River)	*Oncorhynchus nerka*	Endangered

In the action areas, critical habitat has been designated only for the western and eastern populations of Steller sea lions (50 CFR 227.12).

The endangered short-tailed albatross (*Diomedea albatrus*), threatened spectacled eider (*Somateria fisheri*), and threatened Steller's eider (*Polysticta stelleri*) occur in the action areas for the three proposed actions; these species are under the jurisdiction of the U.S. Fish and Wildlife Service (USFWS). A letter dated December 2, 1998 from the USFWS to Steven Pennoyer, NMFS, Administrator, Alaska region, extends the USFWS's 1997-1998 Biological Opinion covering these species until it is superseded by a subsequent amendment to that opinion. Based upon current information, USFWS does not anticipate the final Biological Opinion will determine that this action places short-tailed albatross in jeopardy of extinction. The listed cetaceans occur within the action areas, but they are not likely to be adversely affected by the proposed actions because of their distribution patterns and life history characteristics; they will not be considered further in this opinion. The listed salmon species are managed by the Northwest Region, NMFS, and are addressed in a separate consultation from that office.

3.1 Steller sea lion

3.1.1 Species description

The Steller sea lion (*Eumetopias jubatus*) is the only extant species of the genus *Eumetopias*, and is a member of the subfamily Otariinae, family Otariidae, superfamily Otarioidea, order Pinnipedia. The closest extant relatives of the Steller sea lion appear to be the other sea lion genera, including *Zalophus*, *Otaria*, *Neophoca*, and *Phocartos*, and the fur seals of the genera *Callorhinus* and *Arctocephalus*. Loughlin *et al*. (1987) provide a brief but informative summary of the fossil record for *Eumetopias*. Repenning (1976) suggests that a femur dated 3 to 4 million years old may have been from an ancient member of the *Eumetopias* genus, thereby indicating that the genus is at least that old. Presumably, *Eumetopias jubatus* evolved entirely in the North Pacific (Repenning 1976).

3.1.2 Distribution

The Steller sea lion is distributed around the North Pacific rim from the Channel Islands off Southern California to northern Hokkaido, Japan. In the Bering Sea, the northernmost major rookery is on Walrus Island (Pribilof Islands) and their northernmost major haulout is on Hall Island (off the northwestern tip of St. Matthew Island). Their distribution also extends northward from the western end of the Aleutian chain to sites along the eastern shore of the Kamchatka Peninsula. The center of distribution has been considered to be in the GOA and the Aleutian Islands (NMFS 1992). Within this distribution, land sites used by Steller sea lions are referred to as rookeries and haulout sites. Rookeries are used by adult males and females for pupping, nursing, and mating during the reproductive season (late May to early July). Haulouts are used by all size and sex classes but are generally not sites of reproductive activity as occurs on rookeries. The continued use of particular sites may be due to site fidelity, or the tendency of sea lions to return repeatedly to the same site, often the site of their birth. Presumably, these sites were chosen and continue to be used because they provide protection from predators, some measure of protection from severe climate or sea surface conditions, and (perhaps most importantly) are in close proximity to prey resources.

The movement patterns of Steller sea lions are not yet well understood. Their movement patterns from a land base (rookery or haulout) might be categorized into at least three types. First, sea lions move on and offshore for feeding excursions. Limited data are available to describe these movements (e.g., Gentry 1970, Sandgren 1970, Merrick and Loughlin 1997), but such descriptions are essential for understanding foraging patterns, nursing strategies, and energetics. Second, at the end of the reproductive season, some females may move with their pups to other haulout sites and males may “migrate” to distant foraging locations [Spaulding 1964, Mate 1973, Porter 1997]). Limited data are available indicating that animals do shift from rookeries to haulouts, but the timing and nature of these movements need further description (i.e., what distances are involved, are movements relatively predictable for individuals, do movements vary with foraging conditions, etc.). Description of these types of movements are essential for understanding seasonal distribution changes, foraging ecology, and apparent trends as a function of season. Third, sea lions may make semi-permanent or permanent one-way movements from one site to another (Chumbley *et al*. 1997, their Table 8; Burkanov *et al*. unpubl. report [cited in Loughlin 1997]). Calkins and Pitcher (1982) reported movements in Alaska of up to1500 km. They also describe wide dispersion of young animals after weaning, with the majority of those animals returning to the site of birth as they reach reproductive age.

The distribution of Steller sea lions at sea is also not well understood. Their at-sea distribution is, however, a critical element to any understanding of potential effects of fisheries on Steller sea lions, and will be considered in greater detail below in the section on foraging patterns.

3.1.3 Reproduction

Steller sea lions have a polygynous reproductive system where a single male may mate with multiple females. As mating occurs on land (or in the surf or intertidal zones), males are able to defend territories and thereby exert at least partial control over access to adult females and mating privileges. The pupping and mating season is relatively short and synchronous, probably due to the strong seasonality of the sea lions’ environment and the need to balance aggregation for reproductive purposes with dispersion to take advantage of distant food resources (Bartholomew 1970). In May, adult males compete for rookery territories. In late May and early July, adult females arrive at the rookeries, where pregnant females give birth to a single pup. The sex ratio of pups at birth is assumed to be approximately 1:1 (e.g., York 1994) or biased toward slightly greater production of males (e.g., Pike and Maxwell 1958, Lowry *et al*. 1982, NMFS 1992).

Mating occurs about one to two weeks later (Gentry 1970). The gestation period is probably about 50 to 51 weeks, but implantation of the blastocyst is delayed until late September or early October (Pitcher and Calkins 1981). Due to delayed implantation, the metabolic demands of a developing fetus are not imposed until well after fertilization.

For females with a pup, the nursing period continues for months to several years. Thorsteinson and Lensink (1962) suggested that nursing of yearlings was common at Marmot Island in 1959. Pitcher and Calkins (1981) suggested that it is more common for pups to be weaned before the end of their first year, but they also observed nursing juveniles (aged 1 to 3). Porter (1997) distinguished metabolic weaning (i.e., the end of nutritional dependence of the pup or juvenile on the mother) from behavioral weaning (i.e., the point at which the pup or juvenile no longer maintains a behavioral attachment to the mother). He also suggested that metabolic weaning is more likely a gradual process occurring over time and more likely to occur in March-April, preceding the next reproductive season. The transition to nutritional independence may, therefore, occur over a period of months as the pup begins to develop essential foraging skills, and depends less and less on the adult female. The length of the nursing period may also vary as a function of the condition of the adult female. The nature and timing of weaning is important because it determines the resources available to the pup during the more demanding winter season and, conversely, the demands placed on the mother during the same period. The maintenance of the mother-offspring bond may also limit their distribution or the area used for foraging.

Relatively little is known about the life history of sea lions during the juvenile years between weaning and maturity. Pitcher and Calkins (1981) reported that females sampled in the late 1970s reached reproductive maturity between ages 2 and 8, and the average age of first pregnancy was 4.9 ±1.2 years. These results suggest a mean age of first birth of about 6 years. The available literature indicates an overall reproductive (birth) rate on the order of 55% to 70% or greater (Pike and Maxwell 1958, Gentry 1970, Pitcher and Calkins 1981, Pitcher *et al*. in review). York (1994) derived the age-specific fecundity rates in Table 4 based on data from Calkins and Pitcher (1982). Those rates illustrate a number of important points and assumptions. First, the probability of pupping is rare (about 10%) for animals 4 years of age or younger. Second, maturation of 100% of a cohort of females occurs over a prolonged period which may be as long as 4 years. Third, the reported constancy of fecundity extending from age 6 to 30 indicates that either senescence has no effect on fecundity, or our information on fecundity rates is not sufficiently detailed to allow confident estimation of age-specific rates for animals older than age 6. Given the small size of the sample taken, the latter is a more likely explanation for such constancy.

Merrick *et al*. (1995) compared pup sizes at different sites where Steller sea lion populations were either decreasing or increasing, to determine if pup size or growth may be compromised in decreasing populations. Their results were not consistent with that hypothesis; rather, they found that pups about two to four weeks of age were larger at sites in the Aleutian Islands and GOA than they were in southeast Alaska or Oregon. These observed differences indicate that at least this phase of reproduction may not be affected; that is, if females are able to complete their pregnancy and give birth, then the size of those pups does not appear to be compromised. Possible alternative explanations for the observed size differences are that pups were measured at different ages (i.e., pups in the GOA and Aleutian Islands may have been born earlier and therefore were older when weighed), or that over time, harsher environmental conditions have selected for larger size in pups born in the Aleutian Islands of the GOA.

The reproductive success of an adult female is determined by a number of factors. The reproductive cycle includes mating, gestation, parturition, and nursing or post-natal care. The adult female's ability to complete this cycle successfully is largely dependent on the resources available to her. While much of the effort to explain the Steller sea lion decline has focused on juvenile survival rates, considerable evidence suggests that the decline may also be due, in part, to decreased reproductive success.

! Younger females collected in the 1970s were larger than females of the same age collected in the 1980s (Calkins *et al*. 1998). As maturity is likely related to size, females in the 1980s would also be more likely to mature and begin to contribute to population productivity at a later age.

! Pitcher *et al*. (in review) provide data from the 1970s and 1980s that suggests a much higher pregnancy rate after the mating season (97%; both periods), which declined to 67% for females collected in the 1970s and 55% for females collected in the 1980s. These changes in pregnancy rate suggest a large fetal mortality rate that could be a common feature of the Steller sea lion reproductive strategy (i.e., may occur even when conditions are favorable and population growth is occurring), but is more likely an indication of stress (possibly nutritional) experienced by individual females.

! The observed late pregnancy rates (67% in the 1970s and 55% in the 1980s) were not significantly different statistically. However, the direction of the difference is consistent with the hypothesis that reproductive effort in the 1980s was compromised.

! Pitcher *et al*. (in review) did observe a statistical difference in the late season pregnancy rates of lactating females in the 1970s (63%) versus lactating females in the 1980s (30%). This difference indicates that in contrast to lactating females in the 1970s, lactating females in the 1980s were less able to support a fetus and complete a consecutive pregnancy.

Males appear to reach sexual maturity at about the same time as females (i.e., 3 and 7 years of age; Perlov 1971 reported in Loughlin *et al*. 1987), but generally do not reach physical maturity and participate in breeding until about 8 to 10 years of age (Pitcher and Calkins 1981). A sample of 185 harem bulls from the Marmot, Atkins, Ugamak, Jude, and Chowiet Islands in 1959 included animals 6 to 17 years of age, with 90% from 9 to 13 years old (Thorsteinson and Lensink 1962).

3.1.4 Survival

Much of the recent effort to understand the decline of Steller sea lions has been focused on juvenile survival, or has assumed that the most likely proximate explanation is a decrease in juvenile survival rates. This contention is supported by direct observations and a modeling study, and is consistent with the notion that juvenile animals are less adept at avoiding predators and obtaining sufficient resources (prey) for growth and survival.

The direct observations consist of extremely low resighting rates at Marmot Island of 800 pups tagged and branded at that site in 1987 and 1988 (Chumbley *et al*. 1997) and observations of relatively few juveniles at Ugamak (Merrick *et al*. 1988). The low resighting rates do not themselves confirm that the problem was a corresponding drop in juvenile survival, but only that many of the marked animals were lost to the Marmot Island population. Migration to other sites where they were not observed is a possibility, but unlikely. If the "loss" of these animals is viewed in the context of the overall sea lion decline in the central GOA (from 1976 to 1994 the number of non-pups counted at Marmot Island declined by 88.9% and by 76.9% at the 14 other trend sites in the Gulf; Chumbley *et al*. 1997), then a significant increase in juvenile mortality is a much more plausible conclusion.

Modeling by York (1994) provides evidence that the observed decline in sea lion abundance in the GOA may have been due to an increase in juvenile mortality. York used the estimated rate of decline between the 1970s and the 1980s, and the observed shift in the mean age of adult females (≥3 years of age) to explore the effects of changes in adult reproduction, adult survival, and juvenile survival. While she pointed out that the observed decline did not rule out all other possible explanations, she concluded that the observed decline is most consistent with a decrease in juvenile survival on the order of 10 to 20% annually.

However, juvenile survival may not be the only factor influencing the decline of the western population of Steller sea lions. Evidence indicating a decline in reproductive success was presented above. In addition, changes in adult survival may also have contributed to the decline. At present, survival rates for adult animals can not be determined with sufficient resolution to determine if those rates have changed over time or are somehow compromised to the extent that population growth and recovery are compromised.

3.1.5 Age distribution

Two life tables have been published with age-specific rates (Table 4). The first was from Calkins and Pitcher (1982) and was based on sea lions killed in the late 1970s. York (1994) created a second life table using a Weibull model and the data from Calkins and Pitcher (1982) and Calkins and Goodwin (1988). York's analysis of these two data sets suggests a shift from the 1970s to the 1980s in the mean age of females older than 3 years of age. The shift was about 1.55 years, and provided the basis for her determination that increased juvenile mortality may have been an important proximate factor in the decline of Steller sea lions. That is, such a shift in mean age would occur as the adult population aged without expected replacement by recruiting young females.

The most apparent limitations of these data and the resulting life tables are 1) the collected sea lions were not from the same locations and the relations between populations at different sites have not been described (e.g., were they experiencing similar trends and were their age structures comparable), 2) the data and estimated vital rates are also time-specific, and do not necessarily apply to the current population, 3) the assumption of a stable age distribution (or distributions) may be faulty even if trends at these different sites were consistent, and 4) the data set is relatively small and does not provide a basis for estimating age-specific survival rates for very young ages (0-2 years of age) or for possibly senescent older animals (say >12 years of age).

Until senescence is assessed, longevity for Steller sea lions will be difficult to describe. The data reported in Pitcher and Calkins (1981) indicate that female sea lions may live to 30 years of age. A Weibull function fit to these data (York 1994) indicates, however, that fewer than 5% of females live to age 20.

The present age distribution may or may not be consistent with these life tables. Nevertheless, these tables provide the best available information on vital parameters, and the present age structure of sea lions may be similar if the immediate causes of the decline (e.g., low juvenile survival or low reproductive rates) have remained relatively constant.

3.1.6 Foraging patterns

The foraging patterns of the Steller sea lion are clearly central to any discussion of the potential for interaction between this species and groundfish (or other) fisheries in the BSAI or GOA. A partial list of foraging studies is provided in Table 5, together with notes on the sample sizes, locations, years, and primary findings of those studies.

3.1.6.1 Methods for researching sea lion foraging behavior

Our current understanding of Steller sea lion foraging patterns are based on the following methods.

Observations: Foraging patterns can be discerned, in part, simply by observation studies. Observations can be useful for identifying areas that may be important foraging sites (e.g., Kajimura and Loughlin 1988, Fiscus and Baines 1966). The designation of foraging areas as part of critical habitat was based, in part, on observations that sea lions use those areas for foraging. Similarly, under certain circumstances observations can be used for identifying prey items, particularly those that may be commercially important (e.g., Jameson and Kenyon 1977). In general, however, the power of observational studies is limited to situations where sea lions bring their prey to the surface and the prey can be identified, or where the sea lions can be observed diving repeatedly and the assumption that they are foraging is reasonable.

Stomach and intestinal contents: Stomach contents are generally considered to be the most reliable indication of foraging patterns. Biases may exist from variable rates of digestion of soft tissues or variable retention of hard tissues (e.g., squid beaks), and Pitcher (1981) indicated that results from intestinal tracts may not correspond to results from stomachs. Results may also be biased by the evaluation method (e.g., use of frequency of occurrence may indicate how many animals ingested a prey type, but may not provide a good indicator of the importance of that prey; see Spalding 1964). Analyses of stomach contents have provided a large portion of our information on sea lion foraging (e.g., Calkins and Pitcher 1982, Calkins and Goodwin 1988), but under most conditions, killing for collection of stomach contents is not considered appropriate and stomach and intestinal contents are now available only from dead animals or live animals that are under sedation and can be lavaged or given an enema.

Scat analysis: Scats, or feces, are being used to study Steller sea lion prey selection, and have provided important information on the frequency of occurrence of both Atka mackerel and pollock in their diet (e.g., Merrick *et al*. 1997). Materials from scats, such as otoliths, can be used with additional information (e.g., size at age) to infer additional information about the prey consumed (Pitcher 1981, Frost and Lowry 1986). Scats are known to be a biased index of prey selection because some prey may not have hard parts that resist digestion and can be identified in a scat, and the scat generally contains prey items consumed relatively recently (depending on the rate of passage through the digestive tract). Nevertheless, scat collections provide a non-lethal means of comparing diet and diet changes over time and space, and estimating relative frequency of occurrence of prey items in the sea lion diet.

Telemetry: At least three types of telemetry are (or have been) used to study sea lion foraging. Very high frequency (VHF) telemetry can be used to determine presence or absence of an animal and, to a limited extent, animal location and whether it is on land or in the water. The use of VHF telemetry to determine the presence or absence of an animal can be used to infer the occurrence and length of foraging trips (e.g., Merrick and Loughlin 1997).

Satellite-linked telemetry is being used to determine animal location and, when coupled with time-depth recorders, diving patterns (e.g., Merrick *et al*. 1994). Satellite-linked telemetry provides an opportunity to collect information on animal location without having to recapture the animal to collect stored data. At present, satellite-linked telemetry is the primary means of assessing the distribution of foraging animals and thereby determining those regions that are critical for Steller sea lions.

Stomach telemetry is being developed and offers an opportunity to determine when an animal has consumed prey, rather than requiring the investigator to infer feeding from diving behavior. Stomach telemetry, in combination with satellite-linked telemetry, may provide greater understanding of foraging behavior and discrimination of at-sea activities that may or may not be related to foraging.

Captive studies: Studies of animals in captivity may be useful for understanding prey selection, diving and foraging physiology, and energetics. Various studies have examined assimilation efficiency, changes in weight as a function of prey type (Fadely *et al*. 1994, Rosen and Trites *in prep*), metabolic rates, and the heat increment of feeding (Rosen and Trites 1998). Energetic and nutritional studies on captive animals will likely form a basis from which dietary requirements of wild animals can be determined and understood. The issue of competition between groundfish fisheries and the Steller sea lion may be decided on the basis of demographic, ecological, or other information, but our understanding of such competition will ultimately depend on our ability to explain their energetic and nutritional needs and physiology.

Fatty acid analysis: Fish species, like pollock and Atka mackerel, vary in fatty acid composition and therefore carry their own “fatty acid signature.” Removal of small tissue (blubber) plugs from Steller sea lions and analysis for fatty acid composition can be used to identify prey types. This method of prey analysis is relatively new (e.g., Iverson 1993), but has been used successfully to identify prey types of harbor seals in different regions of Prince William Sound (Iverson *et al*. 1997). The NMFS laboratory at Auke Bay is developing the capability to conduct such analyses, and this approach to prey determination will likely prove to be useful in the near future.

Isotope analysis: Isotope ratios for various elements differ in prey types in a manner that allows estimation of general prey category and trophic level. These analyses can be conducted using small amounts of tissue (e.g., vibrissae or whiskers) and may provide evidence of long term changes in prey type, trophic level, or feeding strategy.

3.1.6.2 Foraging distributions

At present, our understanding of Steller sea lion foraging distribution is based on observations of foraging behavior (or presumed foraging behavior) in areas such as the southeastern Bering Sea (Fiscus and Baines 1966, Kajimura and Loughlin 1988), records of incidental take in fisheries (Perez and Loughlin 1991), and satellite telemetry studies (e.g. Merrick *et al*. 1994, Merrick and Loughlin 1997). Observations and incidental take of sea lions (Loughlin and Nelson 1986, Perez and Loughlin 1991) in the vicinity of Seguam Pass, the southeastern Bering Sea, and Shelikof Strait provided a basis for establishment of those areas as critical habitat (FR 58:45269-45285).

The results of telemetry studies suggest that foraging distributions vary by individual, size or age, season, site, and reproductive status (i.e., is the female still supporting a pup; Merrick and Loughlin 1997). The foraging patterns of adult females differed during summer months when females were with pups versus winter periods when considerable individual variation was observed, but may be attributable to the lactation condition of the females. Trip duration for females (n = 14) in summer was approximately 18 to 25 hours. For five of those females that could be tracked, trip length averaged 17 km and they dove approximately 4.7 hours per day. For five females tracked in winter months, mean trip duration was 204 hours, mean trip length was 133 km, and they dove 5.3 hours per day. The patterns exhibited by females in winter varied considerably, from which the investigators inferred that two of them may still have been supporting a pup. Those two females continued to make relatively shorter trips (mean of 53 km over 18 hours) and dove 8.1 hours per day, whereas the other three ranged further, dove 3.5 hours per day, and spent up to 24 days at sea. Five winter young-of-the-year exhibited foraging patterns intermediate between summer and winter females in trip distance (mean of 30 km), but shorter in duration (mean of 15 hours), and with less effort devoted to diving (mean of 1.9 hours per day). Estimated home ranges (mean ± 1 SE) were 319 ± 61.9 km^2 for adult females in summer, 47,579 ± 26,704 km^2 for adult females in winter, and 9,196 ± 6799 km^2 for winter young-of-the-year.

The sea lions used in Merrick and Loughlin's (1997) study were from the GOA (Sugarloaf Island, Latax Rocks, Marmot Island, Long Island, Chirikof Island, Atkins Island, and Pinnacle Rock), and the BSAI region (Ugamak Island and Akun Island). This information is, therefore, directly pertinent to the action areas for both the GOA and BSAI fisheries, although it is perhaps most relevant to the GOA action area.

3.1.6.3 Foraging depths

The sea lions in the Merrick and Loughlin (1997) study tended to make relatively shallow dives, with few dives recorded at greater than 250 m (Fig. 13). Maximum depth recorded for the five summer adult females were in the range from 100 to 250 m, and maximum depth for the five winter adult females was greater than 250 m. The maximum depth measured for winter young-of-the-year was 72 m. These results suggest that sea lions are generally shallow divers, but are capable of deeper dives (i.e., greater than 250 m).

The instruments used to record diving depths do not determine the purpose of a dive, and many of the recorded dives (Fig. 13) may not be indicative of foraging effort. Dives between 4 and 10 m depth may be for foraging, or they may simply be grooming, porpoising, or transiting between locations. For example, animals transiting to and from foraging locations during rough sea surface conditions may transit in a series of long, shallow dives to avoid such conditions. The relatively large number of dives recorded between 4 and 10 m may therefore bias the assessment of “foraging” depths for these sea lions.

The results from this study also may not be indicative of diving depths and patterns for other sea lions at other times of year or in other locations. The winter young-of-the-year were instrumented in the period from November to March, when they were probably about five to nine months old and may have still been nursing. At this age, they are just beginning to develop foraging skills, which may take years to learn. The diving depths and patterns exhibited by these young-of-the-year are likely poor indicators of the foraging patterns of older juveniles (one- to three-year-olds). For example, Swain and Calkins (1997) report dives of a 2-year-old male sea lion to 252 m, and regular dives of this animal and a yearling female to 150 m to 250 m (Fig. 14). Clearly, if young-of-the-year are limited to relatively shallow depths, and older animals are capable of diving to much greater depths, then those younger animals are just beginning to develop the diving and foraging skills necessary to survive. The rate at which they develop those skills and, for example, begin to dive to greater depths or take prey at greater depths, is unknown, but probably occurs rapidly after weaning to take advantage of otherwise unavailable prey resources.

3.1.6.4 Prey, energetics and nutrition, and diversity

At the least, an understanding of Steller sea lion foraging requires a listing of their prey species, a qualitative or (preferably) quantitative measure of the relative importance of different prey types, descriptions of prey characteristics and predator-prey dynamics, and an assessment of diet diversity. A (partial) listing of Steller sea lion prey species or prey types would include (not in order of priority): Atka mackerel, capelin, crabs, dogfish sharks, eulachon, flatfish, greenling, hake, halibut, herring, lamprey, lingcod, molluscs, octopus, Pacific cod, pollock, ratfish, rockfishes, salmon, sand lance, sculpins, shrimps, smelt, squid, and yellowfin sole.

Qualitative or quantitative indices of prey importance might be developed on the basis of prey "selection" or "preference." However, we rarely have information on the distribution or availability of different prey types, and therefore don't have a basis for inferring "selection" or "preference" (Lowry *et al*. 1982, Frost and Lowry 1986). In most studies of Steller sea lion prey, rank frequency of occurrence is used as a qualitative (or semi-quantitative) index of relative importance. For example, the data from Merrick *et al*. (1997) and NMFS (1995) indicate that throughout the range of the western population of Steller sea lions, either pollock or Atka mackerel are the dominant prey on the basis of frequency of occurrence. Therefore, pollock and Atka mackerel can reasonably be assumed to be essential prey of Steller sea lions. Quantitative estimation of the importance of different prey types is considerably more difficult. The value of a prey type should be quantified on the basis of the observed net gain in calories and nutrients resulting from predation on that prey type versus other prey types. Such a determination would require information on biomass consumed, caloric and nutrient content of that biomass, energy and nutrients gained, and energy and nutrients expended (i.e., the costs of predation). Caloric and nutrient content of different prey types are relatively easy to determine using proximate analysis, although Stansby (1976) cautioned that individuals of the same prey type may vary considerably as a function of season, site, reproductive condition, and other factors. Assimilation efficiency has also been studied (Fadely *et al*. 1994, Rosen and Trites *in prep*) and appears to be relatively straightforward. Biomass consumed and costs of predation are more difficult to quantify, particularly with respect to any particular prey type. Many of the studies on Steller sea lion foraging patterns (Table 5) provide information on frequency of occurrence, but such information cannot be readily converted into biomass consumed unless additional data are provided. Biomass estimates are more readily determined from volumetric measurements of stomach contents, but can also be estimated from length-weight relationships combined with measured lengths of prey or estimated length at age (with age based on otoliths; e.g., Frost and Lowry 1986). Costs of predation may also vary considerably by prey type, depending on the distribution, life history characteristics, and behavior of the prey.

Important prey characteristics include their tissue or body composition, individual size (mass), availability, depth in the water column, their degree of association with the bottom, their reproductive behaviors, their degree of aggregation (e.g., solitary versus schooling), and their temporal and spatial distribution patterns. To date, the limited information available indicates that sea lions generally forage at depths less than 250 m. Many of their prey are, at one life stage or another, associated with the bottom. Predation on prey associated with the bottom is a common pinniped strategy, perhaps because the bottom limits the spatial dimensionality of the predator-prey arena and thereby limits the prey's alternatives for escape. Male Atka mackerel may be susceptible to predation because they fertilize and then guard eggs laid by the female on the bottom. Schooling behavior of pollock and Atka mackerel probably enhances their value as prey as such schooling may increase sea lion consumption relative to costs associated with searching and capture.

The spatial and temporal distributions of prey types is a critical determinant of their availability to sea lions. The consistent pattern of the Atka mackerel fishery over time indicates that aggregations of Atka mackerel are distributed in patches that are relatively predictable. Aggregations of pollock are less predictable in time and space than aggregations of Atka mackerel, but also demonstrate considerable predictability, particularly for winter and spring spawning aggregations. To varying degrees, then, both of these prey species appear to be distributed in more (Atka mackerel) or less (pollock) predictable prey patches, and the availability and characteristics of those patches may be essential to the foraging success of sea lions. Important patch characteristics may include their size, location, persistence, and density (number of patches per area).

The quality of the sea lion diet appears to be determined not only by the individual components (species) of the diet, but also by the mix or diversity of prey in the diet. Merrick *et al*. (1997) found a correlation between a measure of diet diversity in different geographic regions of the western population and population trends in those regions. Their conclusions were that reliance on a single prey type may not be conducive to population growth; a diversity of prey may be necessary for recovery of the western population. Unfortunately, diet diversity is a function not only of prey selection, but of the diversity of prey available. To the extent that pollock or Atka mackerel currently dominate the prey field, sea lions survive on those prey.

3.1.6.5 Foraging - integration and synthesis

While much remains to be learned about Steller sea lions, the available information is sufficient to begin a description of their foraging patterns. The emerging picture appears to be that:

- Steller sea lions are land-based predators but their attachment to land and foraging patterns/distribution may vary seasonally and as a function of age, sex, and reproductive status;
- Steller sea lions tend to be relatively shallow divers but also exploit deeper waters;
- Steller sea lions consume a variety of demersal, semi-demersal, and pelagic prey;
- a diet of a diversity of prey appears to be advantageous to Steller sea lions
- at present, pollock and Atka mackerel appear to be their most common or dominant prey;
- the life history and spatial/temporal distribution of pollock and Atka mackerel are therefore likely important determinants of sea lion foraging success;

- ! foraging patterns and prey requirements probably vary by season, due to changes in reproductive status, prey availability, and environmental conditions;
- ! foraging sites relatively close to rookeries may be particularly important during the reproductive season when lactating females are limited by the nutritional requirements of their pups; and
- ! the transition by young animals from dependence on their mothers to independent feeding may occur over a period of months or even years.

The question of whether competition exists between the Steller sea lion and pollock or Atka mackerel fisheries is a question of sea lion foraging success. For a foraging sea lion, the net gain in energy and nutrients is determined, in part, by the availability of prey or prey patches it encounters within its foraging distribution. Competition occurs if the fisheries reduce the availability of prey to the extent that sea lion condition, growth, reproduction, or survival are diminished, and population recovery is impeded. The question of whether competition occurs will be addressed in the "environmental baseline" and "effects of the action" sections below.

3.1.7 Natural predators

The Recovery Plan for the Steller Sea Lion (NMFS 1992) states: "Steller sea lions are probably eaten by killer whales and sharks, but the possible impact of these predators is unknown. The occurrence of shark predation on other North Pacific pinnipeds has been documented, but not well quantified (Ainley *et al*., 1981)." The likelihood of shark attack is probably greater for Steller sea lions off the Washington, Oregon, and California coasts than in waters further north. A killer whale attack has been documented off the Oregon coast (Mate 1973), but killer whales are probably much more frequent predators in the waters of British Columbia and Alaska (Barrett-Lennard *et al*., unpubl. rep.). Barrett-Lennard *et al*. surveyed 126 respondents to estimate the rate of observation of sea lion/killer whale interactions. Of 492 interactions witnessed, 32 (6.5%) reportedly involved sea lion mortality. The lethal interaction rate appeared to be greatest in the Aleutian Islands region, but those results were based on the "vague recollection" of one observer of 3 kills over a 24-year period. Perhaps the most noteworthy anecdotal observation of apparent killer whale predation on sea lions occurred in 1992, when flipper tags from 14 sea lions that were both tagged and branded were found in the stomach of a killer whale dead on the beach in Prince William Sound (NMFS 1995). Barrett-Lennard *et al*. (unpubl. rep.) model sea lion mortality due to killer whales, and suggest that while such predation may account for a significant portion of natural mortality at the current low size of the sea lion population, it was not likely to have been the cause of the decline. The most recent status report on Steller sea lions (NMFS 1995) concurs and points out that relative abundance of killer whales is likely greater off southeast Alaska, where sea lion populations have been slowly increasing.

3.1.8 Natural competitors

Competition may take several forms. For exploitative competition to occur, the potential competitors must utilize the same resource, the availability of that resource must be limited relative to the needs of the potential competitors, and use of the available resource by one of the potential competitors must impede use by the other (Krebs 1985). Interference competition can occur even when resources are not limited if the use of the resource by one potential competitor harms another. With respect to other (nonhuman) species, Steller sea lions are most likely to compete with for food, although they may also compete for habitat (e.g., potential competition with northern fur seals for rookery or haulout space).

Steller sea lions forage on a variety of marine prey that are also consumed by other marine mammals (e.g., northern fur seals, harbor seals, humpback whales), marine birds (e.g., murres and kittiwakes), and marine fishes (e.g., pollock, arrowtooth flounder). To some extent, these potential competitors may partition the prey resource so that little direct competition occurs. For example, harbor seals and northern fur seals may consume smaller pollock than Steller sea lions (Fritz *et al*. 1995). Competition may still occur if the consumption of smaller pollock limits the eventual biomass of larger pollock for sea lions, but the connection would be difficult to demonstrate. Such competition may occur only seasonally if, for example, fur seals migrate out of the area of competition in the winter and spring months. Similarly, competition may occur only locally if prey availability or prey selection varies geographically for either potential competitor. Finally, competition between sea lions and other predators may be restricted to certain age classes, as diet may change with age or size. .

3.1.9 Disease

Hoover (1988) lists evidence of exposure of sea lions to leptospirosis (Fay *et al*. 1978), chlamydiosis (Goodwin and Calkins 1985), and San Miguel sea lion virus (Goodwin and Calkins 1985, Barlough *et al*. 1987). Barlough *et al*. (1987) also present evidence of eight types of calicivirus (including seven types of San Miguel sea lion virus and Tillamook [bovine] virus). And recent tests, indicate exposure to brucellosis (pers. comm., K. Pitcher, Alaska Department of Fish and Game, 333 Raspberry Road, Anchorage, AK 99518).

Hoover (1988) also lists parasites known to infect sea lions, including cestodes of the genera *Diplogonoporus*, *Diphyllobothrium*, *Anophryocephalus*, *Adenocephalus*, and *Pyramicocephalus*; trematodes of the genera *Pricetrema*, *Zalophotrema*, and *Phocitrema*; acanthocephalans of the genera *Bulbosoma* and *Corynosoma*; and nematodes of the genera *Anisakis*, *Contracaecum*, *Parafilaroides*, *Uncinaria*, and *Phocanema* (Hill 1968, Dailey and Brownell 1972, Daily 1975, Fay *et al*. 1978, Geraci 1979, Dieterich 1981). In addition, Thorsteinson and Lensink (1962) reported two types of parasites: Body louse (*Antarctophthirus michrochir*) severely infesting pups and nose mites *(Orthohalarachne diminuta*) invariably found on adults. And Scheffer (1946) reported ascarid worms (*Porocaecum decipiens*) nearly always found in adult stomachs.

While a range of different diseases or maladies have been documented for Steller sea lions, the available evidence is not sufficient to demonstrate that disease has played or is playing any significant part in the decline of the western population. Disease may have contributed to the *in utero* mortality rate observed in animals collected in 1975-1978 and 1985-1986 (Pitcher *et al*. in review) but, again, that hypothesis is not substantiated by any data. The long-term continuous nature of the decline, and the lack of morbid or moribund specimens argue that disease has not been a primary factor.

3.1.10 Population dynamics

The breeding range of the Steller sea lion covers virtually all of the North Pacific Rim from about 34° N to 60°N lat. Within this range, sea lions are found in hundreds of rookeries and haulouts. These rookery and haulout sites are frequently grouped into rookery/haulout clusters on the basis of politics, geography, demographic patterns, genetics, foraging patterns, or other reasons related to scientific study or management. Political divisions are drawn to separate animals that are found off Japan or the Republic of Korea, in Russian territories, in Alaska, British Columbia, or along the western coast of Washington, Oregon, and California. These divisions are largely for the purpose of management or jurisdiction, but may be related to sea lion population dynamics because of differing management strategies or objectives.

Geographic distinctions are frequently made on the basis of variable habitat or ecosystem characteristics in differing parts of the range. For example, rookeries and haulouts in the Aleutian Islands are often separated from those in the GOA, and these two areas are again separated from southeastern Alaska and British Columbia. These distinctions may have demographic significance because of the important variability in ecosystem features such as prey resources. Sea lion rookeries and haulouts are also grouped on the basis of observed demographic trends (York *et al*. 1996).

Many, if not most, descriptions of the decline of Steller sea lions begin with the statement that the decline was first witnessed in the eastern Aleutian Islands in the mid 1970s and then spread westward to the central Aleutian Island and eastward to the western GOA in the late 1970s and early 1980s. Similarly, counts are frequently presented for the area from Kenai to Kiska Island, which is considered to enclose the center of abundance for the species. Genetic studies (Bickham *et al*. 1996, Loughlin 1997) provided the basis for distinguishing western and eastern management stocks of the sea lion, and additional work may allow further differentiation of stocks. The relation between diet diversity and population trend was studied using rookery groups identified by geographic location and rates of change. The rookery groups were those identified by York *et al*. (1996). These examples indicate that, depending on the purpose at hand, the total sea lion population may be split meaningfully into subpopulations in any number of ways.

However, if the purpose is to study or understand the natural (i.e., without human influence) population structure of the Steller sea lion, then the biogeography of the species must be defined more narrowly. Genetic studies may provide the best description of the result of biogeographic patterns, as they are likely the least influenced by human interaction. Demographic trends and foraging patterns may be influenced by human activities and, clearly, the artificial boundaries determined for political purposes should not have an influence on the natural biogeography of sea lions.

Those natural factors that determine their biogeography include climate and oceanography, avoidance of predators, distribution of prey, the reproductive strategy of the species, and movement patterns between sites. The marine habitat of the Steller sea lion tends to reduce variation in important environmental or climatic features, allowing the sea lion to disperse widely around the rim of the North Pacific Ocean. The decline of Steller sea lions off California may indicate a contraction in their range, depending on the explanation for that decline. Avoidance of terrestrial predators must clearly be an important factor, as rookeries and haulouts are virtually all located at sites inaccessible to such predators. Distribution of prey is likely a critical determinant of sea lion biogeography, and probably determines the extent of their dispersion during the non-reproductive season. The reproductive strategy of the species, on the other hand, requires aggregation at rookery sites, and therefore likely places important limits on the species' movement patterns and dispersion. Finally, movement patterns between sites determine, in part, the extent to which such groups of sea lions at different rookeries and haulout sites are demographically independent. Steller sea lions are generally not described as migrators. Adult males, for example, are described as dispersing widely during the non-reproductive seasons, and juveniles are described as dispersing widely after weaning and not returning to the reproductive site until they are approaching reproductive age (Calkins and Pitcher 1982).

An understanding of the natural biogeography of the Steller sea lion is essential to describe their population dynamics and identify the effects of potential human-related influences on their dynamics. Without a better understanding of movement patterns of sea lions, the geographic extent of potential fisheries effects can not be estimated with confidence. For example, we can not, at this time, describe the geographic extent of fishing for Atka mackerel at Seguam pass because we can not confidently determine whether the sea lions foraging at that site are from just Seguam and Agligadak Island rookeries, or perhaps also from Yunaska and Kasatochi Island rookeries or sites more distant. Similarly, the pollock fisheries in Shelikof Strait may have influenced the dynamics of sea lion populations at Chirikof and Chowiet Islands, or may have even farther reaching effects if, for example, sea lions from the Shumagin Islands forage in Shelikof Strait. In addition, descriptions of population size, variability, and stability may vary depending on the definition of population units.

3.1.11 Population status and trends

Assessments of the status and trends of Steller sea lion populations are based largely on (a) counts of nonpups (juveniles and adults) on rookeries and haulouts, and (b) counts of pups on rookeries in late June and early July. Both kinds of counts are indices of abundance, as they do not necessarily include every site where animals haul out, and they do not include animals that are in the water at the time of the counts. Population size can be estimated by standardizing the indices (e.g., with respect to date, sites counted, and counting method), by making certain assumptions regarding the ratio of animals present versus absent from a given site at the time of the count, and by correcting for the portion of sites counted. Population estimates from the 1950s and 1960s (e.g., Kenyon and Rice 1961; see also Trites and Larkin 1992, 1996) are used with caution because counting methods and dates were not standardized, and the results contain inconsistencies that indicate the possibility of measurement error at some sites in some years. Efforts to standardize methods began in the 1970s (Braham *et al*. 1980); as a result, counts conducted since the late 1970s are the most reliable estimates of the total population or subpopulations.

For the western U.S. population (i.e., west of 144°W long.), counts of adults and juveniles have fallen from 109,880 animals in the late 1970s to 22,167 animals in 1996, a decline of 80% (Fig. 15); Hill and DeMaster *in prep*, and based on NMFS 1995, Strick *et al*. 1997, Strick *et al*. *in press*). Although the number of animals lost appears to have been far greater from the late 1970s to the early 1990s, the rate of decline has remained high. The 1996 count was 27% lower than the count in 1990. Final results from counts conducted in 1998 are not yet available, but preliminary results for trend sites between the Kenai Peninsula to Kiska Island indicate a decline of about 9% in nonpups since 1996, and 19% in pups since 1994.

From the late 1970s to 1996, abundance estimates for the GOA dropped from 65,296 to 9,782 (85%), and for the BSAI region dropped from 44,584 to 12,385 (72%). Counts in Russian territories (to the west of the action area for the BSAI pollock and Atka mackerel fisheries) have also declined and are currently estimated to be about one-third of historic levels (NMFS 1992). Counts in southeast Alaska (to the east of the action area for the GOA pollock fishery) are increasing slowly.

Some demographic patterns are lost when estimates are pooled for large areas. The index counts are often described by geographic region (Fig. 16; Table 6; T. Loughlin, pers. comm.). Counts at all trend sites by region indicate a slow decline in the central and western GOA between 1976 and 1985, followed by a severe drop in both regions from 1985 to 1989, and continued decline in the central Gulf continuing to at least 1997. Counts in the eastern, central, and western Aleutians all declined sharply from the late 1970s to the early 1990s, and since have been variable but declining in the western region, declined moderately in the central region, and relatively stable in the eastern region, at least through 1996. The decline of sea lions in the GOA and BSAI regions has effectively shifted the center of abundance for the species to the east. In the 1970s, for example, Ugamak Island in the eastern Aleutian Islands was the largest rookery in the world. As abundance declined at Ugamak Island, rookeries at Marmot and Sugarloaf Islands in the Central GOA became numerically dominant. But as abundance at these sites declined, the rookery at Forrester Island (southeast Alaska) became dominant.

Although the decline of the western population has occurred over extensive areas, site-by-site evaluation of the counts may be essential to understand the decline, and to anticipate the nature of threats to the species as local populations dwindle to extremely low numbers. However, changes observed at specific sites must be interpreted with caution because animals are known to move between sites on temporary, seasonal, and permanent bases. Therefore, the extent to which the collection of animals at a given site represent an independent or meaningful population unit is not yet clear.

For the eastern population (east of 144°W long.), counts of nonpups (adults and juveniles) have increased overall from just under 15,000 in 1982 to just over 20,000 in 1994 (Hill and DeMaster *in prep*). Counts of nonpups in California/Oregon were essentially unchanged from 1982 to 1996 at about 3,300. In California alone, the counts during this period represent a decline of over 50% since the first half of this century (NMFS 1995). Counts of nonpups in British Columbia increased from 4,700 to 8,100 in 1994. The increase in British Columbia likely represents partial recovery from the effects of control programs in the earlier part of the century. In 1913, 10,000-12,000 animals (including pups) were counted; in 1965, 4,000 were counted (Bigg, 1988). In southeast Alaska, counts have increased from 6,400 in 1979 to 8,200 in 1996 (NMFS 1995, Strick *et al*. *in press*). The number of pups born in southeast Alaska increased from ca. 2,200 in 1979 to ca. 3,700 in 1994 (NMFS 1995). Pup production increased at Hazy Islands, a rookery was established at White Sisters, and pup production at Forrester Islands also increased. Forrester Island has become the largest rookery for the entire species, with just under 3,300 pups born there in 1991 (NMFS 1995).

3.1.12 Population variability and stability

Populations change as a function of births, deaths, immigration, and emigration. During the nonreproductive season, some sea lions may move between the western and eastern populations (Calkins and Pitcher 1981), but net migration out of the western population is not considered a factor in the decline. The amount of growth observed in the eastern population is equivalent to only a small fraction of the losses in the western population. Thus, the decline must be due primarily to changes in birth and death rates. As mentioned above, computer modeling (York 1994) and mark-recapture experiments (Chumbley *et al*. 1997) indicate that the most likely problem leading to the decline is decreased juvenile survival, but lower reproductive success is almost certainly a contributing factor. Finally, adult survival has not been characterized and even small changes in the survival rate of adult females may be contributing significantly to past or current population trends.

These changes in vital rates would likely lead to changes in the age structure which, in turn, may tend to destabilize populations. With declining reproductive effort or juvenile survival, populations tend to become top heavy with more mature animals (e.g., the increase in mean age of adult females described by York [1994]), followed by a drop in population production as mature animals die without replacement through recruitment of young females. The extent to which the age structure is destabilized and the effect on population growth rate depends, in part, on the length of time that reproduction and/or juvenile survival remain suppressed. Increased mortality of young adult females may have the strongest effect on population growth and potential for recovery, as these females have survived to reproductive age but still have their productive years ahead of them (i.e., they are at the age of greatest reproductive potential).

Vital rates and age structures may change as a function of factors either extrinsic or intrinsic to the population. This biological opinion addresses the question of potential effects of the three fishery actions (i.e., extrinsic factors) on the Steller sea lion. However, the potential effects will be determined, in part, by the sensitivity of the western population to extrinsic influence, its resilience, and its recovery rate. Steller sea lions fit the description of a “K-selected” species of large-bodied long-lived individuals with delayed reproduction, low fecundity, and considerable postnatal maternal investment in the offspring. These characteristics should make sea lion populations relatively tolerant of large changes in their environment. Thus, the observed decline of the western population over the past two to three decades is not consistent with the description of the species as K-selected, and suggests that the combined effect of those factors causing the decline has been severe. The ability of the population to recover (i.e., its resilience) and the rate at which it recovers will be determined by the same K-selected characteristics (longevity, delayed reproduction, and low fecundity), as well as its metapopulation structure. Its maximum recovery rate will likely be limited to 8% to 10% annually (based on its life history characteristics and observed growth rates of other Otariids), which means that recovery could require 20 to 30 years. The metapopulation structure of the western population may enhance or deter recovery. Dispersal of populations provides some measure of protection for the entire species against relatively localized threats of decline or extinction. And rookeries that go extinct may be more likely recolonized by seals migrating between sites. On the other hand, the division of the whole population into smaller demographic units may exacerbate factors that accelerate small populations toward extinction (e.g., unbalanced sex ratios, allee effects, inbreeding depression). Such acceleration has been referred to as an “extinction vortex” (Gilpin and Soulé 1986).

Finally, any description of population stability for the Steller sea lion should be written with caution. Over the past three decades (or perhaps longer), we have witnessed a severe decline of the western population throughout most of its range. Our inability to anticipate those declines before they occurred, and our limited ability to explain them now, and our limited ability to predict the future suggests that we are not yet capable of describing the stability of Steller sea lion populations.

3.1.13 Population projections

Population viability analyses have been conducted for the western population by Merrick and York (1994) and York *et al*. (1996). While such analyses require some assumptions, they provide a context for management and an indication of the severity and urgency of the sea lion dilemma, given the set of assumptions made in the analyses.

The results of these analyses indicate that the next 20 years may be crucial for the western population of Steller sea lions, if the rates of decline observed in 1985 to 1989 or 1994 continue. Within this time frame, it is possible that the number of adult females in the Kenai-to-Kiska region could drop to less than 5000. Extinction rates for rookeries or clusters of rookeries could increase sharply in 40 to 50 years, and extinction for the entire Kenai-to-Kiska region could occur in the next 100-120 years.

Based on recent trends in southeast Alaska and British Columbia, prospects for recovery of the eastern population are encouraging.

3.1.14 Listing Status

On 26 November 1990, the Steller sea lion was listed as threatened under the Endangered Species Act of 1973 (55 FR 49204). The listing followed a decline in the U.S. population of about 64% over the three decades prior to the listing. In 1997, the species was split into two separate stocks on the basis of demographic and genetic dissimilarities (Bickham *et al*. 1996, Loughlin 1997), the status of the western stock was changed to endangered, and the status of the eastern stock was left unchanged (62 FR 30772).

3.1.15 Critical habitat description

The term "critical habitat" is defined in the Endangered Species Act (16 U.S.C. 153) to mean: (i) the specific areas within the geographic area occupied by the species, at the time it is listed in accordance with the provisions of section 4 of this Act, on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management consideration or protection; and (ii) the specific areas outside of the geographical area occupied by the species at the time it is listed in accordance with the provisions of section 4 of this Act, upon a determination by the Secretary that such areas are essential to the conservation of the species.

The definition continues to "Except in those circumstances determined by the Secretary, critical habitat shall not include the entire geographical area which can be occupied by the threatened or endangered species."

By this definition, critical habitat includes those areas that are essential to the "conservation" of a threatened or endangered species. The ESA defines the term "conservation" as: ". . . to use and the use of all methods and procedures which are necessary to bring any endangered species or threatened species to the point at which the measures provided pursuant to this Act are no longer necessary." That is, the status of the species would be such that it would be considered "recovered." Therefore, the area designated as critical habitat should contain the physical and biological resources necessary to support and sustain a population of a threatened or endangered species that is sufficiently large and persistent to be considered recovered.

3.1.15.1 Establishment of Critical Habitat

The areas designated as critical habitat for the Steller sea lion were determined on the basis of the available information on life history patterns of the species, with particular attention paid to land sites where animals haul out to rest, pup, nurse their pups, mate, and molt, and to marine sites considered to be essential foraging areas. The foraging areas were determined on the basis of sightings of sea lions at sea, incidental catch data (Loughlin and Nelson 1986, Perez and Loughlin 1991), and foraging studies using satellite-linked tracking systems. Critical habitat areas were determined with input from NMFS scientists and managers, the Steller Sea Lion Recovery Team, independent marine mammal scientists invited to participate in the discussion, and the public. The proposed rule for establishment of critical habitat for the Steller sea lion was published on 1 April 1993 (58 FR 17181), and the final rule was published on 27 August 1993 (58 FR 45269). The following areas have been designated as critical habitat in the action area of one or more of the proposed fisheries (Fig. 17).

(a) Alaska rookeries, haulouts, and associated areas. In Alaska, all major Steller sea lion rookeries identified in Table 1 [their Table 1] and major haulouts identified in Table 2 [their Table 2] and associated terrestrial, air, and aquatic zones. Critical habitat includes a terrestrial zone that extends 3,000 feet (0.9 km) landward from the baseline or base point of each major rookery and major haulout in Alaska. Critical habitat includes an air zone that extends 3000 feet (0.9 km) above the terrestrial zone of each major rookery and major haulout in Alaska, measured vertically from sea level. Critical habitat includes an aquatic zone that extends 3,000 feet (0.9 km) seaward in State and Federally managed waters from the baseline or basepoint of each major haulout in Alaska that is east of 144° W long. Critical habitat includes an aquatic zone that extends 20 nm (37 km) seaward in State and Federally managed waters from the baseline or basepoint of each major rookery and major haulout in Alaska that is west of 144° W long.

Three special aquatic foraging areas in Alaska. Three special aquatic foraging areas in Alaska, including the Shelikof Strait area, the Bogoslof area, and the Seguam Pass area.

(1) Critical habitat includes the Shelikof Strait area in the GOA which . . . consists of the area between the Alaska Peninsula and Tugidak, Sitkinak, Aiaktilik, Kodiak, Raspberry, Afognak and Shuyak Islands (connected by the shortest lines): bounded on the west by a line connecting Cape Kumlik (56°38″/157°26´W) and the southwestern tip of Tugidak Island (56°24′/154°41′W) and bounded in the east by a line connecting Cape Douglas (58°51´N/153°15´W)and the northernmost tip of Shuyak Island (58°37´N/152°22´W).

(2) Critical habitat includes the Bogoslof area in the Bering Sea shelf which . . . consists of the area between 170°00´W and 164°00´W, south of straight lines connecting 55°00´N/170 00´W and 55°00´N/168°00´W; 55°30´N/168°00´W and 55°30´N/166°00´W; 56°00´N/166°00´W and 56°00´N/164°00´W and north of the Aleutian Islands and straight lines between the islands connecting the following coordinates in the order listed:

52°49.2´N/169°40.4´W; 52°49.8´N/169°06.3´W;
53°23.8´N/167°50.1´W; 53°18.7´N/167°51.4´W;
53°59.0´N/166°17.2´W; 54°02.9´N/163°03.0´W;
54°07.7´N/165°40.6´W; 54°08.9´N/165°38.8´W;
54°11.9´N/165°23.3´W; 54°23.9´N/164°44.0´W

(3) Critical habitat includes the Seguam Pass area which . . . consists of the area between 52°00´N and 53°00´N and between 173°30´W and 172°30´W.

3.1.15.2 Physical and biological features of Steller sea lion critical habitat

For the Steller sea lion, the physical and biological features of its habitat that are essential to the species' conservation are those that support reproduction, foraging, rest, and refuge. Land or terrestrial habitat is relatively easy to identify on the basis of use patterns and because land use patterns are more easily observed. The areas used are likely chosen because they offer refuge from terrestrial predators (e.g., are inaccessible to bears), include suitable substrate for reproductive activities (pupping, nursing, mating), provide some measure of protection from the elements (e.g., wind and waves), and are in close proximity to prey resources.

Prey resources are the most important feature of marine critical habitat. Marine areas may be used for a variety of other reasons (e.g., social interaction, rafting or resting), but foraging is the most important sea lion activity that occurs when the animals are at sea. Two kinds of marine habitat were designated as critical. First, areas around rookeries and haulouts were chosen based on evidence that many foraging trips by lactating adult females in summer may be relatively short (20 km or less; Merrick and Loughlin 1997). Also, mean distances for young-of-the-year in winter may be relatively short (about 30 km; Merrick and Loughlin 1997). These young animals are just learning to feed on their own, and the availability of prey in the vicinity of rookeries and haulouts must be crucial to their transition to independent feeding after weaning. Similarly, areas around rookeries are likely to be important for juveniles. While the foraging patterns of juveniles have not been studied in the BSAI region, it is possible that they depend considerably on resources close to haulouts. Evidence indicates that decreased juvenile survival may be an important proximate cause of the sea lion decline (York 1994, Chumbley *et al*. 1997), and that the growth rate of individual young seals was depressed in the 1980s. These findings are consistent with the hypothesis that young animals are nutritionally stressed. Furthermore, young animals are almost certainly less efficient foragers and probably have relatively greater food requirements which, again, suggests that they may be more easily limited or affected by reduced prey resources or greater energetic requirements associated with foraging at distant locations. Therefore, the areas around rookeries and haulouts must contain essential prey resources for at least lactating adult females, young-of-the-year, and juveniles, and those areas were deemed essential to protect.

Second, three areas were chosen based on 1) at-sea observations indicating that sea lions commonly used these areas for foraging, 2) records of animals killed incidentally in fisheries in the 1980s, 3) knowledge of sea lion prey and their life histories and distributions, and 4) foraging studies. In 1980, Shelikof Strait was identified as a site of extensive spawning aggregations of pollock in winter months. Records of incidental take of sea lions in the pollock fishery in this region provide evidence that Shelikof Strait is an important foraging site (Loughlin and Nelson 1986, Perez and Loughlin 1991). The southeastern Bering Sea north of the Aleutian Islands from Unimak Island past Bogoslof Island to the Islands of Four Mountains is also considered a site that has historically supported a large aggregation of spawning pollock, and is also an area where sighting information and incidental take records support the notion that this is an important foraging area for sea lions (Fiscus and Baines 1966, Kajimura and Loughlin 1988). Finally, large aggregations of Atka mackerel are found in the area around Seguam Pass. These aggregations have supported a fishery since the 1970s, and are in close proximity to a major sea lion rookery on Seguam Island and a smaller rookery on Agligadak Island. Atka mackerel are an important prey of sea lions in the central and western Aleutian Islands. Records of incidental take in fisheries also indicate that the Seguam area is an important for sea lion foraging (Perez and Loughlin 1991).

While many of the important physical and biological elements of Steller sea lion critical habitat can be identified, most of those features (particularly biological features) cannot be described in a complete and quantitative manner. For example, prey species within critical habitat can not be described in detail or with a demonstrated measure of confidence, and the lack of such information is an important impediment to the analysis of fishery effects. Walleye pollock, Atka mackerel, Pacific cod, rockfish, herring, capelin, sand lance, other forage fish, squid, and octopus are important prey items found in Steller sea lion critical habitat but for most (if not all) of these species, we are not able to reliably describe their abundance, biomass, age structure, or temporal and geographic distribution within critical habitat with sufficient clarity and certainty to understand how they interact with Steller sea lions or other consumers, including fisheries. Atka mackerel may be one of the more easily characterized sea lion prey items, but we can not describe their onshore and offshore movements, their distribution inside and outside of critical habitat or in the vicinity of rookeries and haulouts, the relation between eastern and western stocks (or whether separate stocks exist), the causes for their (apparent) two- to three-fold changes in abundance over the last two decades, and so on. Pollock appear to be considerably more dynamic in their spatial and temporal patterns, and their presence within Steller sea lion critical habitat is even more difficult to describe in a detailed or quantitative fashion.

3.1.15.3 Critical habitat and environmental carrying capacity

Prey resources are not only the primary feature of Steller sea lion critical habitat, but they also appear to determine the carrying capacity of the environment for Steller sea lions. Therefore, the concepts of critical habitat and environmental carrying capacity are closely linked: critical habitat reflects the geographical extent of the environment needed to recover and conserve the species. The term “environmental carrying capacity” is generally defined as the number of individuals that can be supported by the resources available. The term has two main uses: first as a descriptive measure of the environment under any given set of circumstances, and the second as a reference point for the environment under “natural” conditions (i.e., unaltered by human activities). Thus, the definition can have markedly different implications depending on whether it is used as a reference point for the natural carrying capacity of the environment, or the carrying capacity of the environment as it may have been altered by human-related activities.

The changes observed in the 1970s and 1980s in Steller sea lion growth, reproduction, and survival are all consistent with limited availability of prey. At this time, the best scientific and commercial data available are not sufficient to distinguish the relative influences of natural (i.e., oceanographic) factors versus human-related activities (i.e., fisheries) on the availability of prey for sea lions. The notion that the observed changes in sea lion vital parameters are consistent with a change in “carrying capacity” does not necessarily mean that the changes are entirely natural. If carrying capacity is defined as a measure of the environment under any set of conditions, then that capacity could also have been reduced by fisheries. That is, natural and human-related changes to the carrying capacity are not mutually exclusive; both types of factors may have been operating at the same time. Natural and human-related factors that may have affected Steller sea lions or their environment in the past are described in the next section.

4.0 ENVIRONMENTAL BASELINE

4.1 Status of the species within the action areas

We begin the environmental baseline with 1) a brief summary of the status of Steller sea lion populations in each of the action areas, 2) some indication of the percent or amount of the species' range or critical habitat that occurs in each action area, and 3) a statement of the potential effects of each action on the population. The action areas for the groundfish fisheries are largely limited to the region from the U.S.-Canadian border northward, including the entire GOA and BSAI regions.

Total abundance for the western population of Steller sea lions in 1996 has been estimated as 39,500 animals (Hill and DeMaster *in prep*; based on 1996 counts [NMFS unpubl. data] and correction factors derived by Loughlin *et al*. [1992]). Based on these counts (as an index of population abundance), the western population declined by 80% since the late 1970s.

The 1996 counts used to derive this estimate included 11,710 animals (nonpups) in the BSAI region and 9,782 animals (nonpups) in the GOA. These counts suggest that, in 1996, about 54% of the western population was in the BSAI region and 46% in the GOA. These estimates should be used with caution as the potential effects of a fishery may extend beyond the distribution of fishing effort, because of mobility of both fish stocks and sea lions. Critical habitat for the western population (west of 144°W long.) has been designated around 40 rookeries and 82 haulouts (approximate, overlapping circles with a radius of 20 nm; Fig. 17) and special foraging areas at Seguam Pass, in the southeastern Bering Sea, and in Shelikof Strait.

Total abundance of the eastern population of Steller sea lions in 1996 has been estimated as ca. 30,400 (Hill and DeMaster *in prep*). This number is a minimum estimate not corrected for animals at sea during the counts. Based on counts in 1994 (20,176) and 1982 (14,895), the eastern population increased by 35% during that period (suggesting an annual growth rate of about 2.5%).

The total abundance estimate of ca. 30,400 for the eastern population was derived by summing counts of animals from southeast Alaska (14,571), California, Oregon and Washington (6,555), and British Columbia (9,277), and includes both nonpups (adults and juveniles) and pups. These counts suggest that, in 1996, about 48% of the eastern population was in southeast Alaska, 22% in California, Oregon, and Washington, and 31% in British Columbia (with rounding error). Critical habitat for the eastern population (east of 144°W long.) has been designated around 3 rookeries and 22 haulouts in the eastern GOA or southeast Alaska and 6 rookeries in California or Oregon. For the eastern population, critical habitat extends 0.9 km seaward from these rookeries and haulouts. No special foraging areas have been included in critical habitat for the eastern population.

The potential effects of the groundfish fisheries on both the western and eastern populations include either operational effects (incidental kill, gear conflict, entanglement, destruction of catch) or biological effects (competition for prey, changes to the community composition, changes in the age/size structure of prey populations). Operational effects could result in injury or death of sea lions. Biological effects could result in decreases in condition, growth, reproduction, or survival.

4.2 Known or suspected factors contributing to the current status of Steller sea lions or their critical habitat

The remainder of the environmental baseline describes the various known and suspected factors that have contributed or may have contributed to the current status of the Steller sea lion, its habitat (including designated critical habitat), and the ecosystems within the action areas.

4.2.1 Predation

As noted in the above section on status of the species, killer whales and sharks prey on Steller sea lions. Anecdotal evidence of such predation is available, but the rate of predation and the potential impact on population trends can not be determined with any measure of confidence. Given the reduced abundance of sea lions at multiple sites (rookeries and haulouts), predation by killer whales and other sources of natural mortality may exacerbate the decline or impede recovery in local areas (e.g., Barrett-Lennard *et al*. unpubl. rep.). Killer whale predation likely occurs in the ranges occupied by both the western and eastern populations of sea lions, and may be more common in southeast Alaska, where the sea lion population is growing slowly.

4.2.2 Disease

Disease and parasitism may also impede population growth, and evidence is available indicating that animals have been exposed to diseases and carry parasites. However, none of the evidence available at this time provides any indication that disease or parasitism caused the decline of the western population or are impeding the recovery of the eastern population. Disease and parasitism are common in all pinniped populations and have been responsible for major die-offs (e.g., Osterhaus and Vedder 1988), but such events are usually relatively short-lived and provide more evidence of morbidity or mortality. The ramifications of disease and parasitism remain unconcern, both as primary and secondary problems, but do not appear to be significant factors at this time or on the basis of the information currently available.

4.2.3 Toxic substances

Several studies indicate that organochlorine pollutant residues in the tissues of California sea lions and harbor seals have been associated with reproductive failure (NMFS 1992). A number of studies (Varanasi *et al*. 1992, Lee *et al*. 1996, Krahn 1997, Krone 1997) have also indicated relatively high concentrations of organochlorine compounds in Steller sea lions in Alaska, although these levels have not yet been associated with any changes in health or vital rates. Steller sea lions were undoubtedly exposed to oil after the Exxon Valdez oil spill, but no significant adverse effects of the oil were confirmed (Calkins *et al*. 1994; see the next section). At the present time, the available information does not support the hypothesis that contaminants are a significant contributor to the decline of sea lions, or an impediment to their recovery.

4.2.4 Oil and gas or mineral development

Previous NMFS biological opinions for both the BSAI and the GOA analyzed this factor under the heading of “human development.” In each case it was noted that human development activities that result in aquatic habitat destruction or the release of contaminants and pathogens (e.g., mineral exploration and extraction, effluent discharges into the marine environment) could directly diminish the health and reproductive success of Steller sea lions or cause them to abandon feeding, breeding, or resting sites. Development and discharge proposals typically undergo ESA section 7 consultation during the Federal permitting process.

On October 15, 1993, NMFS completed a biological opinion on the leasing and exploration activities of the Minerals Management Service in the Cook Inlet/Shelikof Strait region (lease sale Number 149). The opinion concluded that such activities were not likely to jeopardize the continued existence of any listed or proposed species, nor were they likely to destroy or adversely modify critical habitats. The biological opinion noted that “Shelikof Strait was designated as critical habitat based on its proximity to major rookeries and important haulouts, its use by foraging sea lions, and its value as an area of high forage fish production. Any impacts attributable to oil and gas development that adversely affect the forage fish resource within Shelikof Strait may also adversely modify this critical habitat.” However, NMFS also noted that “the probability of an oil spill during exploration is low, and the forage resource base within Cook Inlet/Shelikof Strait is unlikely to be impacted to the point of adversely affecting this critical habitat.”

In 1995, NMFS conducted another section 7 consultation with the Minerals Management Service and concluded that the lease sale and exploration activities for the proposed oil and gas Lease Sale Number 158, Yakutat were not likely to jeopardize the continued existence of any listed or proposed species, nor were the activities likely to destroy or adversely modify critical habitats.

Oil spills are expected to result in adverse effects if they contact Steller sea lions, haulouts, or rookeries when occupied, or large proportions of major prey. Potential effects could include: oil exposure, including surface contact and pelage fouling, inhalation of contaminant vapor, and ingestion of oil or oil-contaminated prey. Because the insulation of nonpup sea lions is provided by a thick fat layer rather than pelage whose insulative value could be destroyed by fouling, oil contact is not expected to cause death from hypothermia; however, sensitive tissues (e.g., eyes, nasal passages, mouth, lungs) are likely to be irritated or ulcerated by exposure to oil or hydrocarbon fumes. Oiled individuals probably will experience effects that may interfere with routine activities for a few hours to a few days; movement to clean water areas is expected to relieve most symptoms. Females returning from feeding trips may transfer oil to pups, which probably are more sensitive to oil contact.

The extent to which sea lions avoid areas that have been oiled is not known; individuals observed in Prince William Sound and the GOA after the Exxon Valdez oil spill did not appear to avoid oiled areas. Sea lions were sighted swimming in or near oil slicks, oil was seen near numerous haulout sites, and oil fouled the rookeries at Seal Rocks and Sugarloaf Island (Calkins *et al*. 1994). All of the sea lions collected in Prince William Sound in October 1989 had high enough levels of metabolites of aromatic hydrocarbons in the bile to confirm exposure and active metabolism at the tissue level. But as noted above, no evidence indicated damage caused to sea lions from toxic effects of the oil (Calkins *et al*. 1994).

Steller sea lions are probably most vulnerable to acute oil spills during mid-May through mid-July, the period of time they are on rookeries (Calkins and Pitcher 1982). An oil spill near any rookery during this time could cause abandonment of pups and interrupt the normal breeding cycle. Loss of a majority of pups from one of the large rookeries plus failure to impregnate females from that rookery could have serious implications for the western population of sea lions. Loss of prey species may pose the most serious, long term threats to sea lions in the GOA (Calkins and Pitcher 1982).

Although Alaska is estimated to contain large petroleum resources on its outer continental shelf and in state waters, the only oil produced from Alaska's outer continental shelf to date has come from Cook Inlet south of Anchorage. In the foreseeable future, the kind of extensive oil and gas activities that characterize the outer continental shelf of the central Gulf of Mexico is not likely for the GOA. Little or no oil and gas exploration or production is occurring or likely to occur soon on the Russian outer continental shelf area of the Bering Sea. The National Research Council recently concluded, therefore, that oil and gas activities in the Bering Sea have not significantly affected the Bering Sea ecosystem (National Research Council 1996).

4.2.5 Disturbance by activities unrelated to fishing

Several studies investigating the potential effects of oil and gas exploration and development on the Steller sea lion have noted human disturbance as a potential factor. Calkins and Pitcher (1982) found that disturbance from aircraft and vessel traffic has extremely variable effects on hauled-out sea lions. Sea lion reaction to occasional disturbances ranges from no reaction at all to complete and immediate departure from the haulout area. The type of reaction appears to depend on a variety of factors. When sea lions are frightened off rookeries during the breeding and pupping season, pups may be trampled or even abandoned in extreme cases. Sea lions have temporarily abandoned some areas after repeated disturbance (Thorsteinson and Lensink 1962), but in other situations they have continued using areas after repeated and severe harassment. Johnson *et al*. (1989) evaluated the potential vulnerability of various Steller sea lion haulout sites and rookeries to noise and disturbance and also noted a variable effect on sea lions. Kenyon (1962) noted permanent abandonment of areas in the Pribilof Islands that were subjected to repeated disturbance. A major sea lion rookery at Cape Sarichef was abandoned after the construction of a light house at that site, but then has been used again as a haulout after the light house was no longer inhabited by humans. The consequences of such disturbance to the overall population are difficult to measure. Disturbance may have contributed to or exacerbated the decline of the western population, although it is not likely to have been a major factor. Disturbance may also impede the recovery of the eastern population, which occupies an area where small vessel traffic is far greater than occurs in the GOA and BSAI. At present, concern is focused on disturbance as an impediment to the study of sea lions and other potential causes of the decline.

4.2.6 Research

Steller sea lions have been taken for scientific research (Thorsteinson and Lensink 1962, Calkins and Pitcher 1982, Calkins and Goodwin 1988, and Calkins *et al*. 1994):

! Experimental commercial harvest of 630 sea lion bulls in 1959. Life history information (age, size, reproductive condition, food habits) was collected.

! Between 1975 and 1978, 250 sea lions were collected by shooting in nearshore waters and on rookeries and hauling areas of the GOA. Stomachs were removed and examined for food content, reproductive organs were preserved for examination, blood samples were taken for disease and parasite studies, body measurements were recorded for growth studies, skulls were retained for age determination, tissue samples were preserved for elemental analysis and pelage samples were taken for molt studies.

! In 1985 and 1986, 178 sea lions were collected in the GOA and Southeastern Alaska to compare food habits, reproductive parameters, growth and condition, and diseases, with the same parameters from animals which were collected in the 1970s. The study was designed to address the problem of declining numbers of sea lions in the North Pacific and particularly in the GOA.

! Sixteen animals were collected under the Natural Resources Damage Assessment study conducted on Steller sea lions in 1989 following the Exxon Valdez oil spill.

4.2.7 Entanglement in marine debris

Observations of Steller sea lions entangled in marine debris have been made throughout the GOA and in southeast Alaska (Calkins 1985), typically incidental to other sea lion studies. Two categories of debris, closed plastic packing bands and net material, accounted for the majority of entanglements. Loughlin *et al*. (1986) surveyed numerous rookeries and haulout sites to evaluate the nature and magnitude of entanglement in debris on Steller sea lions in the Aleutian Islands. Of 30,117 animals counted (15,957 adults; 14,160 pups) only 11 adults showed evidence of entanglement with debris, specifically, net or twine, not packing bands or other materials. Entanglement rates of pups and juveniles appear to be even lower than those observed for adults (Loughlin *et al*. 1986). It is possible that pups were too young during the survey to have encountered debris in the water or that pups and juveniles were unable to swim to shore once entangled and died at sea. Trites and Larkin (1992) assumed that mortalities from entanglement in marine debris were not a major factor in the observed declines of Steller sea lions and estimated that perhaps fewer than 100 animals are killed each year.

4.2.8 Commercial harvest of Steller sea lions

In 1959, the Bureau of Commercial Fisheries awarded a contract to a commercial fishing company to develop techniques for harvesting sea lions in Alaskan waters. The two-fold purpose of the contract was to reduce the sea lion herds (because of alleged depredations on salmon and halibut fisheries) and to provide an economical source of protein for fur farms, fish hatcheries, and similar purposes (Thorsteinson and Lensink 1962). In 1959, 630 sea lion bulls were killed in an experimental harvest, but the harvest proved to be uneconomical. Another study was contracted by the Bureau of Indian Affairs of the Department of Interior to analyze the feasibility of a commercial sea lion harvest in Alaska. A total of 45,178 pups of both sexes were killed in the eastern Aleutian Islands and GOA between 1963 and 1972 (Merrick *et al*. 1987). Such harvests could have depressed recruitment in the short term and may have explained declines noted at some sites in the eastern Aleutian Islands or the GOA. These harvests do not appear to explain declines in other regions. Bigg (1988) lists the numbers of animals culled at rookeries and haulouts in British Columbia from 1912 to 1968. The impact of such culls on numbers of sea lions in southeast Alaska is not clear, but through migration, may well have affected the distribution and numbers of sea lions throughout the entire region.

4.2.9 Subsistence harvest of Steller sea lions

The MMPA authorizes the taking of any marine mammal by Alaska Natives for subsistence purposes or for the purpose of creating and selling authentic native articles of handicrafts and clothing, given that it is not done in a wasteful manner (MMPA, Section 101[b]). The ESA also contains provisions that allow for the continued subsistence use of listed species. Both the ESA and the MMPA contain provisions that allow regulation of the subsistence harvest of endangered, threatened, or depleted species, if necessary (NMFS 1995).

Subsistence harvest of Steller sea lions from 1960 to 1990 has been estimated at 150 animals per year (Alverson 1992), but the estimate was subjective and not based on any referenced data. This estimate is well below the levels observed in the 1990s (Hill and DeMaster *in prep*), which seems inconsistent with the fact that sea lion populations are at their lowest recorded levels. In 1986, a working group organized by NMML suggested that subsistence harvest had a potentially low impact on recent Steller sea lion population declines in Alaska (Loughlin 1987). More recent estimates (Wolfe and Mishler 1993, 1994, 1995, 1996) indicate a mean annual subsistence take of 448 animals from the Western U.S. stock (i.e., the endangered population) from 1992 to 1995. The majority (79%) of sea lions were taken by Aleut hunters in the Aleutian and Pribilof Islands. The great majority (99%) of the statewide subsistence take was from west of 144°W long. (i.e., the range of the western population). Therefore, the expected effect of subsistence harvesting on the eastern population is expected to be negligible with respect to population trends.

The overall impact of the subsistence harvest on the western population will be determined by the number of animals taken, their sex and age class, and the location where they are taken. As is the case for other sources of mortality, the significance of subsistence harvesting may increase as the western population decreases in size unless the harvesting rate is reduced accordingly. The current subsistence harvest represents a large proportion of the potential biological removal that was calculated for the western stock of the Steller sea lion pursuant to the Marine Mammal Protection Act (Hill and DeMaster *in prep*). However, the subsistence harvest accounts for only a relatively small portion of the animals lost to the population each year. For example, a population of about 40,000 growing at 8% per year would be expected to increase to 43,200 after one year; a gain of 3,200 animals. If, instead, that population is observed to decline by about 5%, then it would drop to 38,000, a loss of 2,000. The difference between expected and observed is, then, 5,200 animals, of which a subsistence harvest of say, 300, would account for 6%. Thus, the number of animals currently taken must contribute to the decline of sea lions, particularly at certain locations, but is not sufficient to explain the decline throughout the range of the population.

4.2.10 Natural environmental change

Discrimination between the relative influence of natural environmental factors versus human activities is controversial in both a scientific and management context. The distinction between natural and human-related impacts gets to the heart of management responsibilities under both the Marine Mammal Protection Act (MMPA) and the Endangered Species Act (ESA). At the time these acts were passed, our conceptual model of natural ecosystems was built largely on the notion of a balance and persistence in nature, or a stable point of ecosystem equilibrium. In the past three decades, we are discovering that the term "stable" may not be such a good descriptor of ecosystems; that is, we are learning that ecosystems vary naturally. At the same time, ecosystems may be seriously perturbed by human activities (e.g., global warming, global pollution, and ever increasing demands for natural products to satisfy growing human populations), and often we can not distinguish natural variation from changes wrought by human activities.

Studies of atmospheric and oceanic circulation and physical properties indicate that the BSAI and GOA ecosystems shift between at least two types of climatic regimes (Ebbesmeyer *et al*. 1991, Trenberth 1990, Brodeur and Ware 1992, Beamish 1993, Francis and Hare 1994, Miller *et al*. 1994, Trenberth and Hurrell 1994; Ingraham *et al*. 1998). While these regimes differ in many ways, they can be simply categorized as "warm" and "cold" depending on atmospheric and oceanic temperatures. One factor inducing the shift between regimes is changes in the position of the Aleutian Low Pressure system, which leads to changes in atmospheric temperature, storm tracks, ice cover, and wind direction (Wyllie-Echeverria and Wooster 1998). Shifts between regimes can be reflected in such indices as the Southern Oscillation Index, Pacific Decadal Oscillation, and the North Pacific Index. Historical studies suggest that over the last 500 years, the system has oscillated between the two distinct regimes every 10-30 years (Ingraham *et al*. 1998).

A well-documented shift from a cold to a warm regime in 1976-77 was associated with dramatic changes in the structure and composition of the invertebrate and fish communities as well as the distribution of individual species in the North Pacific ocean and Bering Sea (Brodeur and Ware 1992, Beamish 1993, Francis and Hare 1994, Miller *et al*. 1994, Hollowed and Wooster 1992; 1995; Wyllie-Echeverria and Wooster 1998). For instance, many groundfish stocks, particularly pollock, Atka mackerel, cod and various flatfish species increased in abundance as a result of strong yearclasses spawned in the mid to late 1970s. Many of the long-lived flatfish species (e.g., arrowtooth flounder, Pacific halibut, yellowfin sole, and rock sole) remained in high abundance since then, while other shorter lived groundfish species (pollock, Atka mackerel, and Pacific cod) have oscillated in abundance. Based on these patterns, researchers have associated "warm" years (and other related environmental conditions, such as southwest winds in April [Wyllie-Echeverria and Wooster 1998]), with the production of strong yearclasses of gadids (Hollowed and Wooster 1992; 1995; Wespestad *et al*. 1997).

Increases in many broadly distributed benthic (e.g., arrowtooth flounder, Pacific halibut) and semi-demersal (e.g., pollock and Pacific cod) piscivorous groundfish species since the late 1970s has been associated with either (or both) a decline in abundance (at least in nearshore environments; Anderson *et al*. 1997) or a change in distribution of short-lived pelagic species such as capelin. Anderson and Piatt (*in prep*) describe an almost complete disappearance of capelin from bays and the nearshore environment of the western and central GOA beginning in the late 1970s and early 1980s, and increases in cod and flatfish. During this time, the prevalence of capelin in the diets of many piscivorous birds and pinnipeds in the GOA also declined. However, Livingston (*in prep*) estimated that capelin consumption in 1990 in the GOA by the groundfish species was at least 300,000 mt. This suggests that capelin didn't necessarily disappear from the GOA (since so much was eaten), but changed its vertical distribution (went deeper), possibly in response to the warm conditions. If this change occurred, capelin would have been more susceptible to predation by piscivorous groundfish and less available to birds and pinnipeds that begin their foraging excursions from the water's surface.

As in the GOA, the prevalence of capelin in the diets of puffins, kittiwakes and other birds on the Pribilof Islands in the BSAI also declined in the mid-1980s. Furthermore, the prevalence of juvenile pollock tended to increase during this time period (Byrd *et al*. 1992, Springer 1992). Further north in the eastern Bering Sea, capelin remains a dominant feature of the kittiwake diet on St. Lawrence Island. This suggests that capelin distribution contracted to the north in response to warming conditions in the EBS in the 1980s and 1990s. Thus, capelin in the EBS may have redistributed horizontally (or geographically) in response to warming, while in the GOA, the redistribution may have been more in the vertical dimension. Regardless, these changes in prey distribution in response to changes in environmental conditions may have reduced the availability of capelin to Steller sea lions in the SE Bering Sea and GOA. During warm regimes, Steller sea lions may then depend on the availability and abundance of other resident prey in these areas for their survival.

Sea lions may have lived through many regime shifts in the few million years that they have existed. What may be different about this most recent shift is the coincident development of extensive fisheries targeting the same prey that sea lions depend on during warm regimes. Fisheries in the Bering Sea and GOA expanded enormously in the 1960s and 1970s. The existence of a strong environmental influence on sea lion trends does not rule out the possibility of significant fisheries-related effect. The cause of the sea lion decline need not be a single factor. To the contrary, strong environmental influences on BSAI and GOA ecosystems could increase the sensitivity of sea lions to fisheries or changes in those ecosystems resulting from fisheries.

4.2.11 Prey quality

Alverson (1992) proposed that the changes in trophic structure observed in the BSAI and GOA regions resulted in the dominance of pollock, and he further proposed that the shift to ecosystems dominated by pollock has been the overriding factor in the decline of Steller sea lions. That is, Alverson (1992) suggested a link between the changes in trophic structure of these ecosystems and the decline of sea lions based on the notion that pollock are a low quality prey for sea lions and the western population has not been able to sustain itself with this low quality prey. This suggestion has become known as the "junk food hypothesis."

The notion that pollock are of low quality is based on the fact that, on average, pollock have a lower fat content (per kilogram) than many of the other species in the sea lion's diet. To illustrate this difference, pollock are frequently compared with herring, which has a higher fat content than other prey species in the sea lion diet. The difference has been used to argue the pollock are a bad prey item for sea lions. Several studies have been conducted on diet physiology of California sea lions (Fadely *et al*. 1994) or Steller sea lions (Rosen and Trites *in prep*) fed solely on pollock. The study of Rosen and Trites (*in prep*) has not been made available in written form, but has been reported at meetings of the North Pacific Fishery Management Council and in other public discussions. The results of both studies are consistent with the notion that on a per kilogram basis, sea lions would have to consume a larger ration of pollock than herring if they were to survive on a diet composed of a single species. The results of the Rosen and Trites study have also been used to suggest that because the sea lions lost weight on the diet of pollock, they could not sustain themselves on that diet. But that conclusion over-reaches the data.

First, it is reasonable to suggest that pollock might not be the preferred prey of sea lions if they had a wide selection from which to choose. But as Alverson (1992) suggested, the observed change in the trophic structure of these ecosystems indicates that they do not have a wide selection. Second, sea lions in the wild are not completely limited to a single prey type. Diet studies conducted to date indicate that sea lions feed on a number of prey. The amount of diversity has varied considerably and may be an important factor (Merrick *et al*. 1997; see the section below on “changes in community composition and diet diversity”), but clearly sea lions are not limited to the extreme of only one prey type. Third, evidence for weight loss does not lead to the conclusion that the sea lions would starve to death, starvation to the point of death is not necessarily a consequence of weight loss over a period of a few weeks. The study by Rosen and Trites should be made available for review, and then should be repeated under the most realistic conditions possible to understand more about the significance of prey types to sea lions. This is a meaningful area of investigation, but it is currently premature to form any conclusions.

The value of any particular prey type is not determined solely by its fatty content, but also by factors such as individual size, total biomass, availability, behavior, degree of aggregation, temporal and spatial distribution, and so on. That is, the value of any particular prey type depends on the net gain to a sea lion from foraging on that prey, and net gain is a function of multiple factors of which fat content is an important, but not the only, determinant.

In spite of any debate about the nutritional value of pollock, the fact remains that pollock is a major prey of sea lions. Simply put, sea lions eat, and therefore depend on, pollock. In the present context, the question to be addressed is whether fishery removal of pollock and other groundfish fishes from critical habitat is to the sea lions’ advantage, disadvantage, or of no particular consequence. If sea lions are food stressed, then the arguments that removal of pollock, in particular, could be to their advantage would be 1) the fishery removes larger cannibalistic pollock and thereby increases the total available biomass (through increased survival of smaller pollock) to sea lions, or 2) the removal of large pollock from sea lion critical habitat will result in a shift in the composition of the prey assemblage in critical habitat and thereby increase the availability of other “better” prey types. If the removal of large cannibalistic pollock does confer an advantage to foraging sea lions, then that advantage would seem most likely from fisheries that occur in summer or autumn months to the north or northwest of the CVOA, where cannibalism appears to be most prevalent. With respect to the second possible advantage, the evidence that heavy fishing of pollock will reverse the trophic shift observed in these regions is not supported by the available data at sites where pollock have already been fished heavily. These questions are addressed in further detail below in the section on fisheries impacts.

4.2.12 Fishery impacts

This consultation considers the potential effects of the BSAI and GOA groundfish fisheries. These fisheries may interact with Steller sea lions in a wide variety of ways, including operational conflicts (e.g., incidental kill, gear conflicts, sea lion removal of catch) and biological conflicts (e.g., competition for prey). Operational conflicts are assessed by observers and have been reduced to low levels (Hill and DeMaster *in prep*) that are considered to be negligible at a sea lion population level. Therefore, the discussion of fishery effects will focus on biological effects and, particularly, competition.

4.2.12.1 Assessing past competition

The issue of competition between fisheries and sea lions is central to this biological opinion and a determination of whether these fisheries jeopardize the survival and recovery of the Steller sea lion or adversely modify its critical habitat. Competition can take a number of forms and involves a range of considerations, each of which will be described below. Competition occurs when two potential competitors use the same resource, the use of the resource by one potential competitor limits the availability or use by a second competitor, and the restriction in availability or use of the resource constrains or limits the second competitor in some manner. The hypothesis that competition occurs or has occurred between the Steller sea lion and these fisheries is based on information pertaining to the life history of sea lions and their population trends, the fish stocks, and the fisheries.

- The fish species targeted in these fisheries are major prey items of Steller sea lions;

- The geographic distributions of these fisheries overlap the foraging distribution of Steller sea lions; and

- Steller sea lions appear to be limited by lack of available prey.

Two approaches have been suggested to assess the potential for competition between sea lions and fisheries. The first approach involves establishment or demonstration of a direct causal link. The second approach does not require establishment of a direct link, but rather searches for correlations between observed changes in sea lion vital rates or population trends and patterns in the fishery or fished stock. This second approach, therefore, assumes a link may occur if a correlation can be demonstrated.

The first approach was suggested by Lowry *et al*. (1982), who provide the following series of questions for assessing a direct causal link between fisheries and Steller sea lion: (a) does the subject fishery affect the diet of Steller sea lions? (b) do any changes in diet compromise the condition of individual animals? (c) are any changes in condition sufficient to reduce growth, reproduction or survival? and (d) are any changes in reproduction and/or survival sufficient to have significant population effects? Unfortunately, the data available to answer these questions is either unavailable or equivocal.

The second approach uses the observation of potential relations (correlations) to indicate that a fishery may have had a significant impact on Steller sea lions. Most examples of this approach include investigations of correlations between indices of the pollock or other fisheries in the BSAI and GOA regions and indices of Steller sea lion populations (Loughlin and Merrick 1989, Alverson 1992, Trites and Larkin 1992, Ferrero and Fritz 1994). The question is whether the removal of fish biomass by the fishery reduces the availability of prey for Steller sea lions to the extent that the condition and vital rates of sea lions are compromised and local populations of sea lions are detrimentally affected.

4.2.12.2 Competition and selection of prey by size

Size selection of prey by fisheries and by sea lions may have significant bearing on the question of whether or not competitive interactions occur. Fisheries may compete with sea lions if they remove the same size of prey from the same areas. Fisheries may also reduce the spawning biomass of prey to the extent that the reproductive capacity of the fish stock is reduced and, over time, fewer fish become available for sea lions. And for pollock fisheries, size selection could alter the rate of cannibalism of young pollock by older pollock, with several potential consequences for sea lions.

The degree of overlap in the sizes of groundfish taken by Steller sea lions and by the various groundfish fisheries is not known for most species, but it is reasonable to assume at least some overlap occurs. The question of size overlap in fishery catch and sea lion prey has been more of an issue with respect to the pollock fishery. The December 3, 1998 Biological Opinion provided evidence that the size of pollock taken by the fishery and by sea lions overlaps. Evaluation of the overlap is confounded by a number of factors. First, the sizes consumed by sea lions are determined by the available prey and any preferential selection of prey by size. In the majority of cases, scientists do not have sufficient information to characterize the available prey and therefore can measure only what was consumed, not necessarily what was preferred. Second, much of the information presented in the scientific literature on sizes of prey taken by sea lions or fisheries has been based on numbers taken by length. Inferences on relative importance of prey by numbers taken by length are, however, misleading, as dietary value is determined by biomass consumed by length, rather than number. That is, sea lions may gain a great deal more nutrition from consumption of a single large prey item than from the consumption of multiple small prey items and, therefore, number, is not the best indicator of dietary value.

4.2.12.3 Competition and depth of prey

The possibility of competition between groundfish fisheries and the Steller sea lion has been argued on the basis of depth of fishing, and depth of diving by sea lions. The

December 3, 1998 Biological Opinion provided sufficient evidence to demonstrate overlap in the depths of Atka mackerel and pollock fishing and foraging by sea lions. With respect to the remainder of the groundfish, similar overlap by depth may occur for any of the species that occur and are taken by fisheries on the shelf or shelf break. This would include Pacific cod, yellowfin sole, arrowtooth flounder, rock sole, flathead sole, other flatfish, sablefish, Pacific ocean perch and other rockfish, and squid. Competition may be less likely for species that tend to be found deeper in the water column, such as sablefish, thornyheads, shortraker and rougheye rockfish, and Greenland turbot.

The extent to which competition between fisheries and sea lions may be avoided by partitioning of resources on the basis of depth can be difficult to judge on the basis of the available information. Scientific studies of sea lion foraging patterns are just beginning to characterize the diving depths and patterns of sea lions, and they are likely capable of foraging patterns not yet understood or anticipated. In addition, prey for sea lions and fisheries move vertically in the water column as a function of life history traits, geography, light levels, and perhaps a range of other factors.

4.2.12.4 Competition and the winter season

Changes in behavior, foraging patterns, distribution, and metabolic/physiologic requirements during the annual cycle are all pertinent to consideration of the potential impact of prey removal by commercial fisheries. Steller sea lions, at least adult females and immature animals, are not like some marine mammals that store large amounts of fat to allow periods of fasting. They need more or less continuous access to food resources throughout the year. Nevertheless, the sensitivity of sea lions to competition from fisheries may be exaggerated during certain times of the year. Reproduction likely places a considerable physiological or metabolic burden on adult females throughout their annual cycle. Following birth of a pup, the female must acquire sufficient nutrients and energy to support both herself and her pup. The added demand may persist until the next reproductive season, or longer, and is exaggerated by the rigors and requirements of winter conditions. The metabolic requirements of a female that has given birth and then become pregnant again are increased further to the extent that lactation and pregnancy overlap and the female must support her young-of-the-year, the developing fetus, and herself. And again, she must do so through the winter season when metabolic requirements are likely to be exaggerated by harsh environmental conditions.

Nursing pups are still dependent, at least to some extent, on their mother. If the mother is able to satisfy all the pup's nutritional needs through the winter, then at least from a nutritional point of view, winter may not be a time of added nutritional risk to the pup. If, on the other hand, the pup begins a gradual transition to independence before or during the winter season, then the challenge of survival may be greater for the pup through the winter.

Weaned pups are independent of their mothers, but may not have developed adequate foraging skills. They must learn those skills, and their ability to do so determines, at least in part, whether they will survive to reproductive maturity. This transition to nutritional independence is likely confounded by a number of seasonal factors. Seasonal changes may severely confound foraging conditions and requirements; winter months bring harsher environmental conditions (lower temperatures, rougher sea surface states) and may be accompanied by changing prey concentrations and distributions (Merrick and Loughlin 1997). Weaned pups' lack of experience may result in greater energetic costs associated with searching for prey. Their smaller size and undeveloped foraging skills may limit the prey available to them, while at the same time, their small size results in relatively greater metabolic and growth requirements.

Diet studies of captive sea lions indicated that they adjust their intake levels seasonally, with increases in fall and early winter months (Kastelein *et al*. 1990). These adjustments varied with age and sex of the studied animals, and the extent to which the patterns observed are reflective of foraging patterns in sea lions in the BSAI or GOA regions is not known. Nonetheless, such studies support the contention that the winter period is a time of greater metabolic demands and prey requirements.

Changes in condition, availability, and behavior of prey may also be essential to successful foraging by all sea lions in winter. For example, pollock in reproductive condition (i.e., bearing roe—toward the end of the winter) are presumably of greater nutritional value to sea lions (for the same reasons that the fisheries would rather take roe-bearing pollock than pollock spent after the spawning season). Also, the relative value of any prey type must also depend on the energetic costs of capturing, consuming, and digesting the prey. Prey spawing aggregations may lead to a reduction in sea lion energetic costs associated with foraging. The characteristics of such aggregations may determine their significance to foraging sea lions. Such characteristics likely include their size, depth, location, composition, density, persistence, and predictability.

Nonetheless, the information that suggests that winter may be a crucial season for Steller sea lions does not lessen the importance of available prey year-round. The observed increases in consumption by captive animals in the fall months indicates that preparation for winter months may also be essential. In addition, Trites (1998) reviewed northern fur seal data that indicated that fur seals undergo a period of faster growth in spring months and, if sea lions experience the same seasonal pattern of growth, then spring months may also be a particularly important period. Spring may also be important as pregnant females will be attempting to maximize their physical condition to increase the likelihood of a large, healthy pup (which may be an important determinant of the subsequent growth and survival of that pup). Similarly, those females that have been nursing a pup for the previous year and are about to give birth may wean the first pup completely, leaving that pup to survive solely on the basis of its own foraging skills. Thus, food availability is surely crucial year-round, although it may be particularly important for young animals and pregnant-lactating females in the winter.

4.2.12.5 Interactive competition versus exploitative competition

Much of the preceding discussion on the potential for competition between the Steller sea lion and BSAI and GOA groundfish fisheries has focused on exploitative competition; that is, competition that occurs when fisheries remove prey and thereby reduce prey availability to sea lions. In addition to exploitative competition, fisheries may affect sea lions through interactive competition. Examples of interactive competition include disruption of normal sea lion foraging patterns by the presence and movements of vessels and gear in the water, abandonment of prime foraging areas by sea lions because of fishing activities, and disruption of prey schools in a manner that reduces the effectiveness of sea lion foraging.

The hypothesis that these types of interactive competition occur can not be evaluated with the information currently available. The only data are from "platforms of opportunity" (R. Ferrero, pers. comm.), and are not sufficient to describe the presence/absence of sea lions and their responses to fishing vessels or activities. For example, few observations of sea lions from fishing vessels could mean that a) sea lions are present and tolerant of fishing but rarely sighted, or b) that sea lions are disturbed by fishing vessels and therefore abandon areas that are being fished. Incidental catch of sea lions in the 1970s and 1980s indicates that at least some sea lions were relatively tolerant of vessels and fishing activities. On the other hand, such interactions are relatively rare today, and it is possible there has been some selection for sea lions that avoid vessels and fishing activities.

The effects of fishing on groundfish schools are not understood. Vessels fishing for Atka mackerel trawl the same locations repeatedly, as they are unable to search for schools (Atka mackerel don't have a swim bladder and therefore are not evident on fish-finders). Analyses (Fritz *in prep*) have shown that this repeated trawling can lead to severe localized depletion. The number of schools affected and the effects on schooling dynamics are not known, but these factors will be important in understanding the overall impact of trawling for Atka mackerel on Steller sea lions.

Vessels trawling for other targets can use fish finders and are therefore able to search for prey until they have found schools or aggregations of suitable density. The strategy used is to continue to trawl that school (or set of schools) until such time as their size or density is no longer sufficient to justify further trawling, and then to resume searching until another aggregation of suitable density is located.

The strategies used by fishing vessels likely alter schooling dynamics and important features of target schools: their number, density, size, and persistence. If sea lion foraging strategies are adapted to take advantage of prey aggregations or schools, then trawling may result not only in exploitative competition through removal of prey, but also in interactive competition through disruption of schools or aggregations and their normal dynamics. For example, the removal of a portion of a fish school by a trawl net must create at least a temporary localized depletion (i.e., a gap in the prey school). How long that gap persists and the responses of the remainder of the schooling prey to trawling are unknown. The school may aggregate again, either quickly or over time, or it may disperse. The short-term effects may be prolonged when trawling is repeated. Hypothetically, it is possible that sea lions in the immediate vicinity of the trawled school are able to take advantage of the disruption to isolate and capture prey. On the other hand, sea lion foraging patterns are more likely adapted to normal schooling behavior of prey, and trawling may disadvantage sea lions not only because it results in removal of potential prey (exploitative competition), but also because it may disrupt normal aggregation of the school.

Thus, the overall effect of interactive competition between fisheries and sea lions is unstudied and unknown, but could exaggerate the effects of exploitative competition or removal of prey.

4.2.12.6 Changes in community composition and prey diversity

Fisheries could alter the composition of the BSAI and GOA ecosystems in a number of ways, including enhancement of a prey species by removal of a predator, enhancement of one competitor by removal of another, and suppression of a predator by removal of prey. Examples of such effects may be more common for terrestrial species, but such effects are also observed in aquatic ecosystems (e.g., Paine 1966, Power and Gregoire 1978). In addition to direct removal or reduction of a species, indirect consequences may accrue depending on the role of the species removed (e.g., keystone predator) and the method of removal (e.g., bottom trawling).

The groundfish under consideration in this opinion must assume a variety of ecological roles in the ecosystems of the BSAI, GOA, and southeast Alaska regions. Those roles and their relative importance to ecosystem structure must depend, in part, on the abundance, distribution, and age composition of the various species included in such biological communities. Those roles may change as a result of multiple factors, both natural and anthropogenic. Our current ability to assess the significance of any particular factor is severely confounded by the complexity of those systems, our poor understanding of their temporal patterns, and our inability to characterize their natural state. Fisheries-related effects may occur as a result of direct removal of components of these ecosystems, or as a result of indirect impacts such as disruption of benthic communities by bottom trawling.

The status and trends of Steller sea lion populations may depend heavily on the health of the ecosystems of which they are a part. Merrick *et al*. (1997) suggested that diet diversity was correlated to population growth in different parts of the Steller sea lion's range. Diversity may be necessary to ensure that sea lions are getting sufficient amounts of calories and essential nutrients, or to ensure that total available prey is adequate even if the availability of certain prey is variable and sometimes inadequate. Prey diversity has also been discussed in the context of changes in the trophic structure in the BSAI and GOA (e.g., Alverson 1992, Anderson *et al*. 1997), which resulted in a biological (prey) community dominated by pollock and flatfish rather than a variety of forage fish. The general consensus seems to be that a more diverse prey assemblage is likely better for sea lions.

The relevance of fisheries to the issue of diversity is based on two questions: (1) did the expansion of fisheries over the past four decades contribute significantly changes in the trophic structure of the fish community and (2) can the changes in trophic structure be reversed (to a more diverse state) by intense fishing of pollock (e.g., Merrick 1995)? The answer to the first question appears to be “yes” based on, for example, observed declines in Pacific ocean perch or yellowfin sole. But the role of fisheries in contributing to the shift from forage fish to a pollock-dominated system is not clear. As described previously, important physical changes in the BSAI and GOA ecosystems have occurred and likely contributed to the shift in community composition. However, current information is not sufficient to distinguish between the effects of fisheries and natural physical or oceanographic changes.

The answer to the second question is equally unclear. Can a fishery, acting as a predator, alter the structure of an ecosystem by controlling a dominant competitor (e.g., pollock)? The concept of predatory control of a dominant competitor is well established in the ecological literature (e.g., Paine 1966). Springer (1992) suggested that pollock may maintain their dominance in the trophic structure both by out-competing some forage fish for zooplankton prey, and by preying on others. Skud (1982) suggested that environmental factors are important determinants of the abundance of dominant competitors, but abundance of subordinate competitors is also determined by interspecific interactions. He also suggested that if the abundance of the dominant competitor is reduced, then the subordinate competitor might increase even if climate factors are not wholly favorable. If BSAI and GOA relationships are, in fact, that simple, then greater removal of pollock may lead to a reversal of the recent changes in community composition and a greater abundance of, for example, forage fish.

The contention that increased fishing of pollock will reverse observed changes in the BSAI and GOA biological communities is, however, questionable. First, if the changes in the 1970s were due, in large part, to changes in physical conditions, then the structure of these ecosystems may be determined primarily by bottom-up processes rather than top-down processes (predator-prey-competitor relations). (As Skud (1982) suggested, both bottom-up and top-down factors may be operating.) Second, certain areas (Donut Hole, Bogoslof, and Shelikof Strait) have been intensely fished for pollock and such fishing may have contributed to significant reductions of pollock in those regions. To date, however, the trophic structure in those regions has not returned to state more consistent with that observed prior to the mid to late 1970s. At present, the primary factors responsible for determining the structure of ecosystems in the BSAI and GOA regions are unclear. Third, the notion that human activities can alter these ecosystems seems reasonable (given the extent of our interaction with them), but the question of whether we can predict the direction of our effect seems presumptuous, at least at present. A review of the Steller sea lion decline, the history of human activities in these ecosystems, and the changes observed in the ecosystems suggests that we are far from a working understanding of these systems, and therefore our ability to predict even the near future is limited, at best.

4.2.12.7 Incidental take of Steller sea lions

Steller sea lions have been caught incidentally in the foreign commercial trawl fisheries in the BSAI and GOA since those fisheries developed in the 1950s (Loughlin and Nelson 1986, Perez and Loughlin 1991). Alverson (1992) suggested that from 1960 to 1990, incidental take may have accounted for over 50,000 animals, or almost 40% of his estimated total mortality due to various fishery and subsistence activities. Perez and Loughlin (1991) reviewed fisheries and observer data and reported that from 1973 to 1988, sea lions comprised 87% (over 3000) of the marine mammal incidental take reported by observers. They extrapolated the take rate to unobserved fishing activities and suggested that the incidental take during 1978 to 1988 was over 6,500 animals. Using the average observed incidental rates during 1973 to 1977, they also estimated that an additional 14,830 animals were incidentally taken in the trawl fisheries in Alaska during 1966 to 1977. Finally, they concluded that incidental take was a contributing cause of the population decline of Steller sea lions in Alaska, accounting for a decline of 16% in the BSAI and 6% in the GOA. However, because the actual decline has exceeded 80 percent since 1960, incidental take does not appear to be the only or principal factor in the decline.

Estimates for more recent years indicate a reduction in the incidental take levels. The mean estimated annual (total) mortality for the BSAI and GOA groundfish trawl and longline fisheries for 1990 to 1996 is 11.4 animals and the estimate from the Prince William Sound salmon drift gillnet fishery is 14.5 animals; resulting in a total estimated mean mortality rate in observed fisheries of 25.9 sea lions per year from the endangered western stock (Hill and DeMaster *in prep*). Similarly, estimates of operational take by fisheries in southeast Alaska are less than 10 animals from the eastern population (Hill and DeMaster *in prep*).

Satellite tracking studies suggest that Steller sea lions rarely go beyond the U.S. EEZ into international waters. Given that the high-seas gillnet fisheries have ended and other net fisheries in international waters are minimal, the probability that significant numbers of Steller sea lions are taken incidentally in commercial fisheries in international waters may be low. NMFS has concluded that the number of Steller sea lions taken incidental to commercial fisheries in international waters is insignificant (Hill and DeMaster *in prep*).

4.2.12.8 Intentional take of Steller sea lions

Historically, Steller sea lions and other pinnipeds were seen as nuisances to the fishing industry and management agencies because they damaged catch and fishing gear and were thought to compete for fish (Mathisen *et al*. 1962). Sea lion numbers were reduced through bounty programs, controlled hunts, and indiscriminate shooting. As noted above, they were also killed for bait in the crab fishery. Government sanctioned control measures and harvests stopped in 1972 with the introduction of the MMPA.

The total number of sea lions killed since the early part of this century is unknown. Alverson (1992) suggested that intentional take may have reached or exceeded 34,000 animals from 1960 to 1990. Fishermen were seen killing adult animals at rookeries, haulout sites, and in the water near boats. The loss of that many animals would have an appreciable effect on the population dynamics of sea lions, but the effect would not account for the total decline of the western population. The effect was likely concentrated in areas closer to fishing communities and less important in more isolated areas (e.g., central and western Aleutian Islands).

Sea lion populations appear to be growing slowly in southeast Alaska, where considerable commercial fishing occurs. Expanded observer coverage in the domestic groundfish fishery after 1989 and increased public awareness of the potential economic and conservation impacts of continued sea lion declines have probably reduced the amount of shooting.

Nevertheless, anecdotal reports of shootings continue and a small number of prosecutions have occurred or are occurring in 1998. The full extent of incidental killing is undetermined and therefore should be considered a potential factor in the decline of sea lions at some locations.

4.2.12.9 Alaska State fisheries

The Alaska Department of Fish and Game (ADF&G) manages fisheries out to three miles, oversees crab fisheries in federal waters (EEZ) under the FMP adopted by the NPFMC. With the exception of the Alaska state sablefish fishery, ADF&G coordinates their fishery openings and in-season adjustments with federal fisheries.

Herring: Herring have been fished in Alaska since 1878. At present, the state fishery is located in the following areas: Prince William Sound, Cook Inlet, Kodiak, Alaska Peninsula, Bristol Bay, Kuskokwim, Norton Sound, Southeast, and Port Clarence. Fisheries in the Southeast and Port Clarence regions are not likely to affect the western population of Steller sea lions and are not considered further. Harvest methods are by gillnet, purse seine, and handpicking of roe from kelp. Herring are primarily caught for their roe during the sac roe harvest in the spring. Harvest levels for 1998 are expected to be about 36,000 mt, similar to the last few years. Figure 18a shows herring catches by season and by region, and also shows the effort level depicted by the number of landings. Bristol Bay is the primary producer with recent catches of about 23,000 mt annually. Effort over the last two decades has decreased in Prince William Sound and Cook Inlet, but increased in Kuskokwim, Kodiak, and Bristol Bay. Since the early 1980s, the total state catch of herring has been relatively constant, with some variability in the late 1980s and early 1990s, but then constant again through 1997 (Figure 18b).

Miscellaneous Shellfish (Invertebrates): Clam, abalone, octopus, squid, snail, scallop, geoduck clams, sea urchins, and sea cucumbers have been harvested throughout the state (Fig. 19a). Of these, octopus and squid are the most likely prey of sea lions. Most of the catch of shellfish is taken from April to September, and they are taken by hand-picking, shovel, trawl, pot, and dredge gear. Harvest levels were relatively consistent through the 1980s, but have increased dramatically in amount and annual variation in the 1990s (Fig. 19b). The variability has been due, in large part, to recent but sporadic catches in Bristol

Bay and the Bering Sea, areas not usually fished for shellfish (Fig. 19a). With the exception of the recent large catches in these areas, most of the shellfish fisheries have traditionally taken place in the Kodiak and Cook Inlet areas.

Crab: The state manages all crab fisheries in the BSAI and GOA. King (brown, red, blue), Dungeness, and Tanner crabs are taken by hand-picking, shovel, trawl, pot, and dredge gear. Crab fisheries began in the early 1960s when the stocks were abundant, then declined due to the King Crab recession in the early 1980s. State crab fisheries occur in Bristol Bay, Dutch Harbor, Alaska Peninsula, Kodiak, Cook Inlet, Adak and W. Aleutian Islands, and Prince William Sound (Fig. 20a). This fishery primarily occurs during the winter season. In the past ten years, the industry has focused on Alaska snow crab (*C. opilio*), and the catch exceeded historical levels of king crab in the early 1990s (Fig. 20b). The Bering Sea fishery produces the vast majority of crab that is harvested in Alaska but has also been declining since 1993. Catch per landing has been greatest in the Bering Sea, and worst in the Kodiak and Cook Inlet areas (Fig. 20a). In the 1970s, the crab fleet purportedly killed sea lions for bait; the numbers killed is not known.

Shrimp: The shrimp fishery occurs primarily in the southeast and Yakutat areas, and to a lesser extent in Prince William Sound, Kodiak, Dutch Harbor, Cook Inlet, and the Alaska Peninsula. Shrimp are harvested by pot gear and often sold to floating processors. In 1995, over 45,000 mt of shrimp were harvested by 351 vessels. In the last ten years, effort has increased in the southeast due, in part, to the availability of floating processors, which allow fishing vessels to devote more of their time to fishing. Figures 21a and b show the decline in shrimp fisheries in areas other than southeast and Yakutat. Effort was highest during the late 1970s and 1980s, but has since ceased in most areas.

Groundfish: The state manages groundfish within the 3-mile limit for lingcod, Pacific Ocean perch, flathead sole, rex sole, arrowtooth flounder, sablefish, black rockfish, and pollock. Fisheries occur in the Alaska Peninsula, Kodiak, Bering Sea, Dutch Harbor, Adak and W. Aleutian Islands, Cook Inlet, Prince William Sound, and Southeast areas.

Pacific Cod: The Pacific cod fishery is undergoing a change in management from federal to state authorities. A total TAC is set for Pacific cod, and that TAC is divided into federal and state shares. In 1997 and 1998, the state assumed management responsibility of 15% of the total TAC for cod, and is expected to manage 20% in 1999. Under current regulations, the state portion of the total TAC can not exceed 25%. The state fishery is limited to pot and jig gear only. The Pacific Cod fishing season is primarily in the winter.

Salmon: The state salmon fishery includes five species: chinook, sockeye, coho, pink, and chum. These fisheries are divided into southeast, Prince William Sound, Cook Inlet, Bristol Bay, Kodiak, Chignik, Alaska Peninsula, Kuskokwim, Yukon, Norton Sound, and Kotzbue management areas (Fig. 22a). The state has a long history of salmon fishing. Salmon are taken by purse seines, gill nets, trolling, and beach seining. The catch in 1974 was just over 60,000 mt, then increased four-fold by 1981, was relatively constant through the 1980s, and then increased in the early 1990s to a record catch of over

450,000 mt (Fig. 22b). In 1997, 123 million salmon were caught in Alaska, amounting to about 280,000 mt. The 1998 catch was expected to be higher than 1997, but has been low due to poor returns in Bristol Bay. Bristol Bay harvest levels have historically been the highest with Kuskokwim and Chignik being the lowest (Fig. 22a). In 1997, 26% of the commercial catch was from hatcheries. Economically, the salmon fishery is worth more than all other state fisheries combined.

4.2.13 Federal fishery management actions affecting the Steller sea lion or its critical habitat

In 1989, the Environmental Defense Fund and 17 other environmental organizations petitioned NMFS to list all populations of Steller sea lions in Alaska as endangered. Justification was based on evidence of a major decline in their abundance throughout most of their range, but most acutely in the core region from the Kenai Peninsula to Kiska Island (Braham *et al*. 1980, Merrick *et al*. 1987). In this region, counts of adult and juvenile Steller sea lions had declined by about 80% since the late 1950s. Since 1990, the decline, while continuing, has slowed to an average of about 5 percent per year through 1996.

Concurrent with the sea lion decline, Alaskan groundfish fisheries underwent a period of unprecedented growth. Between the late 1950s and the early 1990s, the total annual removal of groundfish from Alaskan waters increased from about 27,000 mt to about 2.1 mmt. The fishing fleets of Japan and the Soviet Union were the first to exploit the region's groundfish resources in the 1950s, targeting Pacific ocean perch and yellowfin sole. By the early 1960s, trawl fisheries for walleye pollock and Pacific cod were established. By the late 1970s, American catcher boats had formed joint ventures with foreign processing vessels, beginning the domestication of Alaska groundfish fishing. Growth of the fishery and decline of the sea lion coincided in time and space, and the two overlapped in target (or prey) species. The following chronology describes management efforts protect the Steller sea lion, and to evaluate and mitigate the potential for competition between the sea lion and fisheries in the BSAI and GOA.

1990: On April 5, 1990, NMFS issued an emergency interim rule (55 FR 12645) to list the Steller sea lion as a threatened species under the ESA and established protective regulations as emergency interim measures to begin the population recovery process. NMFS implemented the following emergency conservation measures:

Management Actions:

1. Monitoring of incidental take and monthly estimates of the level of incidental kill of Steller sea lions in observed fisheries.

2. Aggressive enforcement of protective regulations, especially as they relate to intentional, lethal takes of Steller sea lions.

3. Establishment of a Recovery Team to provide recommendations on further conservation measures.

Protective Regulations:

1. Prohibition of shooting at or within 100 yds of Steller sea lions (this did not apply to Alaska native subsistence hunting).

2. Establishment of 3 nm "no-approach" buffer zones around the principle Steller sea lion rookeries in the GOA and AI.

3. Reduction of incidental kill quota from 1,350 to no more than 675 Steller sea lions.

Fritz *et al*. (1995) summarized the rationale supporting these actions and reviewed their impact on the groundfish fishing industry. NMFS issued the final rule for the Steller sea lion listing as threatened under the ESA and for the above actions on November 26, 1990 (55 FR 49204). NMFS also appointed a Recovery Team in 1990.

1991: On January 7, 1991, NMFS issued a final rule to implement regulations for BSAI/GOA FMP amendments 14/19 that limited pollock roe-stripping and seasonally allocated the pollock TAC in the BSAI and GOA (56 FR 492). For BSAI fisheries, the pollock TAC was divided between an A (roe) season and a B season (summer-fall). In the GOA fisheries, the pollock TAC for the Central and Western (C/W) Regulatory Areas was divided into 4 equal seasons. NMFS noted in the proposed rule (55 FR 37907, September 14, 1990) that "shifting fishing effort to later in the year may reduce competition for pollock between the fishery and Steller sea lions whose populations have been declining in recent years". Also, given the recent listing of Steller sea lions as threatened under the ESA, a conservative course of action seemed prudent.

The listing of the Steller sea lion also prompted NMFS to initiate section 7 consultation on the GOA and BSAI FMPs. On April 5, 1991, NMFS issued biological opinions to evaluate the potential impacts of the pertinent fisheries on endangered and threatened species, including the Steller sea lion. The potential adverse effects to Steller sea lions of the GOA and BSAI groundfish fisheries include: 1) reduction of food availability (quantity and/or quality) due to harvest; 2) unintentional entanglement of marine mammals in fishing gear; 3) intentional harassment (including killing and wounding) of animals by fishermen; and 4) disturbance by vessels and fishing operations. Both biological opinions concluded that the fishery was not likely to jeopardize continued existence and recovery of the Steller sea lion. The following conservation recommendations were made:

1. NMFS should expand its research effort and initiate projects specifically designed to assess the effects of fisheries on Steller sea lion, their prey, and their feeding efficiency.

2. Law enforcement efforts should be increased to ensure compliance with Steller sea lion rookery buffer zones and shooting prohibitions.

3. NMFS should continue the Steller sea lion public relations and fishery information effort to maintain awareness of the Steller sea lion decline and conservation prohibitions in place.

4. NMFS should work with the State of Alaska to obtain more accurate estimates of the subsistence take of Steller sea lions.

5. NMFS and the State of Alaska should initiate an outreach program to facilitate efficient taking, as well as to obtain biological data from harvested animals.

On June 5, 1991, NMFS issued a biological opinion that focused on the potential effects of the GOA pollock fishery, as specified in the 1991 TAC specification, on food availability to Steller sea lions. Although the opinion concluded that the GOA 1991 pollock TAC specification was not likely to jeopardize the continued existence of any endangered or threatened species under NMFS' jurisdiction, the opinion noted that changes in the temporal and spatial distribution of the pollock fishery may have contributed to the Steller sea lion decline. Specifically, the fishery operated more in fall and winter, caught the quota in less time, and fished more often in areas later designated (in 1993) as Steller sea lion critical habitat under the ESA (Fritz *et al*. 1995).

On June 19, 1991, NMFS issued an emergency interim rule (effective through September 17, 1991) to ensure that pollock fishing did not jeopardize the continued existence or recovery of the threatened Steller sea lion (56 FR 28112). The preamble to this rule referenced the April 19 and June 5, 1991 biological opinions. The rule contained measures to protect the Steller sea lion by:

1. allocating the pollock TAC for the combined W/C Regulatory Areas equally between two subareas located east and west of 154°W,

2. limiting the amount of unharvested pollock TAC that may be rolled over to subsequent quarters in a fishing year, and

3. prohibiting fishing with trawl gear in the EEZ within 10 nm of 14 Steller sea lion rookeries.

On September 19, 1991, NMFS extended the above measures through December 16, 1991 (56 FR 47425).

NMFS reinitiated Section 7 consultation on the GOA pollock fishery because the 1991 3rd quarter pollock TAC was exceeded by 26%. On September 20, 1991, NMFS concluded that because of the small size of the 4th quarter harvest (27,000 mt), a fishery-caused reduction in local abundance of pollock, and thus, availability to Steller sea lions, does not appear likely. This opinion concluded that the proposed 1991 4th quarter pollock harvest was not likely to jeopardize the continued existence or recovery of Steller sea lions.

Since 1991, NMFS has conducted numerous section 7 informal consultations on the effects of various GOA and/or BSAI groundfish fishery management actions on the Steller sea lion (Table 1). In these instances, NMFS determined that the action was not likely to affect listed species under NMFS' jurisdiction in a way that was not already considered in previous biological opinions, therefore, section 7 formal consultation was not required. The 1992 to 1995 consultations on the potential effects of the GOA groundfish TAC specifications and the 1993 to

1995 consultations on the potential effects of the BSAI groundfish TAC specifications were informal as described above.

Section 4(f) of the ESA requires NMFS to develop and implement plans for the conservation and survival of endangered and threatened species. NMFS had appointed a Steller Sea Lion Recovery Team to draft a Recovery Plan, and the draft Recovery Plan was released for public review and comment on March 15, 1991.

1992: On January 23, 1992, NMFS issued a final rule to implement amendments 20/25 to the BSAI and GOA FMPs (57 FR 2683). The amendments authorized regulations to protect marine mammal populations as follows:

1. prohibited trawling year-round within 10 nm of 37 Steller sea lion rookeries in the GOA and BSAI;

2. expanded the prohibited zone to 20 nm for 5 of these rookeries from January 1 through April 15 each year;

3. established 3 GOA pollock management districts; and

4. imposed a limit on the amount of an excess pollock seasonal harvest that may be taken in a quarter in each district.

On January 21, 1992, NMFS issued a biological opinion that evaluated the potential adverse effects of the 1992 BSAI fishery on Steller sea lions and concluded that the 1992 TAC specifications and the BSAI groundfish fishery were not likely to jeopardize their continued existence and recovery. The biological opinion also included the following discretionary conservation recommendation:

> "NMFS should amend the BSAI FMP to provide a mechanism to spatially allocate TACs in the Aleutian Islands in the future. For example, Atka mackerel are abundant in shelf waters near AI Steller sea lion rookeries and are eaten by Steller sea lions. Presently, the Atka mackerel harvest is only a minor component of the exploitable biomass and spatial and/or temporal concentration of the fishery is not expected to have any biological significance. However, if yearly TACs increase, as appears likely, spatial distribution of the harvest may be warranted to prevent local depletion of fish stocks."

On March 4, 1992, NMFS issued a biological opinion that evaluated the likely effects of the proposed BSAI FMP amendment 18 to proportionately allocate the yearly available harvest of pollock to inshore, offshore, and western Alaska community sectors of the BSAI fishing industry. This biological opinion concluded that based on the available data and management measures currently in place, that adoption of the proposed FMP amendment was not likely to jeopardize the continued existence and recovery of Steller sea lions. The biological opinion continued that:

> "However, since the southeastern Bering Sea shelf is considered to be an important foraging habitat for Steller sea lions, concerns regarding fishery removals from this area

> remain. Therefore, NMFS will continue to evaluate the suitability of existing management measures for the BSAI fishery to ensure adequate protection of Steller sea lions and their essential habitats. Since knowledge regarding the relationship between Steller sea lions and the commercial fishery remains very limited, it is essential that results from 1992 fisheries and Steller sea lion research efforts be factored into this analysis.

Additional management measures for the southeastern Bering Sea shelf fishery that will be evaluated during 1992 include: (1) limits on total harvest from the southeastern Bering Sea shelf; (2) modification of Steller sea lion rookery buffer zones; and (3) limits on available pollock TAC in the "A" season. Evaluation and selection of an appropriate management regime will be conducted in consultation with NPFMC and the concerned public, and be completed prior to the start of the 1993 fishery."

1993: NMFS provided notice on January 7, 1993 that the final Recovery Plan for the Steller sea lion was available (58 FR 3008).

On March 12, 1993, NMFS issued a final rule to implement an expanded no-trawl zone around the Ugamak Island Steller sea lion rookery in the eastern Aleutian Islands during the pollock roe fishery season in the BSAI (58 FR 13561). The expanded zone was expected to better encompass Steller sea lion winter habitats and juvenile foraging areas in this portion of the southeastern Bering Sea shelf during the BSAI winter pollock fishery.

On April 28, 1993, NMFS issued a biological opinion that evaluated the potential effects on Steller sea lions of delaying the start of the BSAI pollock fishery "B" season from June 1 to August 15. NMFS concluded that it would take appropriate steps to ensure that delaying the BSAI "B" season would not result in a concentration of the BSAI fishery into the winter months and the southeastern Bering Sea shelf. Therefore, the proposed action was not likely to jeopardize the continued existence and recovery of Steller sea lions. Possible management measures to mitigate any significant increase in the winter fishery could include: 1) establishing a directed pollock fishery closure date of November 1 to ensure no increase in winter harvests, or 2) seasonally expanding rookery trawl closure zones until the entire "B" season TAC has been harvested to provide additional protection to Steller sea lion foraging areas.

On July 13, 1993, NMFS issued a final rule to implement regulations (BSAI FMP amendment 28) that subdivided the Aleutian Islands subdistrict into three subareas (areas 541, 542, 543) (58 FR 37660). This rule was implemented because of concerns that the concentration of fishery removals, particularly Atka mackerel, in the eastern Aleutian Islands could cause localized depletion of groundfish stocks. While dispersal of the Atka mackerel TAC was initiated to conserve fish, it was also consistent with the objectives of the fishery management measures enacted for Steller sea lion recovery.

On August 27, 1993, pursuant to the ESA, NMFS designated critical habitat for the Steller sea lion (58 FR 45269). The primary benefit of the designation is that it provides notice to Federal agencies that a listed species is dependent on these areas (and their features) for its continued existence and that any Federal action that may affect these areas (and their features) is subject to the consultation requirements of section 7 of the ESA.

On November 1, 1993, NMFS initiated a status review of the Steller sea lion to determine whether a change in classification to endangered is warranted (58 FR 58318). NMFS solicited comments and biological information concerning the status of the Steller sea lion to be used for consideration in its comprehensive review.

1994: On November 29-30, 1994, NMFS convened the Steller Sea Lion Recovery Team specifically to consider the appropriate ESA listing status for the Steller sea lion and to evaluate the adequacy of ongoing research and management programs. The Recovery Team recommended that NMFS list the Steller sea lion as two separate population segments, split to the east and west of 144°W. The Recovery Team also recommended that the western population segment be listed as endangered and the eastern population segment be listed as threatened.

1995: On February 22, 1995, NMFS Alaska Region (AKR) and the Alaska Fisheries Science Center AFSC) forward its recommendation to NMFS Headquarters that: 1) the U.S. Steller sea lion population should be managed as two distinct population segments under the ESA, split to the east and west of 144°W, and 2) that the listing status of the western population should be changed to endangered. The AKR/AFSC recommendation was supported by a draft proposed rule and a draft status review document.

1996: On January 26, 1996, NMFS reinitiated a section 7 formal consultation on the effects of the BSAI and GOA FMPs and the 1996 TAC specifications on the Steller sea lion. Although NMFS had evaluated the effects of proposed changes to both the BSAI groundfish fishery the GOA groundfish fishery since 1991, it had been over 4 years since the last formal consultation on either fishery. During this period, the Steller sea lion population had continued to decline. Furthermore, NMFS had also collected additional data on Steller sea lions and the GOA and BSAI groundfish fisheries.

NMFS concluded that the BSAI and GOA FMPs, fisheries, and harvests under the proposed 1996 TAC specifications were not likely to jeopardize the continued existence of Steller sea lions or to result in the destruction or adverse modification of their critical habitat. NMFS noted that “the reasons for the decline of Steller sea lion populations and the possible role of the fisheries in the decline remain poorly understood.

The biological opinion included the following conservation recommendations: (1) In consultation with the Steller Sea Lion Recovery Team, the NPFMC, and other affected parties, NMFS should review the adequacy of existing buffer zones around Steller sea lion rookeries and the ecological consequences of various harvest strategies for groundfish; (2) In cooperation with the state of Alaska, NMFS should review the location, duration, and effects of state-managed herring and salmon fisheries; (3) NMFS should fund and/or undertake research to determine the local effects of fishing on sea lion prey resources.

The biological opinion also included an incidental take statement, in which NMFS specified an annual incidental take level of 15 sea lions for the GOA groundfish fishery and 30 for the BSAI groundfish fishery. NMFS also identified a (non-discretionary) reasonable and prudent measure necessary to minimize the impact of the incidental take: For both BSAI and GOA, NMFS must ensure that observers monitor the take of Steller sea lions incidental to the groundfish fisheries.

On March 12, 1996, NMFS issued a final rule to implement GOA FMP amendment 45 that combines the 3rd and 4th quarterly allowances for pollock in the 3 statistical areas of the combined W/C Regulatory Area into single seasonal allowances that will become available on September 1 of each fishing year (61 FR 9972).

1997: On January 17, 1997, NMFS issued a Decision Memorandum on the BSAI and GOA 1997 TAC Specifications with respect to Steller sea lion section 7 consultations. Based on available information on the fishery and Steller sea lions, NMFS determined that the GOA and the BSAI groundfish fisheries were not likely to affect Steller sea lions in a way or to an extent not already considered in previous section 7 consultations on these fisheries. Therefore, reinitiation of consultation under the ESA was not required.

On May 5, 1997, NMFS reclassified Steller sea lions as two distinct population segments under the ESA (62 FR 24345). The reclassification was based on biological information collected since the species was listed as threatened in 1990. The Steller sea lion population segment west of 144°W (a line near Cape Suckling, AK) was reclassified as endangered; the listing for the remainder of the U.S. Steller sea lion population remained as threatened.

1998: On February 26, 1998, NMFS noted a) the conclusion of the 1996 opinion that the BSAI groundfish fishery was not likely to jeopardize the continued existence of Steller sea lions or destroy or adversely modify their critical habitat, and b) NMFS had previously determined that reinitiation of consultation was not required for the 1997 fishery because none of the elements that would trigger reinitiation had occurred. NMFS also noted that the 1996 biological opinion remained valid for the 1998 BSAI groundfish fishery.

On March 2, 1998, NMFS issued a biological opinion that evaluated the effects of the GOA FMP and the 1998 pollock TAC specifications on the Steller sea lion. NMFS concluded that the 1998 GOA fishery was not likely to jeopardize the continued existence and recovery of Steller sea lions or to adversely modify critical habitat. NMFS noted that the biological opinion only addressed the 1998 fishery, not the continued implementation of the GOA FMP beyond 1998. The Alaska Region would need to reinitiate Section 7 consultation for the fishery in 1999 and beyond.

The March 2, 1998 opinion authorized the same incidental take level that was authorized in the 1996 opinion (15 Steller sea lions for the GOA). The authorization would be re-evaluated when additional data become available on the number of sea lions injured or killed annually by gear associated with this fishery. No reasonable and prudent measures were identified. NMFS must monitor the level of incidental take that occurs as a result of the 1998 GOA fishery and complete a report by March 15, 1999.

NMFS included the following conservation recommendations in this biological opinion: (1) Fritz and Ferrero (1998), in an analysis of options in Steller sea lion recovery and groundfish fishery management, suggest three general categories of management measures that could be employed to minimize the effects of fishing on Steller sea lion recovery: (a) gear modifications or restrictions, (b) reductions in total catch, and (c) further temporal and spatial distribution of the fisheries. NMFS should carefully analyze and consider the potential benefits of these options; (2) Initiate studies of the efficacy of buffer zones as soon as possible; (3) Continue studies to determine the foraging range of young-of-the-year Steller sea lions; (4) Continue to educate the fishing community about Steller sea lions and techniques to reduce or eliminate incidental take of the species; (5) Conduct studies of the site-by-site relation between fishing effort and trends in juvenile survival or counts at nearby rookeries.

On March 17, 1998, NMFS issued regulations for amendments 36/39 to the BSAI and GOA FMPs (63 FR 13009). This action created a forage fish species category in FMPs and implemented associated management measures. Directed fishing for forage fish would be prohibited at all times in the Federal waters of the BSAI and GOA. The intended effect of this action was to prevent the development of a commercial directed fishery for forage fish, a critical food source for many marine mammal, seabird, and fish species. The proposed rule (62 FR 65402, December 12, 1997) stated that a) forage fish are important prey for marine mammals, seabirds, and commercially important groundfish species, and b) decreases in the abundance of these predators may be related to declines in forage fish.

On June 11, 1998, NMFS issued a final rule to change the seasonal apportionment of the pollock TAC in the W/C Regulatory Areas of the GOA by moving 10% of the TAC from the 3rd fishing season (starting September 1) to the 2nd fishing season (starting June 1; 63 FR 31939). This seasonal shift of TAC was a precautionary measure intended to reduce the potential impacts of pollock fishing on Steller sea lions by reducing the percentage of the pollock TAC that is available to the fishery during the fall and winter months.

At its June 1998 meeting, the NPFMC adopted a precautionary approach by approving a regulatory amendment to reduce the probability of localized depletion of Atka mackerel in critical habitat for Steller sea lions. The NPFMC recommended both spatial and temporal redistribution of the BSAI Atka mackerel TAC as a further sea lion protective measure.

On December 3, 1998, NMFS issued a biological opinion on the authorization of the BSAI Atka mackerel fishery (1999-2002) and the BSAI and GOA pollock fisheries (1999-2002) under the respective fishery management plans. The opinion concluded that the BSAI and GOA pollock fisheries are likely to jeopardize the continued existence of the western population of Steller sea lions and adversely modify its designated critical habitat. The finding of jeopardy and adverse modification was based on 1) the major role of pollock in the diet of Steller sea lions, 2) the overlapping distributions of fishing and foraging by Steller sea lions, 3) the evidence that Steller sea lions are prey-limited, 4) the concentration of fishing effort in space (Steller sea lion critical habitat) and time (including during the winter period when sea lions may be more sensitive to competition for prey), and 5) the evidence of excessive local harvest rates in sea lion critical habitat in contrast to stock-wide harvest rates. Principles for a reasonable and prudent alternative and an example reasonable and prudent alternative were included in the December 3, 1998 opinion. The NPFMC was asked to develop conservation measures to satisfy the principles of the reasonable and prudent alternative, and passed a motion consisting of a set of such conservation measures. NMFS has subsequently determined 1) that the majority of those conservation measures, with some modification, partially satisfy the principles, and 2) that the NPFMC should be consulted again for further conservation measures pertaining, in particular, to the B and C seasons in the Bering Sea and to no-pollock-trawl zones.

4.3 Integration and synthesis of the environmental baseline

The decline of the western population of Steller sea lions is not the result of a single factor, and to search for *the single cause* is a misleading oversimplification. Multiple factors have contributed to the decline, and multiple factors may still be preventing recovery. The identification of one such factor does not rule out the possibility that others are also acting, perhaps synergistically, to prolong the decline. Furthermore, the causes for the decline appear to include both natural and anthropogenic influences.

! Intentional take of sea lions has occurred coincident with fisheries. From the 1950s (and probably before) to the 1970s, such take was not only condoned, but in many cases encouraged or rewarded. The rate or magnitude of intentional take has been estimated (Alverson 1992), although reporting and documentation have not been sufficient to provide reliable estimates of total take. Intentional take has likely subsided considerably since the passage of the MMPA and other protective legislation, although anecdotal reports indicate that some level of intentional take may still continue.

! Incidental take in trawl fisheries included thousands or tens of thousands of animals (Loughlin and Nelson 1986, Perez and Loughlin 1991) through the 1980s, and contributed to the decline of the population in the 1970s and 1980s. Currently, however, incidental take has been reduced to negligible levels.

! Commercial harvest of adult males in 1959 likely had no significant effect on population trends. However, harvest of over 45,000 pups in 1963 to 1972 contributed to local population trends in the 1960s through the early 1980s in the GOA and the eastern Aleutian Islands. Similarly, subsistence harvests prior to the 1990s were not measured but may have contributed to population decline in localized areas where such harvests were concentrated.

! Pollutants and marine debris (entanglement) may have contributed to the decline by altering growth, reproduction, or survival of sea lions. The evidence available to date does not support the contention that these factors have played a significant role.

! Harassment has likely occurred in many areas and may have been very disruptive to sea lion colonies on rookeries or haulouts, thereby leading to redistribution or deaths of animals. Such harassment could have contributed to mortality if animals were shot, females were separated from their pups for long periods, or animals (especially pups) were trampled or crushed or otherwise injured in the stampedes that often accompany such harassment. Nevertheless, harassment is thought to be less common at present, and the data are not sufficient to demonstrate that harassment was a significant contributor to the decline. Harassment is also a less likely explanation in the remote areas of the sea lion range where declines have, nonetheless, been observed (e.g., central and western Aleutian Islands).

! Disease has the potential to cause a major decline but, to date, the available information does not support the contention that disease was a significant factor.

! Killer whales and sharks take Steller sea lions, but such predation is not thought to have caused the decline. The significance of predation may have increased with the decline of sea lions. That is, if the number of sea lions taken has remained relatively constant, then the rate of mortality due to predation would increase because the abundance of sea lions has declined so significantly. However, the number of sea lions taken by killer whales and sharks is not known, and it is also possible that the number of sea lions taken has decreased in proportion to the decline of sea lions.

! Major changes have occurred in the BSAI and GOA ecosystems. Variation in physical and biological factors, in combination, likely contributed to the observed shift in trophic structure, and the dominance of pollock and flatfish in these systems.

! At the same time, the BSAI and GOA ecosystems have experienced the development and expansion of major fisheries for essential sea lion prey. The fisheries have also contributed to changes in the trophic structure of these ecosystems, but as is the case with natural changes, the extent of fisheries-related effects on the ecosystems, at large, can not be determined. To date, neither our science nor our management regimes are structured to distinguish natural from fisheries related effects on these ecosystems. With respect to Steller sea lions, however, fisheries target important prey resources at times and in areas where sea lions forage.

In the face of all these changes and influencing factors, the western population of Steller sea lions has not been able to maintain itself. The available evidence suggests that a significant part of the problem is lack of available prey. Studies of animals collected in the GOA in 1975-1978 and 1985-1986 indicate that animals in the latter collection were smaller, took longer to reach reproductive maturity, produced fewer offspring, tended to be older, and exhibited signs of anemia --- all observations consistent with the hypothesis of nutritional stress (Calkins and Goodwin 1988, Pitcher *et al*. *in review*, York 1994). In addition, survival of juvenile animals appeared to have dropped in both the eastern Aleutian Islands (Ugamak Island; Merrick *et al*. 1987) and the GOA (Marmot Island; Chumbley *et al*. 1997). These results, the evidence of substantial changes in the physical and biological features of the BSAI and GOA ecosystems, and the expansion of fisheries in these regions all support the contention that lack of available prey has contributed significantly to the past decline of the western population, and may still be so contributing.

Trends of the eastern population likely reflect a change in human activities that contributed to their decline in the earlier part of this century. Since at least 1912, or earlier, sea lions were killed as pests and to reduce their supposed effect on commercial fish stocks. Growth and recovery in the latter part of this century may be due to reductions in both killing and disturbance in the waters of southeast Alaska and British Columbia. The relatively slow recovery (2-3% annually from 1982 to 1994) suggests that some factors may still be acting to slow recovery, but recovery is still occurring for the eastern population.

5.0 EFFECTS OF THE ACTIONS

This biological opinion assesses the effects of two separate Federal actions on the endangered western population and the threatened eastern population of Steller sea lions and the critical habitat designated for them: (1) authorization of 1999 BSAI groundfish fisheries under the BSAI groundfish Fishery Management Plan and based on TAC specifications recommended by the NPFMC; and (2) authorization of 1999 GOA groundfish fisheries under the GOA Fishery Management Plan and based on TAC specifications recommended by the NPFMC. Based on this effects analysis and an analysis of cumulative effects, NMFS separately determines whether one or both of these proposed fisheries are likely to jeopardize the continued existence of the eastern or western populations of the Steller sea lion, or destroy or adversely modify their designated critical habitat.

Jeopardy analyses usually focus on the effects of an action on a species' population dynamics while adverse modification analyses usually focus on the effects of an action on the physical, chemical, and biological resources that support a population. A conclusion of "jeopardy" for an action (any one of the fisheries) means that the action could reasonably be expected to reduce appreciably the likelihood of both the survival and recovery of the western population of Steller sea lions. A conclusion of "adverse modification" means that the action could reasonably be expected to appreciably diminish the value of critical habitat for both the survival and recovery of the western population. Such actions include, but are not limited to, alterations adversely modifying any of those physical or biological features that were the basis for determining the habitat to be critical (50 CFR 402.02).

This section of the Biological Opinion assesses the potential effects of the proposed fisheries based on the description of the fisheries, the status of the Steller sea lion, and the information just presented in the environmental baseline. We begin by describing a conceptual model of sea lion foraging, based on the available life history information. We use that review and model to identify key principles or criteria on which to judge the potential effects of the proposed actions, and finally we re-examine each of the fisheries being considered in this Biological Opinion using those principles and criteria. NMFS used this approach earlier this year in a December 3, 1998, Biological Opinion on the effects of proposed BSAI Atka mackerel fishery and BSAI and GOA pollock fisheries. The following effects analysis focuses on all of the proposed groundfish fisheries except the proposed fisheries for Atka mackerel and walleye pollock, which were evaluated in the December 3, 1998, Biological Opinion.

5.1 Background to the Effects Analysis

Fisheries interact with marine mammals either operationally or biologically (Lowry *et al*. 1982). Operational interactions between marine mammals and fishing gear (whether it is actively fishing or derelict; e.g., ghostfishing or entanglement in debris) consist of removal or destruction of catch from the gear by marine mammals, or either incidental or intentional injury or killing of marine mammals. Operational interactions may directly affect marine mammals populations, but are not likely to directly affect their habitat. Biological interactions result from disturbance of normal marine mammal foraging behavior, competition with marine mammals for prey, changes in prey size/age structure, and changes in the composition of the marine community. This Biological Opinion assess the effects of both forms of interaction between the proposed groundfish fisheries and Steller sea lions.

Assessing the operational effects of the proposed fisheries is possible because fishery observer programs have generated substantial information on operational interactions between Steller sea lions and fisheries. Prior to the passage of the Marine Mammal Protection Act in 1972, the operational effects of fisheries on Steller sea lions were significant; in some areas, those effects were devastating. However, based on more recent data, gear associated with groundfish fisheries in the Bering Sea, Aleutian Islands, and Gulf of Alaska has a negligible, direct effect on the status and trends of Steller sea lions (Hill and DeMaster *in prep*).

The potential biological effects of the proposed fisheries on Steller sea lions are more significant than current operational effects. There is general scientific agreement that the decline of the western population of Steller sea lions results primarily from a decline in the survival of juvenile Steller sea lions. In addition, considerable evidence suggests that productivity of adult females has been compromised. There is also general scientific agreement that the cause of these declines probably has a dietary or nutritional cause. There is much less agreement on whether fishery-induced changes in the forage base of Steller sea lions have contributed to and continue to contribute to the decline of the Steller sea lion. However, based on the best scientific and commercial information available, the proposed groundfish fisheries may adversely affect juvenile and adult female Steller sea lions by (a) competing with Steller sea lions by reducing the abundance of Steller sea lion prey and (b) affecting the structure of the fish community in ways that reduce the availability of alternative prey (National Research Council 1996).

Any suggestion that one or more of the proposed fisheries may compete with Steller sea lions by reducing the abundance of Steller sea lion prey at local scales relevant to individual sea lions raises questions of local depletions. In our December 3, 1998, Biological Opinion, NMFS was not able to demonstrate, conclusively, that the proposed pollock trawl fishery locally-depleted the pollock resource or that the pollock biomass remaining in local areas after fishing effort was limiting to Steller sea lions. The same is true for the various groundfish fisheries being considered in this Biological Opinion. The information required to conclusively determine the presence *or absence* of local depletions has not been collected.

For many years, investigators have analyzed the available data in a search for conclusive evidence of the relationship between the status and trends of Steller sea lions and their forage base, with no success (Alverson 1992, Ferrero and Fritz 1994, Fritz 1993, Loughlin and Merrick 1989, Merrick et al. 1987, Merrick et al. 1997, Springer 1992, Trites 1992). Workshops that specifically addressed the issue of the effects of groundfish fisheries on food in the Aleutian Island, Bering Sea, and Gulf of Alaska ecosystems have been held by the Alaska Sea Grant (1993) and National Research Council (1996) only to conclude that there is no conclusive evidence available to resolve the issue and associated questions.

No new studies have been conducted that provide conclusive evidence to help us resolve this issue in this Biological Opinion. Trites (personal communication) recently completed a study that suggests that walleye pollock have lower caloric and nutritive value to Steller sea lions than species like herring, capelin, or eulachon. There seems to be general agreement in the scientific community that the western population of Steller sea lions would improve on a diet consisting of herring, capelin, or eulachon. We have less information on the caloric or nutritive value of other groundfish and flatfish to Steller sea lions, although the data available suggest that these species are a smaller component of Steller sea lion diets.

The December 3, 1998, Biological Opinion on the proposed Atka mackerel and walleye pollock fisheries focused on whether the proposed fisheries were likely to reduce the availability of food to Steller sea lions in a way that appreciably reduced their likelihood of survival and recovery in the wild. In the absence of definitive data or conclusive evidence, NMFS made the following assumptions to address that question in that Biological Opinion:

1. The abundance of any species in a particular space at a particular time is finite. Therefore, it seems reasonable to assume that fishing gear that can remove up to several hundred metric tons of fish in a single tow would, on at least a very local scale and for short periods of time, reduce the biomass of the targeted fish remaining in the ocean. By extension, it seemed reasonable to assume that, as fishing effort using such gear increased or was concentrated in a particular area in a specific period of time, the extent and duration of those reductions would increase.

2. The likelihood of locally depleting a fish resource increases when that resource is patchily distributed. That is, fish species are not homogeneously distributed throughout the water column. Instead, there are specific areas that have larger numbers of fish and other areas that have extremely limited numbers of fish (Bakun 1996). Walleye pollock and Atka mackerel are schooling fish that are patchily distributed: within a school their biomass is very high while outside of a school their densities are very low. By contrast, other species included in the groundfish fishery (such as sole, turbot, flounder, rockfish, and skates) are not schooling fish in the same sense as pollock or mackerel, which lessens our concern for this potential effect.

In our December 3, 1998, Biological Opinion, NMFS also assumed that reductions in schools of pollock or mackerel occur within the foraging areas of the endangered western population of Steller sea lions, reduced the availability of prey and the foraging effectiveness of sea lions. These assumptions were reasonable for the Biological Opinion on Atka mackerel and walleye pollock and were consistent with assumptions made by others who tried to resolve the issue of fishery effects on Steller sea lions (National Research Council 1996). However, based on the information available for this Biological Opinion, we cannot reach the same conclusion for many of the other species being addressed in this consultation. Specifically, many of the species being considered in this Biological Opinion are not schooling fish. We have no information to determine whether or not gear used to harvest these non-schooling fish species is likely to locally-deplete the prey base in a way that is likely to adversely affect Steller sea lions. One possible exception to this conclusion is Pacific cod, which is a demersal species that forms major spawning aggregations in small geographic areas in the late winter. Major aggregations occur between Unalaska and Unimak Islands, southwest of the Pribilof Islands and near the Shumagin group in the western Gulf (Shimada and Kimura 1994).

The December 3, 1998, Biological Opinion cited evidence of localized depletions of walleye pollock possibly associated with pollock fishing effort that was drawn from the Bogoslof Island area of the Aleutian Islands, the “donut hole” region of the Bering Sea, and Shelikof Strait in the Gulf of Alaska where pollock were once abundant, were heavily exploited by fisheries, and now consist of reduced stocks. The December 3, 1998, Biological Opinion also cited evidence that the Atka mackerel fishery locally-depleted mackerel stocks in the Aleutian Islands (Fritz *in prep*). There are no similar data available for the other groundfish fisheries being considered in this Biological Opinion that can be used to suggest whether or not the proposed fisheries are likely to locally deplete fish stocks in a way that affects the foraging success of Steller sea lions.

Steller Sea lion foraging model

NMFS assessed the potential biological effects of the Atka mackerel and walleye pollock fisheries by first applying the following conceptual model of the probable foraging behavior of the western population of Steller sea lions, which is derived from the information available: Sea lions are land-based predators that venture away from rookeries and haulouts to find sufficient resources (prey) to sustain growth, reproduction, and survival.

Virtually all of the foraging studies conducted to date indicate that pollock and Atka mackerel are, at least at present, essential prey. The characteristics of Atka mackerel and walleye pollock (i.e., their temporal and spatial distributions, their life history characteristics, their tendency to form patchy aggregations, their depth and movements in the water column, their composition and reproductive traits, etc.) are all relevant to their value as prey resources for sea lions.

The movement patterns of Steller sea lions identified from satellite telemetry, incidental kill records, and direct observations suggest that foraging areas that can be accessed in a day's outing are particularly important during the reproductive season, including the nursing period. These areas may be particularly important because they allow for relatively short absences of female sea lions from their pups, and because they reduce energetic and nutritive costs that would be higher if foraging required travel and searching at more distant sites. The winter months are an important foraging period for Steller sea lions because their greater metabolic demands during the harsh winter period increase their energy demands and make them more sensitive to reductions in prey availability.

Steller sea lions are limited to the prey available to them in their foraging environment. Whether recent changes in the fish community of the BSAI and GOA were caused by changes in oceanographic conditions (the regime shift), from effects of fishing effort in the 1960s and 1970s, or both, sea lions must survive with the prey resources that are available: Atka mackerel and pollock. Steller sea lions appear to prey on Atka mackerel and pollock by targeting larger schooling fish that are pelagic, semi-demersal, or demersal. Whether sea lions forage in groups or as individuals, their foraging strategy is oriented toward prey that occur in schools or similar aggregations. Pollock may not be the optimal prey because of its reduced fat content compared to other species that occur in Steller sea lion diets (Alverson 1992, Trites, personal communication). Nevertheless, the overall value of pollock as prey is not determined by its fat content, but by its availability to Steller sea lions: while pollock may not be optimal prey for Steller sea lions, it appears to be essential for sea lion survival when "better" prey is not available.

The importance of the groundfish species being addressed in this Biological Opinion in the diets of Steller sea lions is less certain. Of the species or species categories listed in the 1999 TAC specifications recommended by the NPFMC, only pollock, Atka mackerel, Pacific cod, and arrowtooth flounder are identified to species in diet studies listed in Table 5. Arrowtooth flounder is reported only in the study by Imler and Sarber (1947), and on that basis does not appear to be a significant prey at this time. Pacific cod is known to be a prey species of Steller sea lions and has been reported in collections from both the GOA and BSAI (NMFS 1995). However, based on multiple studies reporting frequency of occurrence, Pacific cod does not appear to be as important in the diets of Steller sea lions as pollock or Atka mackerel.

Assessment Approach

We tried to use a synthesis of the preceding information to determine whether one or more of the proposed groundfish fisheries were likely to appreciably reduce the likelihood of both the survival and recovery of the endangered western or threatened eastern populations of Steller sea lions (that is, the jeopardy standard) or appreciably reduce the value of critical habitat that has been designated for these populations of Steller sea lions (the standard for destruction or adverse modification of designated critical habitat).

Unlike the assessment we conducted for the Atka mackerel and walleye pollock fisheries, our assessment of the other groundfish fisheries was limited by the availability of information. The information available in most published diet studies was not sufficient to determine, to the species level, all (or precisely which) species were consumed by sea lions. For example, papers frequently report “flatfish” and “rockfish,” but both of these types of fish contain multiple species with varying biomass, distribution, and life history characteristics. Whether and to what extent the proposed fisheries could remove fish species that would otherwise be used by sea lions was, therefore, difficult to assess with the available information.

This assessment was further limited by the lack of available information on the distribution of fishing effort relative to Steller sea lions rookeries and haulouts and designated critical habitat. Although some of this information could be developed after several months of analysis, those analyses could not be completed in the time allowed for this consultation.

5.2 The proposed BSAI and GOA Groundfish Fisheries

In the Bering Sea and Aleutian Islands Region of Alaska, NMFS proposes to authorize a groundfish fishery in 1999. The BSAI is divided into nineteen reporting areas (Fig. 1), some of which are combined for TAC specifications purposes. The Aleutian Islands group comprises regulatory Areas 541, 542, and 543. When the Aleutian Islands are referred to individually, 541 represents the Eastern Aleutian Islands, 542 the Central Aleutian Islands, and 543 the Western Aleutian Islands. The GOA is divided into eight reporting areas (Fig. 2). The Western Gulf is Area 610, the Central Gulf includes Areas 620 and 630, and the Eastern Gulf includes Areas 640 and 650. State waters in Prince William Sound comprise Area 649. State waters in southeast Alaska comprise Area 659.

The fishing year coincides with the calendar year, January 1 to December 31. Depending on the target species’ spatial allocation (detailed below), additional specifications are made to particular seasons (quarters of the year or combinations of quarters) within the year. Fisheries are opened and closed by regulatory announcement. Closures are made when in-season information indicates the apportioned TAC or available PSC has been or will soon be reached, or at the end of the specified season, if the particular TAC has not been taken.

In the Bering Sea, Amendment 46 of the BSAI Groundfish FMP allocated 51%, 47%, and 2% of the Pacific cod TAC to longline and pot gear, trawls, and jig gear, respectively. Harvests of Pacific cod are also constrained by halibut bycatch limits (Witherell 1996). Within trawl gear, Pacific cod is further allocated between trawlers that catch and process Pacific cod and those that catch and deliver Pacific cod to a mothership or shore based processor. In the BSAI, the 1995 directed fishery for Pacific cod was prosecuted from about March 1to April 24 by trawl vessels, January 1 through May 7 by hook and line vessels, and March through October by jig and pot vessels. Most trawling occurs north and west of Unimak Island, while most longline effort occurs north and west of the Pribilof Islands (Witherell 1996).

In the Gulf of Alaska, Pacific cod are exploited primarily by trawls and smaller amounts of longlines, jigs, and pots (DiCosimo 1998). In recent years, catches using pot gear have increased partially because of the relatively low levels of halibut bycatch rates associated with this gear. In the Gulf of Alaska, Pacific cod is allocated between the processing components, 90% to inshore and 10% to offshore. In 1998, trawl gear was prohibited east of 140º West longitude (East Yakutak/Southeast subarea). In the GOA, the 1997 Pacific cod fishery using fixed gear opened on January 1; the fishery using trawls opened on January 20.

Sablefish are allocated between trawl and hook-and-line (longline) gear in both the BSAI and GOA. In the Eastern Regulatory Area, trawl gear may only retain sablefish as bycatch in other trawl fisheries. The hook-and-line allocation is utilized entirely by an individual quota program (IFQ). Each year the Regional Administrator determines the opening and closing dates of the IFQ sablefish fishery, taking into account the opening date of the Pacific halibut fishery so that they may be concurrent. Since the beginning of the IFQ management program, the open season for hook-and-line gear has been from March 15 through November 15 each fishing year in both FMP areas. The IFQ season for longline pot gear in the BSAI is from March 15 through May 30 and from June 30 through November 15.

Flatfish in both the BSAI and GOA are not allocated to gear or subject to seasonal apportionments except for arrowtooth flounder and Greenland turbot in the BSAI, for which directed fishing is open from May 1 through December 31. It should, however, be noted that the harvest of these targets is severely constrained by prohibited species catch limits which are specified by season, area, and gear type, as discussed below.

Rockfish fisheries open July 1 for trawl gear and January 1 for other gear types and close December 31 in both FMP areas if the NMFS determines the TACs available are large enough to manage the fishery. BSAI Plan Amendment 53 allocated 70% of the shortraker and rougheye rockfish TAC in the Aleutian Islands subarea to trawl gear and 30% to non-trawl gear. For several rockfish targets the Regional Administrator has established a directed fishery allowance of 0 mt after considering the amount of incidental catch expected in other directed fisheries. These actions have effectively closed directed fishing for rockfish throughout the year in all, or portions of, the BSAI and GOA. Examples include Pacific ocean perch, and other red rockfish in the BSAI (shortraker/rougheye, “other” northern rockfish, and thornyheads in the GOA).

Other species in the BSAI consist of sculpins, skates, sharks, and octopus; a separate ABC and TAC is established for squid. In the GOA the "other species" assemblage includes sculpins, skates, sharks, squid, and octopus. The GOA FMP specifies that the annual TAC for these species is 5% of the sum of the combined TACs for other groundfish targets.

Certain areas are closed for protection of marine mammals (Figure 3-12). Pending appropriate rule-making procedures, the number of closed areas will increase in 1999 from 35 to 123, primarily as a result of reasonable and prudent alternatives adopted for the pollock trawl fisheries as a result of the December 3, 1998, Biological Opinion. Some of the closure areas are year-round and some are in place. When marine mammal closure areas are in effect, the TAC allocated to the management unit or regulatory area may be taken from the portion of the regulatory unit or area not otherwise closed.

5.3 Effects of the proposed BSAI and GOA Groundfish Fisheries

In a December 3, 1998, Biological Opinion, NMFS assessed the potential effects of the proposed Atka mackerel fishery in the BSAI and the walleye pollock fisheries in the BSAI and GOA on the endangered western population of Steller sea lions (NMFS 1998b). That Biological Opinion concluded that the proposed walleye pollock fisheries were likely to jeopardize the continued existence of the western population of Steller sea lions and were likely to adversely modify designated critical habitat for the sea lions. Those conclusions were based on the behavior of the fishery - its concentration in space and time - not the total allowable catch, per se. The reasonable and prudent alternatives of that Biological Opinion were designed to change the behavior of the fishery by distributing it in space and time to reduce potential competition between the fishery and foraging Steller sea lions.

This Biological Opinion considers the probable effects of the proposed 1999 Total Allowable Catch specifications for groundfish in the BSAI and GOA on Steller sea lions. As discussed previously, the proposed groundfish fisheries may adversely affect the Steller sea lions by incidentally taking them in fishing gear or by affecting their foraging success. Based on recent data, gear associated with groundfish fisheries in the BSAI and GOA have a negligible, adverse effect on Steller sea lion populations, although small numbers of individual animals are still caught incidental to these fisheries. Consequently, we believe that incidental take of Steller sea lions associated with the proposed fisheries is not likely to appreciably diminish the likelihood of the continued existence of the Steller sea lion. However, despite the negligible levels of take by these fisheries, we have included an Incidental Take Statement with this Biological Opinion.

This assessment focuses on the biological effects of the proposed Total Allowable Catches for groundfish fisheries on Steller sea lions (other than the proposed Atka mackerel and walleye pollock fisheries, which were evaluated in our December 3, 19998, Biological Opinion). As we concluded in our December 3, 1998, Biological Opinion, our primary concern was with the distribution of the fishing effort over time and space, not the TAC itself.

Thus, our assessment had to consider (1) whether the spatial and temporal distribution of the proposed fisheries was likely to result in competition between the fisheries and foraging Steller sea lions and (2) if competition was likely, whether the potential loss of species that are a smaller component of sea lion diets (than pollock) was likely to appreciably reduce the likelihood of Steller sea lion survival and recovery in the wild. For example, of the species or species categories listed in the 1999 TAC specifications recommended by the NPFMC, only pollock, Atka mackerel, Pacific cod, and arrowtooth flounder are identified to species in diet studies listed in Table 5. Arrowtooth flounder is reported only in the study by Imler and Sarber (1947), and on that basis does not appear to be a significant prey for Steller sea lions. Pacific cod is known to be a prey species of Steller sea lions and has been reported in collections from both the GOA and BSAI (NMFS 1995). However, based on multiple studies reporting frequency of occurrence, Pacific cod appears to be much less important to the diets of Steller sea lions as pollock or Atka mackerel.

This assessment of effects was made more difficult because of the limited information available on most of the target species. Based on the information available, most of these target species are a much smaller component of Steller sea lion diets than walleye pollock. Some of the target species of the proposed fisheries are not known to appear in the diets of Steller sea lions. Further, many of these species occur at depths much deeper than the expected foraging range of Steller sea lions. For example, sablefish generally occur at depths greater than 200 m and can occur as deep as 1,000 m. Similarly, the biology and ecology of the flatfish minimizes the degree to which those species aggregate and, therefore, minimizes the degree to which the proposed fisheries concentrate spatially or temporally inside or outside of critical habitat. Without more information on the distribution and abundance of these fish populations, their response to fishing effort, and their importance to the diets of Steller sea lions, we cannot determine whether or to what degree the proposed fisheries are likely to appreciably reduce the likelihood of the survival and recovery of Steller sea lions. However, based on the information currently available, we have to conclude that the likelihood of competition between these fisheries and Steller sea lions is small.

A possible exception is Pacific cod which, as stated previously, is known to occur in Steller sea lion diets. Competition between Steller sea lions and the Pacific cod fishery could occur if the fishery removes all or a significant portion of its TAC from the foraging area of Steller sea lions in a manner that could produce localized depletions. However, since the mid 1980s, less than 50% of the Pacific cod TAC has been removed annually from designated Steller sea lion critical habitat (in all years, except 1988 and 1989). Although the amount of catch has increased from about 20,000 mt to over 100,000 mt, this increase appears to have been due to an increase in the harvest rate, as the catch in the eastern Bering Sea which was < 10% of the estimated biomass (of age 3+) until 1990, then ranged from 10% to 16% through 1998 (Thompson and Dorn 1998). However, we have little information on the spatial and temporal distribution of the proposed Pacific cod fishery that can be used to determine the likelihood of localized depletions within foraging areas of Steller sea lions. Nevertheless, we know the peak of the proposed Pacific cod fishery would occur between March 1 and April 24, as opposed to the mid-winter peak fisheries for associated with the Atka mackerel and pollock fisheries. We also know that the multiple gear types used to fish for Pacific cod (i.e., trawls and longline), the fisheries tend to be more dispersed temporally.

Thus the conduct of this fishery appears to be analogous to the levels we tried to achieve through the reasonable and prudent alternatives in our December 3, 1998, Biological Opinion on the walleye pollock fishery. Similarly, the Pacific cod fishery appears to be analogous to the level of exploitation produced by the conservation measures the North Pacific Fishery Management Council implemented for the Atka mackerel fishery (which caused us to conclude that the proposed Atka mackerel fishery was not likely to jeopardize the continued existence of the Steller sea lion). Based on the information currently available, we have to conclude that the proposed Pacific cod fishery is not likely to appreciably reduce the likelihood of the survival and recovery of Steller sea lions. However, additional analyses of existing, but unanalyzed datasets, may provide the information which could alter this conclusion.

6.0 CUMULATIVE EFFECTS

Cumulative effects include the effects of future State, tribal, local, or private actions that are reasonably certain to occur in the action area considered in this biological opinion. Future federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

As discussed in the Environmental Baseline, the Alaska Department of Fish and Game (ADF&G) manages fisheries out to three miles, and oversees crab fisheries in federal waters (EEZ) under the FMP adopted by the NPFMC. These fisheries are expected to continue into the foreseeable future. With the exception of the Alaska state sablefish fishery, ADF&G coordinates their fishery openings and in-season adjustments with federal fisheries. At present, the state fishery for herring is located in the following areas: Prince William Sound, Cook Inlet, Kodiak, Alaska Peninsula, Bristol Bay, Kuskokwim, Norton Sound, Southeast, and Port Clarence. Harvest methods for herring consist of gillnet, purse seine, and handpicking of roe from kelp. Herring are primarily caught for their roe during the sac roe harvest in the spring. Harvest levels for 1998 are expected to be about 36,000 mt, similar to the last few years. Figure 18a shows herring catches by season and by region, and also shows the effort level depicted by the number of landings. Bristol Bay is the primary producer with recent catches of about 23,000 mt annually. Effort over the last two decades has decreased in Prince William Sound and Cook Inlet, but increased in Kuskokwim, Kodiak, and Bristol Bay. The potential adverse effects of the state of Alaska herring fishery on Steller sea lions is uncertain, although herring have higher caloric and nutritional value to Steller sea lions.

Clam, abalone, octopus, squid, snail, scallop, geoduck clams, sea urchins, and sea cucumbers have been harvested throughout the state (Fig. 19a). Of these, octopus and squid are the most likely prey of sea lions. Most of the catch of shellfish is taken from April to September, and they are taken by hand-picking, shovel, trawl, pot, and dredge gear. Harvest levels were relatively consistent through the 1980s, but have increased dramatically in amount and annual variation in the 1990s (Fig. 19b). The variability has been due, in large part, to recent but sporadic catches in Bristol Bay and the Bering Sea, areas not usually fished for shellfish (Fig. 19a). With the exception of the recent large catches in these areas, most of the shellfish fisheries have traditionally taken place in the Kodiak and Cook Inlet areas.

The state manages all crab fisheries in the BSAI and GOA. King (brown, red, blue), Dungeness, and Tanner crabs are taken by hand-picking, shovel, trawl, pot, and dredge gear. State of Alaska crab fisheries occur in Bristol Bay, Dutch Harbor, Alaska Peninsula, Kodiak, Cook Inlet, Adak and W. Aleutian Islands, and Prince William Sound (Fig. 20a). This fishery primarily occurs during the winter season. In the past ten years, the industry has focused on Alaska snow crab (*C. opilio*), and the catch exceeded historical levels of king crab in the early 1990s (Fig. 20b). The Bering Sea fishery produces the vast majority of crab that is harvested in Alaska but has also been declining since 1993. Catch per landing has been greatest in the Bering Sea, and worst in the Kodiak and Cook Inlet areas (Fig. 20a).

The State of Alaska shrimp fishery occurs primarily in the southeast and Yakutat areas, and to a lesser extent in Prince William Sound, Kodiak, Dutch Harbor, Cook Inlet, and the Alaska Peninsula. Shrimp are harvested by pot gear and often sold to floating processors. In 1995, over 45,000 mt of shrimp were harvested by 351 vessels. In the last ten years, effort has increased in the southeast due, in part, to the availability of floating processors, which allow fishing vessels to devote more of their time to fishing. Figures 21a and b show the decline in shrimp fisheries in areas other than southeast and Yakutat.

The state of Alaska manages groundfish within the 3-mile limit for lingcod, Pacific Ocean perch, flathead sole, rex sole, arrowtooth flounder, sablefish, black rockfish, and pollock. Fisheries occur in the Alaska Peninsula, Kodiak, Bering Sea, Dutch Harbor, Adak and W. Aleutian Islands, Cook Inlet, Prince William Sound, and Southeast areas.

The State of Alaska Pacific cod fishery is undergoing a change in management from federal to state authorities. A total TAC is set for Pacific cod, and that TAC is divided into federal and state shares. In 1997 and 1998, the state assumed management responsibility of 15% of the total TAC for cod, and is expected to manage 20% in 1999. Under current regulations, the state portion of the total TAC can not exceed 25%. The state fishery is limited to pot and jig gear only. The Pacific Cod fishing season is primarily in the winter.

The State of Alaska salmon fishery includes five species: chinook, sockeye, coho, pink, and chum. These fisheries are divided into southeast, Prince William Sound, Cook Inlet, Bristol Bay, Kodiak, Chignik, Alaska Peninsula, Kuskokwim, Yukon, Norton Sound, and Kotzbue management areas (Fig. 22a). The state has a long history of salmon fishing. Salmon are taken by purse seines, gill nets, trolling, and beach seining. The catch in 1974 was just over 60,000 mt, then increased four-fold by 1981, was relatively constant through the 1980s, and then increased in the early 1990s to a record catch of over 450,000 mt (Fig. 22b). In 1997, 123 million salmon were caught in Alaska, amounting to about 280,000 mt. The 1998 catch was expected to be higher than 1997, but has been low due to poor returns in Bristol Bay. Bristol Bay harvest levels have historically been the highest with Kuskokwim and Chignik being the lowest (Fig. 22a). In 1997, 26% of the commercial catch was from hatcheries. Salmon caught in these fisheries are seasonally important in the diet of Steller sea lions

The subsistence harvest of Steller sea lions by Alaska Natives is expected to continue into the foreseeable future. The majority (79%) of sea lions were taken by Aleut hunters in the Aleutian and Pribilof Islands. The great majority (99%) of the statewide subsistence take was from west of 144°W long. (i.e., the range of the western population). The overall impact of the subsistence harvest on the western population will be determined by the number of animals taken, their sex and age class, and the location where they are taken. As is the case for other sources of mortality, the significance of subsistence harvesting may increase as the western population decreases in size unless the harvesting rate is reduced accordingly. However, the subsistence harvest accounts for only a relatively small portion of the animals lost to the population each year.

7.0 CONCLUSION

After reviewing the current status of the Steller sea lion, the environmental baseline for the action area, the effects of the 1999 BSAI and GOA groundfish fisheries with the TAC levels proposed, the cumulative effects, and the conservation measures that will result from recommendations of the NPFMC, it is NMFS' biological opinion that the action, as proposed, is not likely to jeopardize the continued existence of the Steller sea lion or adversely modify its critical habitat. This opinion is contingent upon development and implementation of a reasonable and prudent alternative to avoid jeopardy and adverse modification as found in the December 3, 1998 Biological Opinion on the BSAI and GOA pollock fisheries.

This opinion will remain in effect until the end of calendar year 1999, at which time the issue of competition between these fisheries and Steller sea lions should be re-examined. The conservation recommendations provided below include recommendations for studies to be completed in the interim period. The results of those studies should facilitate re-examination of the question of competition between these groundfish fisheries and the Steller sea lion.

8.0 INCIDENTAL TAKE STATEMENT

Section 9 of the Act and Federal regulation pursuant to section 4(d) of the Act prohibit the take of endangered and threatened species, respectively, without special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or attempt to engage in any such conduct. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the Act provided that such taking is in compliance with the reasonable and prudent measures and terms and conditions of this Incidental Take Statement.

The measures described below are non-discretionary, and must be undertaken by NMFS so that they become binding conditions of any grant or permit issued, as appropriate, for the exemption in section 7(o)(2) to apply. NMFS has a continuing duty to regulate the activity covered by this incidental take statement. If NMFS (1) fails to require the applicant to adhere to the terms and conditions of the incidental take statement through enforceable terms that are added to the permit or grant document, and/or (2) fails to retain oversight to ensure compliance with these terms and conditions, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impact of incidental take, NMFS must report the progress of the action and its impacts on the species as specified in the incidental take statement.

In the accompanying biological opinion, the Service determined that this level of anticipated take is not likely to result in jeopardy to the species or destruction or adverse modification of critical habitat.

The incidental take levels specified in the 1996 biological opinions for BSAI and GOA groundfish fisheries were 30 and 15 annually for the BSAI and GOA groundfish fisheries, respectively. These are minimal levels of take that have resulted from the efforts of the industry and previous actions by the North Pacific Fishery Management Council. These levels remain valid, with the addition of the following reasonable and prudent measure, terms and conditions, and conservation recommendations. NMFS must ensure that observers monitor the take of Steller sea lions incidental to the BSAI and GOA groundfish fisheries.

This reasonable and prudent measure is designed to minimize the impact of incidental take that might otherwise result from the proposed action. If, during the course of the action, this level of incidental take is exceeded, such incidental take represents new information requiring reinitiation of consultation and review of the reasonable and prudent measure provided. The Federal agency must immediately provide an explanation of the causes of the taking and review with the Service the need for possible modification of the reasonable and prudent measure.

9.0 CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the Act directs Federal agencies to utilize their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans, or to develop information.

1. Increase survey effort in the BSAI and GOA to determine the distribution of all species of groundfish taken in commercial fisheries. If the distribution of all species can not be determined, then emphasis should be placed on species that are known to be importantor common prey items of Steller sea lions (e.g., pollock, Atka mackerel, and Pacific cod).

2. Better define Steller sea lion foraging patterns, including their foraging distribution, and prey taken (to the lowest possible taxonomic level). Conduct a review of previous diet studies to determine if the data reported reflect prey analysis to the lowest taxonomic level possible.

3. Increase studies of the factors which may be contributing to the decline of Steller sea lions.

4. Assess the effects of other fisheries on Steller sea lions. Include fisheries managed by the Federal government and the State of Alaska.

5. Monitor and evaluate the effect of management measures intended to facilitate the recovery of Steller sea lions.

6. Establish 3-nm no-entrance zones around haulout sites used by the western population of Steller sea lions.

7. Continue to educate the fishing community about Steller sea lions and techniques to reduce or eliminate incidental take of the species.

To keep NMFS informed of actions minimizing or avoiding adverse effects or benefitting listed species or their habitats, notification of the implementation of any conservation recommendations should be provided.

10.0 REINITIATION - CLOSING STATEMENT

This concludes formal consultation on the 1999 TAC specifications for the BSAI and GOA groundfish fisheries. As provided in 50 CFR 402.16, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained (or is authorized by law) and if: (1) the amount or extent of incidental take is exceeded; (2) new information reveals effects of the agency action that may affect listed species or designated critical habitat in a manner or to an extent not considered in this opinion; (3) the agency action is subsequently modified in a manner that causes an effect to the listed species or designated critical habitat not considered in this opinion; or (4) a new species is listed or critical habitat designated that may be affected by the action. In instances where the amount or extent of incidental take is exceeded, any operations causing such take must cease pending reinitiation of consultation.

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12.0 TABLES AND FIGURES

Table 1. Consultation history on Bering Sea / Aleutian Island Groundfish Fishery Management Plan and Gulf of Alaska Groundfish Fishery Management Plans as they pertain to Steller sea lions and other protected species.

Region	Year	Date	Consultation	ACTION	CONCLUSION
BSAI					
	1998	3-Dec	Formal	1999 pollock, Atka mackerel fisheries	Jeopardy and adverse modification by pollock fishery
	1998	26-Feb	Informal	1998 TAC	Reinitiation not triggered
	1997	17-Jan	Informal	1997 TAC	No adverse affects not already considered, reinitiation not necessary
	1996	26-Jan	Formal	1996 TAC and BSAI FMP	No jeopardy
	1995	26-Sep	Informal	Effect of I/O (38/40) on SSL	No adverse affects not already considered, reinitiation not necessary
	1995	25-Aug	Informal	Amendments 38/40, other species	No adverse affects not already considered, reinitiation not necessary
	1995	3-Feb	Informal	1995 TAC	No adverse affects not already considered, reinitiation not necessary
	1994	2-Feb	Informal	1994 TAC	No adverse affects not already considered, reinitiation not necessary
	1993	28-Apr	Formal	Delay of pollock "B" season	No jeopardy
	1993	20-Jan	Informal	1993 TAC	No adverse affects not already considered, reinitiation not necessary
	1992	9-Oct	Informal	Amendments 20/25	No adverse affects not already considered, reinitiation not necessary
	1992	11-Jun	Informal	IFQ fishery	No adverse affects likely, therefore further consultation not required
	1992	4-Mar	Formal	Amendment 18 inshore/offshore	No jeopardy
	1992	21-Jan	Formal	1992 TAC	No jeopardy
	1991	22-Oct	Informal	Amendments 17/22 & 20/25	No adverse affects not already considered, reinitiation not necessary
	1991	19-Apr	Formal	BSAI FMP	No jeopardy
	1990	30-Oct	Formal	Bering Sea snail fishery	No jeopardy
	1990	24-Oct	Formal	BSAI crab FMP	No jeopardy
	1989	5-Jul	Formal	Issue of MMPA exemptions	No jeopardy
	1979	14-Dec	Formal	BSAI FMP	No jeopardy (only whales listed under ESA at this time)
GOA					
	1998	3-Dec	Formal	1999 pollock fishery	Jeopardy and adverse modification
	1998	2-Mar	Formal	1998 TAC	No jeopardy
	1997	10-Sep	Informal	Amendment 46	Action will not adversely affect listed species

Table 1 cont.

Region	Year	Date	Consultation	ACTION	CONCLUSION
GOA					
	1997	17-Jan	Informal	1997 TACs	No adverse affects not already considered, reinitiation not necessary
	1996	26-Jan	Formal	1996 TAC and GOA FMP	No jeopardy
	1995	26-Sep	Informal	Effect of I/O (38/40) on SSL	No adverse affects not already considered, reinitiation not necessary
	1995	25-Aug	Informal	Amendments 38/40, other species	No adverse affects not already considered, reinitiation not necessary
	1995	3-Feb	Informal	1995 TAC	No adverse affects not already considered, reinitiation not necessary
	1994	31-Jan	Informal	1994 TAC	No adverse affects not already considered, reinitiation not necessary
	1993	6-Jul	Informal	Amendment 31	No adverse affects not already considered, reinitiation not necessary
	1993	16-Feb	Informal	Season 2nd quarter delay	No adverse affects not already considered, reinitiation not necessary
	1993	27-Jan	Informal	1993 TAC	No adverse affects not already considered, reinitiation not necessary
	1993	6-Jan	Informal	EFP	Action will not adversely affect listed species
	1992	11-Jun	Informal	IFQ fishery	No adverse affects likely, therefore further consultation not required
	1992	4-Mar	Informal	Season 2nd quarter delay	Action will not adversely affect listed species
	1991	23-Dec	Informal	1992 TAC	No adverse affects not already considered, reinitiation not necessary
	1991	12-Nov	Informal	Amendment 23	No adverse affects not already considered, reinitiation not necessary
	1991	22-Oct	Informal	Amendments 17/22 & 20/25	No adverse affects not already considered, reinitiation not necessary
	1991	20-Sep	Formal	4th quarter pollock fishery	No jeopardy
	1991	5-Jun	Formal	1991 pollock TAC	No jeopardy
	1991	19-Apr	Formal	GOA FMP	No jeopardy

Table 2. BSAI groundfish specifications (mt) recommended by the NPFMC for 1999.

Species	Area	1999 Biomass	1999 OFL	1999 ABC	1999 TAC	1998 TAC	1998 Catch
Pollock	EBS	7,040,000	1,720,000	992,000	992,000	1,110,000	1,020,720
	Winter seasons				40%	45%	
	Summer/fall				60%	55%	
	AI	106,000	31,700	23,800	2,000	23,800	21,945
	Bogoslof	403,000	21,000	15,300	1,000	1,000	8
Pacific cod	BSAI	1,210,000	264,000	177,000	177,000	210,000	179,115
Yellowfin sole	BSAI	3,180,000	308,000	212,000	207,980	220,000	95,036
Greenland	BSAI	177,000	29,700	14,200	8,000	15,000	8,856
	BS			67%	67%	67%	
	AI			33%	33%	33%	
Arrowtooth	BSAI	819,000	219,000	140,000	134,354	16,000	14,930
Rock sole	BSAI	2,320,000	444,000	309,000	120,000	100,000	33,454
Flathead sole	BSAI	636,000	118,000	77,300	77,300	100,000	24,228
Other flatfish	BSAI	618,000	248,000	154,000	154,000	89,434	15,137
Sablefish	EBS	17,000	2,090	1,340	1,340	1,300	573
	AI	26,000	2,890	1,860	1,380	1,380	615
POP complex							
True POP	EBS	45,500	3,600	1,900	1,400	1,400	1,031
Other POP	EBS	11,600	358	267	267	267	107
True POP	AI	236,000	19,100	13,500	13,500	12,100	9,070
	Eastern			3,430	3,430	3,070	2,000
	Central			3,850	3,850	3,450	2,500
	Western			6,220	6,220	5,580	4,570
Sharp/northernn	AI	94,000	5,640	4,230	4,230	4,230	3,652
Sharp/rougheye	AI	46,500	1,290	965	965	965	668
Other rockfish	EBS	7,030	492	369	369	369	205
	AI	13,000	913	685	685	685	361
Atka mackerel	AI	595,000	148,000	73,300	66,400	64,300	55,782
	Eastern			17,000	17,000	14,900	12,000
	Central			25,600	22,400	22,400	20,000
	Western			30,700	27,000	27,000	24,000
Squid	BSAI	n/a	2,620	1,970	1,970	1,970	908
Other species	BSAI	843,000	129,000	32,860	32,860	25,800	23,448
BSAI total		18,243,630	3,719,391	2,247,846	2,000,000	2,000,000	1,509,849

EBS = eastern Bering Sea
BSAI = Bering Sea and Aleutian Islands
BS = Bering Sea
AI = Aleutian Islands

OFL = overfishing level
ABC = acceptable biological catch
TAC = total allowable catch

A:B season split for CDQ is 45%:55%
AI pollock TAC is for bycatch only

1998 catch as of 7 November 1998

Table 3. GOA groundfish specifications (mt) recommended by the NPFMC for 1999.

		1998				1999			
Species	Area	OFL	ABC	TAC	Catch[1]	Area	OFL	ABC	TAC
Pollock	W(61)		29,790	29,790	29,311	W(61)		23,120	23,120
	C(62)	170,500	50,045	50,045	49,128	C(62)	134,100	38,840	38,840
	C(63)		39,315	39,315	39,047	C(63)		30,520	30,520
	E	15,600	10,850	5,580	6,367	W. Yakutat	12,300	8,440	2,110
						E. Yak./SEO			6,330
	Total	186,100	130,000	124,730	123,853	Total	146,400	100,920	100,920
Pacific Cod[2]	W		27,260	23,170	19,845	W		29,540	23,630
	C		49,080	41,720	41,632	C		53,170	42,935
	E		1,560	1,170	850	E		1,690	1,270
	Total	141,000	77,900	66,060	62,327	Total	134,000	84,400	67,835
Flatfish, Deep Water	W		340	340	16	W		240	240
	C		3,690	3,690	2,348	C		2,740	2,740
	E		3,140	3,140	108	W. Yakutat		1,720	1,720
						E. Yak./SEO		1,350	1,350
	Total	9,440	7,170	7,170	2,472	Total	8,070	6,050	6,050
Rex Sole	W		1,190	1,190	439	W		1,190	1,190
	C		5,490	5,490	2,197	C		5,490	5,490
	E		2,470	2,470	35	W. Yakutat		850	850
						E. Yak./SEO		1,620	1,620
	Total	11,920	9,150	9,150	2,671	Total	11,920	9,150	9,150
Flatfish Shallow Water	W		22,570	4,500	269	W		22,570	4,500
	C		19,260	12,950	3,199	C		19,260	12,950
	E		1,320	1,180	72	W. Yakutat		250	250
						E. Yak./SEO		1,070	1,070
	Total	59,540	43,150	18,630	3,540	Total	59,540	43,150	18,770
Flathead Sole	W		8,440	2,000	568	W		8,440	2,000
	C		15,630	5,000	1,171	C		15,630	5,000
	E		2,040	2,040	8	W. Yakutat		1,270	1,270
						E. Yak./SEO		770	770
	Total	34,010	26,110	9,040	1,747	Total	34,010	26,110	9,040
Arrowtooth	W		33,010	5,000	2,997	W		34,400	5,000
	C		149,640	25,000	9,687	C		155,930	25,000
	E		25,690	5,000	379	W. Yakutat		13,260	2,500
						E. Yak./SEO		13,520	2,500
	Total	295,970	208,340	35,000	13,063	Total	308,880	217,110	35,000
Sablefish[3]	W		1,840	1,840	1,425	W		1,820	1,820
	C		6,320	6,320	5,778	C		5,590	5,590
	W. Yakutat		5,960	2,473	1,877	W. Yakutat		5,290	2,090
	E. Yak./SEO			3,487	3,421	E. Yak./SEO		-	3,200
	Total	23,450	14,120	14,120	12,501	Total	19,720	12,700	12,700
Rockfish, Other Slope	W		20	20	47	W		20	20
	C		650	650	701	C		650	650

Table 3. (cont.)

		1998					1999		
Species	Area	OFL	ABC	TAC	Catch[1]	Area	OFL	ABC	TAC
	E		4,590	1,500	112	W. Yakutat		470	470
						E.Yak./SEO		4,130	4,130
	Total	7,560	5,260	2,170	860	Total	7,560	5,270	5,270
Rockfish, Northern	W		840	840	67	W		840	840
	C		4,150	4,150	2,974	C		4,150	4,150
	E		10	10	10	E		-	-
	Total	9,420	5,000	5,000	3,051	Total	9,420	4,990	4,990
Pacific Ocean Perch	W		1,810	1,810	850	W	2,610	1,850	1,850
	C		6,600	6,600	7,501	C	9,520	6,760	6,760
	E		4,410	2,366	610	W. Yakutat	6,360	1,350	820
						E.Yak./SEO		3,160	3,160
	Total	18,090	12,820	10,776	8,961	Total	18,490	13,120	12,590
Shortraker/Rougheye	W		160	160	124	W		160	160
	C		970	970	865	C		970	970
	E		460	460	701	E		460	460
	Total	2,740	1,590	1,590	1,690	Total	2,740	1,590	1,590
Rockfish, Pelagic Shelf[4]	W		620	620	60	W		530	530
	C		3,260	3,260	2,477	C		3,370	3,370
	E		1,000	1,000	572	W. Yakutat		740	740
						E. Yak./SEO		240	240
	Total	8,040	4,880	4,880	3,109	Total	8,190	4,880	4,880
Rockfish, Demersal Shelf	SEO	950	560	560	306	SEO	950	560	560
Atka Mackerel	Gulfwide	6,200	600	600	316	Gulfwide	6,200	600	600
Thornyhead	W		250	250	206	W		260	260
	C		710	710	572	C		700	700
	E		1,040	1,040	352	E		1,030	1,030
	Total	2,840	2,000	2,000	1,130	Total	2,800	1,990	1,990
Other Species	Gulfwide		NA	15,570	3,698	Gulfwide		NA	14,600
GULF OF ALASKA	**TOTAL**	817,270	548,650	327,046	245,295	**TOTAL**	778,890	532,590	306,535
[1]catch through November 7, 1998.									
[2]TAC reduced by 15% GHL for W/C state fishery apportionment (25% for EGOA)									
[3]WY and EY/SEO ABC combined; 5% trawl TAC allowance in EY/SEO reallocated to WY, so: 90% of WY=fixed gear; 100% of EY/SEO=fixed gear									
[4]nearshore component removed from PSR in 1998									

Table 4. Life history table for Steller sea lions based on Calkins and Pitcher (1982) and York (1994). (From York 1994.)

Ages			Calkins-Pitcher life table			York life table		
From	To	Fecundity	Cum. survival	Annual survival	Percent at age	Cum. survival	Annual survival	Percent at age
0	1	0.000	1.000	0.776	16.676	1.000	0.782	16.251
1	2	0.000	0.776	0.776	12.546	0.782	0.782	12.709
2	3	0.000	0.603	0.776	9.438	0.612	0.782	9.938
3	4	0.105	0.468	0.868	7.100	0.478	0.930	7.772
4	5	0.267	0.406	0.879	6.163	0.445	0.909	7.228
5	6	0.286	0.357	0.888	5.417	0.404	0.895	6.570
6	7	0.315	0.317	0.893	4.811	0.362	0.884	5.880
7	8	0.315	0.283	0.898	4.296	0.320	0.875	5.198
8	9	0.315	0.254	0.874	3.857	0.280	0.867	4.548
9	10	0.315	0.222	0.899	3.372	0.242	0.859	3.943
10	11	0.315	0.200	0.893	3.031	0.208	0.853	3.338
11	12	0.315	0.178	0.896	2.707	0.178	0.847	2.889
12	13	0.315	0.160	0.895	2.425	0.150	0.841	2.447
13	31	0.315	0.160	0.895	15.99	0.150	p(x)d	11.239

Table 5. A partial listing of studies on the prey of Steller sea lions. When prey are listed in order of frequency of occurrence reported, an asterisk (*) or dagger (†) indicate that rank of the marked prey item was tied with the similarly marked prey item listed before or after. Sample sizes (*n*) for studies of stomach contents are given only for the number of stomachs with contents; empty stomachs are not included. Note that some studies used the same data and results are therefore redundant (e.g., Merrick and Calkins [1996] present reanalysis of data reported in Pitcher [1981], Calkins and Pitcher [1982], and Calkins and Goodwin [1988]).

Study	Years	Location	Methods	Main findings
Imler and Sarber 1947	1945-1946	Sitka to Kodiak Island	Stomach contents (*n* = 15)	- Eight sea lions sampled in southeast Alaska; all but one fed principally on pollock, and exception contained a skate and an octopus. - Three sampled from Barren Islands contained pollock, starry flounder, tom cod, arrow-toothed halibut, common halibut, and octopus. - Two from Chiswell Island contained salmon. - Two from Kodiak Island contained pollock and arrow-toothed halibut.
Sleptsov 1950 (cited in Spaulding 1964)	Unknown	Kuril Islands	Unknown	- Reported sea lion feeding on octopus.
Wilke and Kenyon 1952	1949, 1951	St. Paul Island	Stomach contents (*n* = 3)	- One sea lion contained primarily sand lance but also starry flounder, one contained halibut, cod, pollock, and flounders, and one contained a large cephalopod beak.
Pike 1958	Summary, 1901-1958	Primarily BC, but also off California and Alaska	Stomach contents, (*n* = 19)	- Reports a range of fish and cephalopods for 12 time/area studies. - Disputes claim that studies provide evidence of serious commercial competition. - For his study (in British Columbia), prey (in order of frequency of occurrence) included squid, herring, rockfish, octopus, salmon*, skate*, and hake*. - For other studies in his table (except Imler and Sarber 1947), prey items listed were (in no particular order) rockfish, perch, herring, skate, shark, squid, octopus, lamprey, salmon, “cod,” “bass,” mussels, clam, crab, dogfish, flatfish, and sardines.
Mathisen *et al*. 1962	1958	Chernabura	Stomach contents (*n* = 94; 14 yearlings, 42 adult females, 18 harem bulls, 20 unattached bulls)	- Prey (in order of frequency of occurrence) included squid/octopus , common bivalves, smelts, greenlings, shrimp/crabs, rockfish, sculpins, isopods, unclassified crustaceans*, segmented worms*, and single occurrences of lamprey, salmon, sand lance, sand dollar, and coelenterate.

Table 5. (cont.)

Study	Years	Location	Methods	Main findings
Thorsteinson and Lensink 1962	1959	Marmot, Atkins, Ugamak, Jude, Chowiet	Stomach contents (*n* = 56); primarily adult males	- Prey (in order of frequency of occurrence) included squid/octopus, clam/mussel/snail, sand lance, rockfish, crab, greenling*, sculpins*, flatfish*, and single occurrences of halibut and lumpfish.
Spaulding 1964	1956-1963(?)	British Columbia	Stomach contents (*n* = 190; overlap with specimens reported in Pike [1958] above)	- Suggests sea lions prey mainly on one item per feeding period. - Some seen feeding at surface on lingcod, rockfish, salmon, or halibut (*n* = 8). - Feed primarily at night (*n* = 269 or 393 sampled). - Consumption of herring and salmon by sea lions, fur seals, and harbor seals estimated about 2% to 4% of commercial catch. - Prey (in order of frequency of occurrence) included octopus, rockfish, herring*, whiting*, salmon, dogfish, squid*, hake*, flatfish†, clam†, ratfish, shrimp*, sand lance*, graycod†, lingcod†, and single occurrences of lamprey, skate, eulachon, halibut, and mackereljack.
Tikhomirov 1964	1962	Bering Sea	Stomach contents *n* = unknown)	- Large numbers of sea lions in the southeastern Bering Sea, winter/spring of 1962. - Suggests herring "staple food" of sea lions during this period. - Suggests sea lion distribution was influenced by the distribution of herring.
Fiscus and Baines 1966	1958-1963	California to Bering Sea	Stomach contents (*n* = 22)	- Steller sea lions taken off central California and Oregon fed only on bottom fish. - Steller sea lions taken in Alaskan waters fed mainly on small, schooling fishes. - Near Unimak Pass in 1962, capelin was the major food species. - A Steller sea lion taken on the Fairweather Grounds in the eastern GOA in May 1958 had eaten three salmon. - Most of the food species (capelin, sand lance, sculpins, rockfishes and flatfishes) found in the stomachs of Steller sea lions suggest that they feed near land or in relatively shallow water (<100 fm, 180 m). - Steller sea lions were seen at distances of 70-85 miles from land by Fiscus and Kenyon in 1960 (Kenyon and Rice 1961).

Table 5. (cont.)

Study	Years	Location	Methods	Main findings
Jameson and Kenyon 1977	1973-1976	Rogue River, Oregon	Observations of sea lions feeding at surface (84 observations; number of sea lions unknown)	- Prey consisted of 73 lampreys, 2 salmonids, 9 unidentified.
Gentry and Johnson 1981	1974-1975	St. George Island (Pribilof Islands)	Observations (163 verified observations, number of sea lions unknown)	- Observed sea lions taking 163 fur seal pups. Estimated such predation may result in the mortality of about 3% to 7% of fur seal pups born at St. George Island.
Jones 1981	1968-73	North and Central California	Stomach contents (n = 9)	- Noted 9 stomachs with fish, and 7 with squid and octopus. - Grouped 127 identified fishes from northern sea lions according to schooling (open-water), bottom-dwelling (rocky), and inshore-schooling species (his Table 6), and suggested results indicate that the northern sea lion feeds mainly on bottom-dwelling fishes.

Table 5. (cont.)

Study	Years	Location	Methods	Main findings
Pitcher 1981	1975-78	GOA	Stomach contents (*n* = 153)	- Stomach contents were 95.7% fishes by volume, and included 14 species of fish in 11 families. - Gadids comprised 59.7% of total contents and occurred in 82.4% of stomachs with food. - Walleye pollock comprised 58.3% of the total volume and occurred in 66.7% of stomachs with food. - Cephalopods occurred in 36.6% of stomachs with contents but made up only 4.2% of total volume. - Predation on salmon and capelin appeared to be largely limited to spring and summer. - Prey (by combination rank index) included pollock, squids, herring, capelin, cod, salmon, octopus, sculpins, flatfishes, rockfishes. - Herring and squids were extensively used by sea lions in Prince William Sound but appeared to be relatively unimportant in other areas. - Results for sea lions similar to results for harbor seals. - Mean fork length of 2030 pollock otoliths was 29.8 cm (range 5.6 to 62.9 cm, SD = 11.6 cm)

Table 5. (cont.)

Study	Years	Location	Methods	Main findings
Calkins and Pitcher 1982 (note redundancy with previous results of Pitcher 1981)	1975-1978	GOA, including northeastern GOA, Prince William Sound, Kenai Coast, Kodiak Island, and the Alaska Peninsula region	Stomach contents (*n* = 153)	- Fishes comprised 72.8%, cephalopods (octopus and Gonatid squids) 21.5%, decapod crustaceans (shrimps, tanner and spider crabs) 4.2%, gastropods (marine snails) 0.8%, and mammals 0.4% of the prey occurrences. - Fishes included minimum of 14 species of 11 families. - Gadids composed nearly half of total occurrences and nearly 60% of total volume. - Harbor seal remains were found in two stomachs (see Pitcher and Fay 1982). - Seven top-ranked prey (in order of modified Index of Relative Importance) were pollock, herring, squids, capelin, salmon, Pacific cod, and sculpins. - Pollock was dominant prey accounting for about 39% of all occurrences and 58% of the total volume. - Pollock was top-ranked prey in all areas except Kodiak, where it was ranked second below capelin. - Herring and squid were used extensively in Prince William Sound, but not in other areas. - Predation on salmon and capelin was largely limited to spring and summer. - Geographic differences in use of salmon and capelin may have been due to sampling at different sites and seasons. - Comparison with previous studies (Imler and Sarber 1947, Mathisen *et al.* 1962, Thorsteinson and Lensink 1962, and Fiscus and Baines 1966) which had more invertebrates, no herring, but included sand lance. Noted differences in sampling for this study (throughout year at wide range of locations) versus earlier studies (near rookeries during breeding season). - Four of the five top-ranked prey were off-bottom schooling species.
Lowry *et al.* 1982	1976	Pribilof Islands	Stomach contents (*n* = 4)	- Prey (in order of frequency of occurrence) included pollock, squids, and single occurrences of octopus, flatfish, lamprey, and prickleback. - Based on otoliths, pollock consumed ranged from 34 cm to 57 cm in length. - Also mentions the following prey items from a preliminary examination of 111 stomach samples collected in the central and western Bering Sea (in no particular order): pollock, cod, Gonatid squids, herring, octopus, and sculpins.

Table 5. (cont.)

Study	Years	Location	Methods	Main findings
Frost and Lowry 1986			Stomach contents (*n* = 90; not stated how many had contents)	- Most pollock eaten by sea lions (76%) were 20 cm or longer. - Younger sea lions (≤4 yr) collected in 1981 (all were males) ate significantly smaller fish ($\bar{x}$ = 22.4 cm, *n* = 37) than did older animals ($\bar{x}$ = 26.9 cm, *n* = 51). - A sea lion collected in 1976 and another collected in 1979 (both near the Pribilofs) had eaten pollock averaging 46.9 cm in length (range 18.4-61.4 cm), while those collected in 1981 to the west had eaten substantially smaller pollock averaging 25.2 cm in length (range 8.3-64.2 cm). - In 1981 sea lions collected in the central Bering Sea had eaten larger pollock than those off the Kamchatka Peninsula ($\bar{x}$ = 26.8 cm vs. 23.5 cm). - “It is unknown whether the consumption patterns described above are a result of actual size selection of prey or if they result from coincidental distribution of predators and prey size classes.” - “ . . . the size range of pollock eaten by both yong and old sea lions was similar.”

Table 5. (cont.)

Study	Years	Location	Methods	Main findings
Calkins and Goodwin 1988	1985-1986	GOA and southeast Alaska	Stomach contents (*n* = 88;47 had only trace amounts. Five with measurable contents and nine with trace amounts from southeast; remainder were from Kodiak area and adjacent portions of Alaska Peninsula.)	Southeast - Fishes comprised 98% of volume, mostly Pacific cod (57% of total volume) and pollock (32%). - Most frequently occurring were pollock (57%) and flatfishes (21%). - Only other prey observed were squid and octopus. - Mean fork length of 80 pollock otoliths from 8 sea lions in southeast was 25.5 cm (range 4.8 to 55.7 cm, SD = 10.4 cm) Kodiak area - Most important by volume were pollock (42%), octopus (26%), and flatfish (25%). - Most frequently occurring were pollock (58%) and octopus (32%). - Other prey (in no particular order) were other fishes, squid, decapod crustaceans, and clams. - Prey rank (based on combined rank index [Pitcher 1981]) in Kodiak area were pollock, octopus, flatfishes, sand lance, Pacific cod, and salmon. - Mean fork length of 1064 otoliths from 43 sea lions in Kodiak area was 25.4 cm (range 7.9 to 54.2 cm, SD = 12.4 cm). - Pollock was the most important prey item in both 1975-1978 collection (39% by frequency of occurrence in Kodiak area) and 1985-1986 collection (58%). - Capelin was most important in Kodiak area in 1975-1978. However, they suggest difference in capelin may be due to seasonal differences when animals collected (spring-summer 1975-1978 versus spring-autumn/early winter 1985-1986). Thus, comparisons may be compromised by potential seasonal bias. - Octopus ranked second in 1985-1986 collection near Kodiak, but fifth in 1975-1978. However, they suggest difference may be due to collection site. Thus comparisons may be compromised by potential location bias. - Sand lance occurred in 26% of sea lions from GOA in 1960s (Mathisen *et al.* 1962, Thorsteinson and Lensink 1962, Fiscus and Baines 1966), were not found in 1975-1978 sample, but were fourth in 1985-1986 sample.

Table 5. (cont.)

Study	Years	Location	Methods	Main findings
Byrnes and Hood 1994	1992	Año Nuevo, California	One observation	- Observed a territorial male Steller sea lion attack, kill, and consume what appeared to be a yearling California sea lion.
Merrick and Calkins 1996 (note redundancy with Pitcher 1981, Calkins and Pitcher 1982, and Calkins and Goodwin 1988)	1975-1978, 1985-1986	GOA	Stomach contents, (n = 178 in 1975-1978 and n = 85 in 1985-1986)	- Prey consumption was based on frequency of occurrence. - Most stomachs contained prey of only one kind. - Pollock were the most common prey of juvenile ($\leq$4 years old) and adult sea lions in virtually all seasons and areas during these two periods. - Juvenile pollock were a major part of the diet in both periods. - Juvenile sea lions ate smaller and relatively more juvenile pollock. - Small forage fish were consumed on a seasonal basis. - Temporal comparisons were possible only in the Kodiak region. - The proportion of sea lions eating pollock increased from 49% in 1975-1978 to 69% in 1985-1986 in the Kodiak area. - Small forage fish were the second most common prey in the 1970s, and flatfish were second in the 1980s. - Of the fish consumed, 73% were < 30 cm, but they accounted for only 26.8% of the biomass consumed. - Half (50.7%) of the pollock mass consumed by juvenile sea lions came from fish <30 cm, while only 21% of the pollock mass consumed by adult sea lions came from juvenile pollock. - Seasonal differences were observed in the consumption of all prey taxa, but differences were not found in 1980s. - Between 1970s and 1980s, the portion consuming pollock and cephalopods increased significantly and the portion consuming small forage fish and other demersal fish decreased. - The increase in pollock consumed was only evident in summer months (all ages combined), but was evident in all seasons for juveniles. - (Note that sampling was not consistent with respect to seasons or specific locations between the two sampling periods, which weakens the basis for comparisons.)

Table 5. (cont.)

Study	Years	Location	Methods	Main findings
Merrick *et al.* 1997	1990-93 (summer - last week June, first week July, or first week August)	Kodiak to Agattu and Alaid - 37 collections at 19 rookeries and 3 haulouts	Scat analysis and population trends. No. scats analyzed = 338. Suggests most scats from adult females. Prey pooled into seven categories, rookeries and haulouts pooled into six areas. Report on 40 and 52 scats from Bogoslof and Ugamak (1985-89 and 1990-93, respectively), and compared with stomach contents in Kodiak area for 1976-78 (20) and 1985-89 (28), and 54 scats in 1990-93.	- Scats contained at least 13 species. - Atka mackerel most common prey category (62%), gadids second (43%), salmon (20%) third, cephalopods (12%) fourth, small schooling fish (9%) fifth, then other demersal fish (7%) and flatfish (3%). - Pollock occurred in 29% of the scats and unidentified gadids (which the authors suggest were probably pollock) in 28%. - Pollock dominated in the GOA, was approximately equal in the eastern Aleutian Islands and the area they designated as central Aleutian Islands 1, and Atka mackerel dominated further west. - Salmon, small schooling fish, and flatfish were found more commonly in the eastern areas. - Diet diversity tended to be greater east to west and was correlated with rate of population change. - "The high correlation between area-specific diet diversity and population changes supports the hypothesis that diet is linked with the Steller sea lion population decline in Alaska." - If diet diversity (as measured in this study) is related to population trends, and the indices of diet are based on adult female foraging patterns, these results would indicate that juvenile survival is not the only vital rate being affected. - Emphasizes the importance of secondary prey.

Table 5. (cont.)

Study	Years	Location	Methods	Main findings
Merrick and Loughlin 1997	1990-1993	GOA to eastern Aleutian Islands	Very High Frequency radio transmitters (*n* = 10 adult females instrumented in June-July); Satellite-linked time-depth recorders (*n* = 5 adult females instrumented in June-July, *n* = 5 adult females instrumented in November-March, and *n* = 5 young-of-the-year instrumented in November-March).	- Mean trip duration for adult females instrumented (either radio transmitter or satellite-linked time-depth recorder) on the order of 18 to 25 hours, with time on shore on the order of 18 to 19 hours, so slightly more than half of the females' cycles were spent at sea. - Mean trip duration for adult females instrumented (satellite-linked time-depth recorder) in winter was 204 hours, but time on shore was approximately the same as for summer adult females. Adult females in winter spent approximately 90% of their time at sea. - Young-of-the-year animals spent a mean time of 15 hours at sea and 25 hours on land, therefore spending about 37% of their time at sea. - Summer adult females dove about 17 times per hour, winter adult females about 12 times per hour, and young-of-the-year about 12-13 times per hour. All groups dove most frequently in the late afternoon and night. - Maximum dive depths for summer adult females was between 150 m and 250 m, for winter adult females was > 250 m, and for young-of-the-year was 72 m. - Mean number of diving hours per day was 4.7 for summer adult females, 5.3 for winter adult females, and 1.9 for young-of-the-year. - Mean trip distance for summer adult females was 17.1 km, winter adult females 133 km, and young-of-the-year 31 km (but were skewed by one trip by a young-of-the-year of 320 km). - Two of the winter adult females foraged in a manner that suggested they still were nursing pups. These females relatively dove 8.1 hours per day, made short trips (mean 53 km over 18 hours), and returned to the same or nearby haulout at the end of each trip. The remaining three winter adult females was 3.5 hours per day and spent up to 24 days at sea before returning to land. - In general, winter adult females spent more time at sea, dove deeper, and had greater home ranges than summer adult females.

Table 6. Counts of Steller sea lions by region (NMFS, unpubl. data). For the GOA, the eastern sector includes rookeries from Seal Rocks in Prince William Sound to Outer Island; the central sector extends from Sugarloaf and Marmot Islands to Chowiet Island; and the western sector extends from Atkins Island to Clubbing Rocks. For the Aleutian Islands, the eastern sector includes rookeries from Sea Lion Rock (near Amak Island) to Adugak Island; the central sector extends from Yunaska Island to Kiska Island; and the western sector extends from Buldir Island to Attu Island.

Year	Gulf of Alaska			Aleutian Islands			Southeast Alaska
	Eastern	Central	Western	Eastern	Central	Western	
1975				19,769			
1976	7,053	24,678	8,311	19,743			
1977				19,195			
1979					36,632	14,011	6,376
1982							6,898
1985		19,002	6,275	7,505	23,042		
1989	7,241	8,552	3,800	3,032	7,572		8,471
1990	5,444	7,050	3,915	3,801	7,988	2,327	7,629
1991	4,596	6,273	3,734	4,231	7,499	2,411	7,715
1992	3,738	5,721	3,720	4,839	6,399	2,869	7,558
1994	3,369	4,520	3,982	4,421	5,790	2,037	8,811
1996	2,133	3,915	3,741	4,716	5,528	2,190	8,231
1997		3,352	3,633				

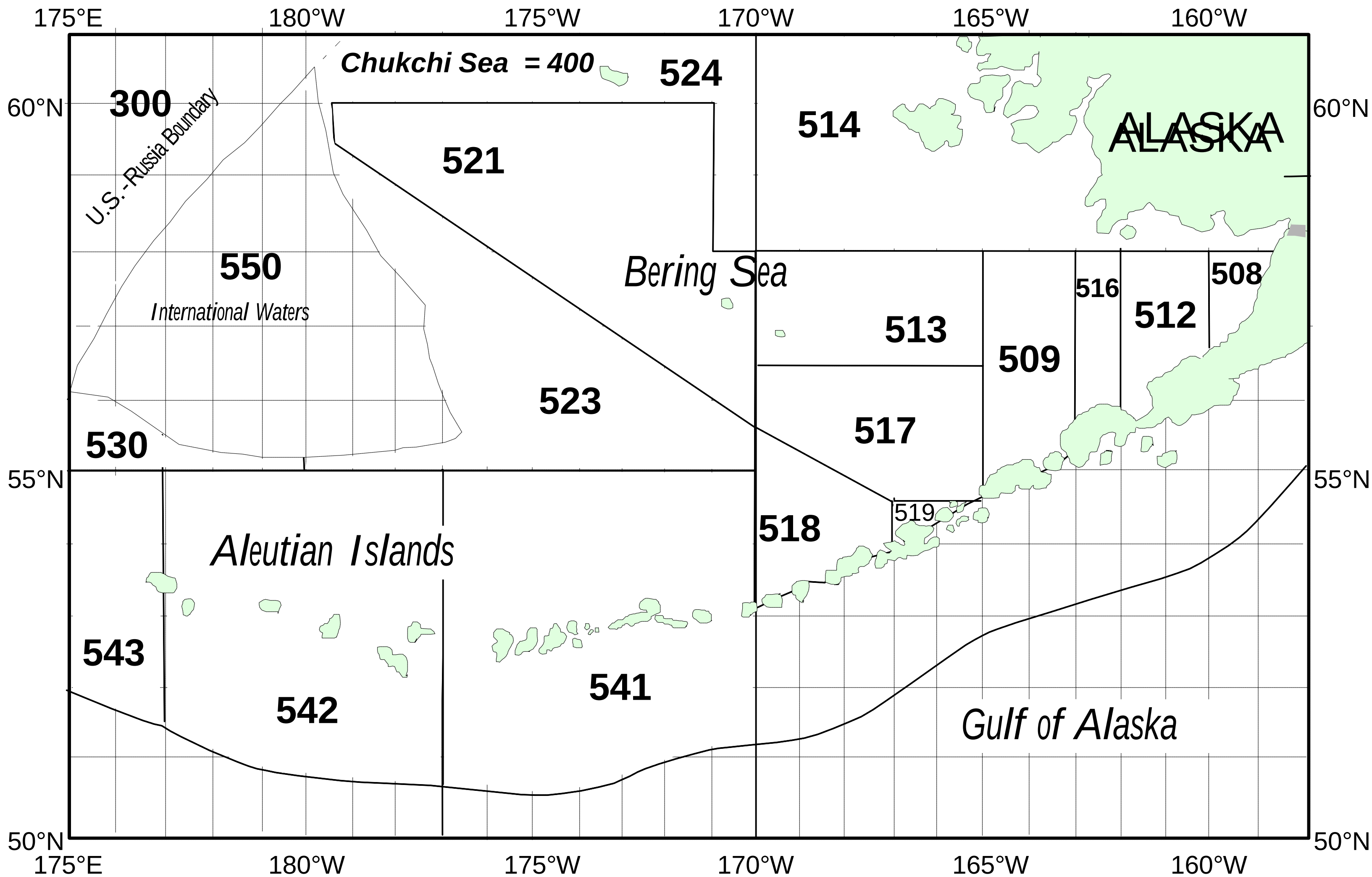


Figure 1 to Part 679. Bering Sea and Aleutian Islands statistical and reporting areas

a. Map

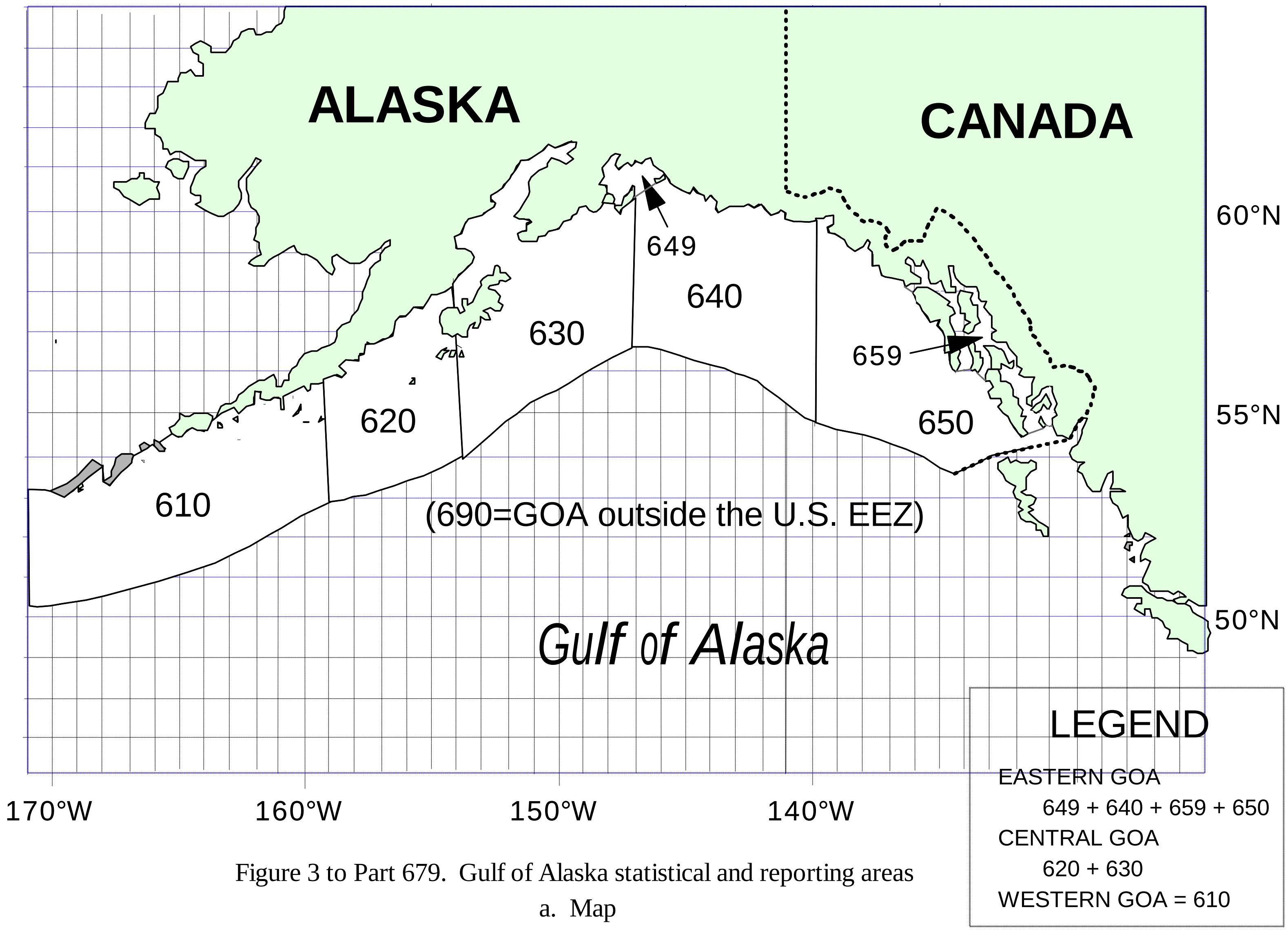
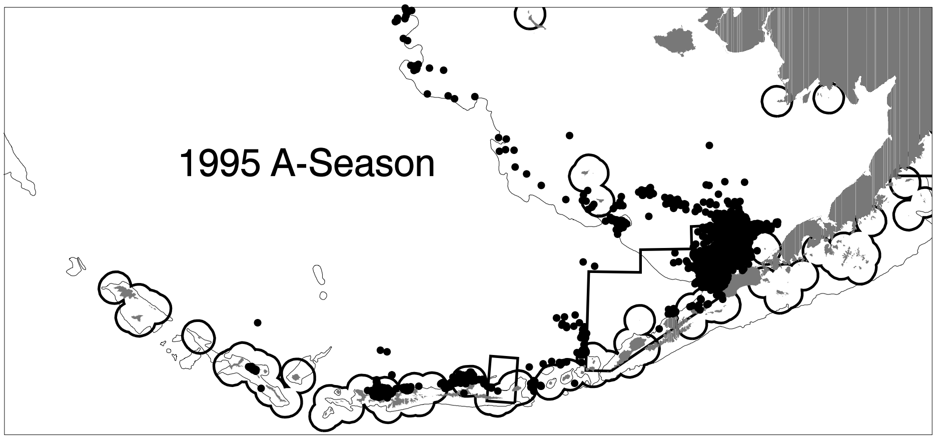
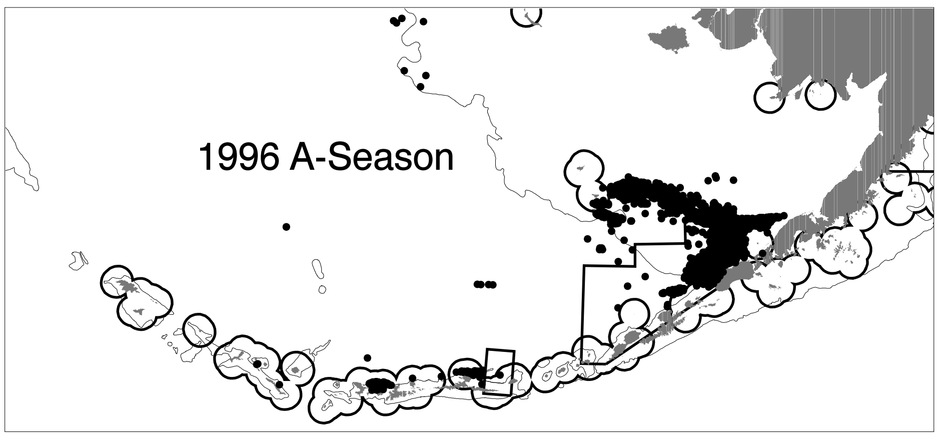
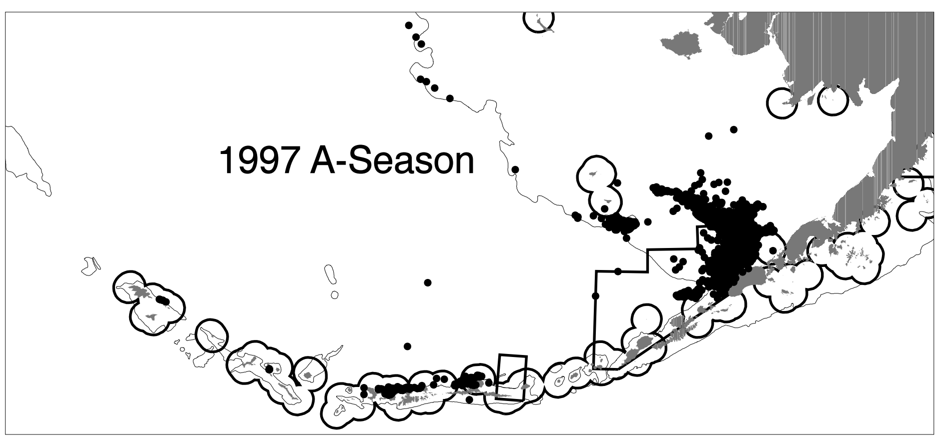


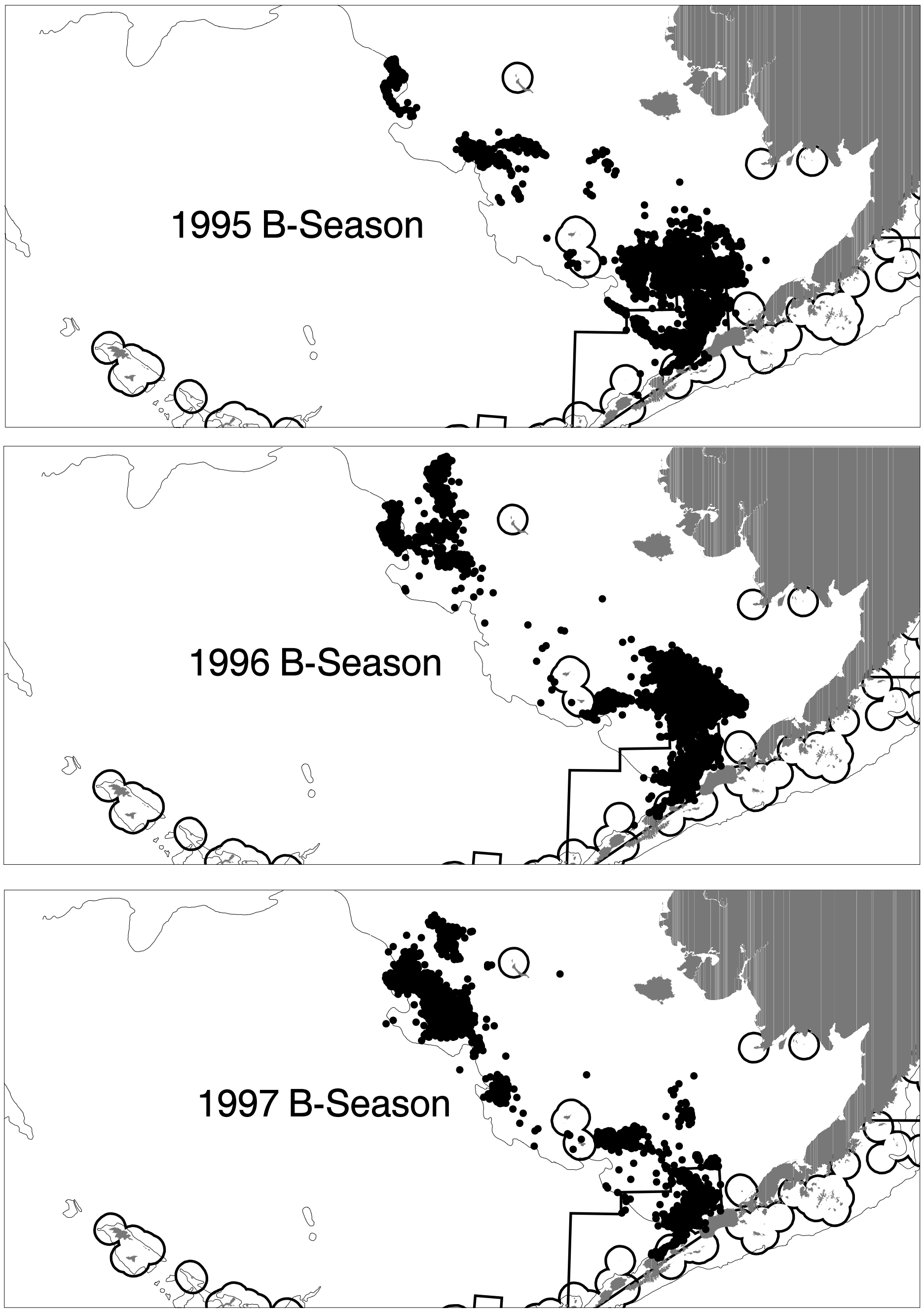
Figure 3 to Part 679. Gulf of Alaska statistical and reporting areas

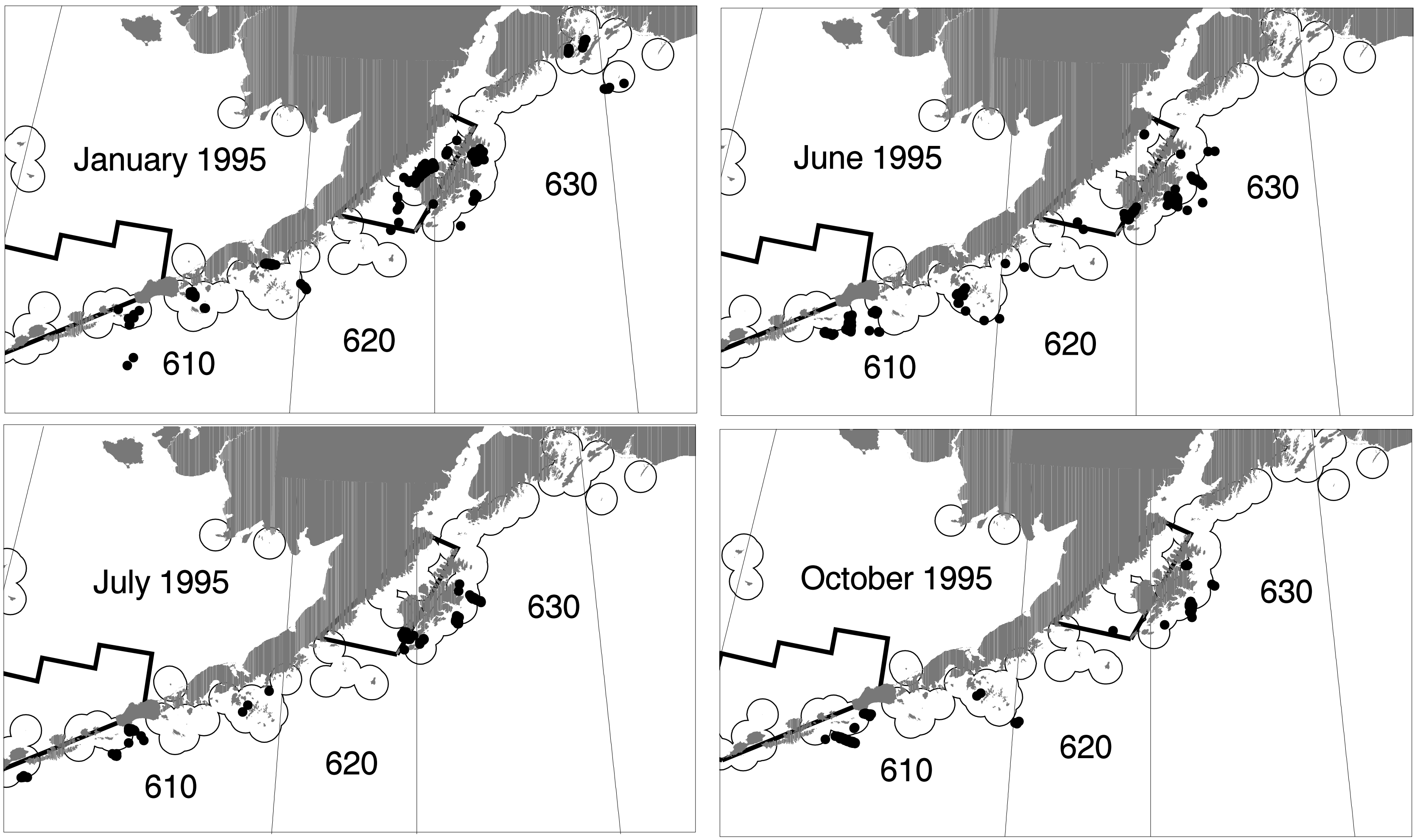
a. Map


1995 A-Season


1996 A-Season


1997 A-Season


1995 B-Season
1996 B-Season
1997 B-Season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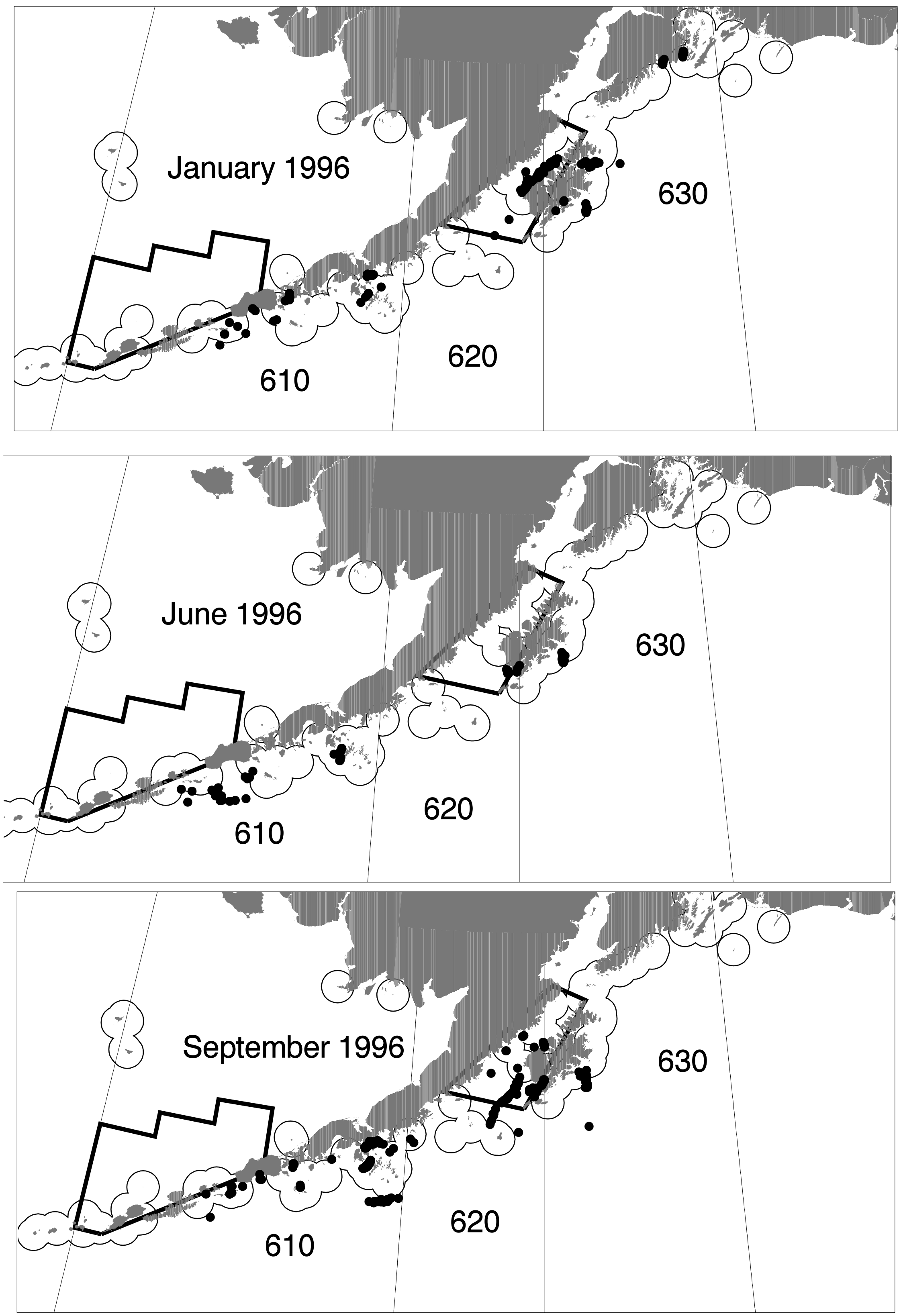
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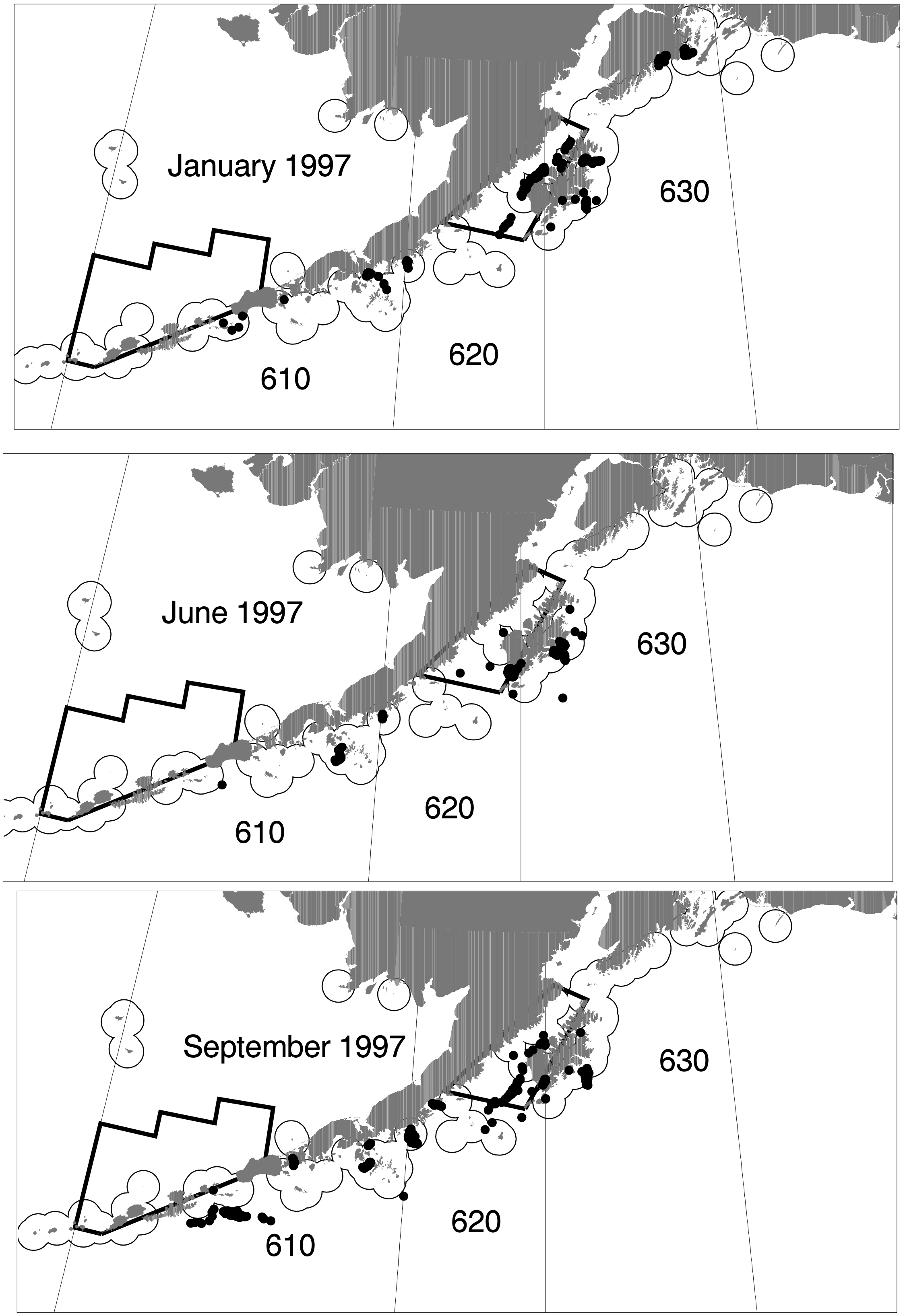
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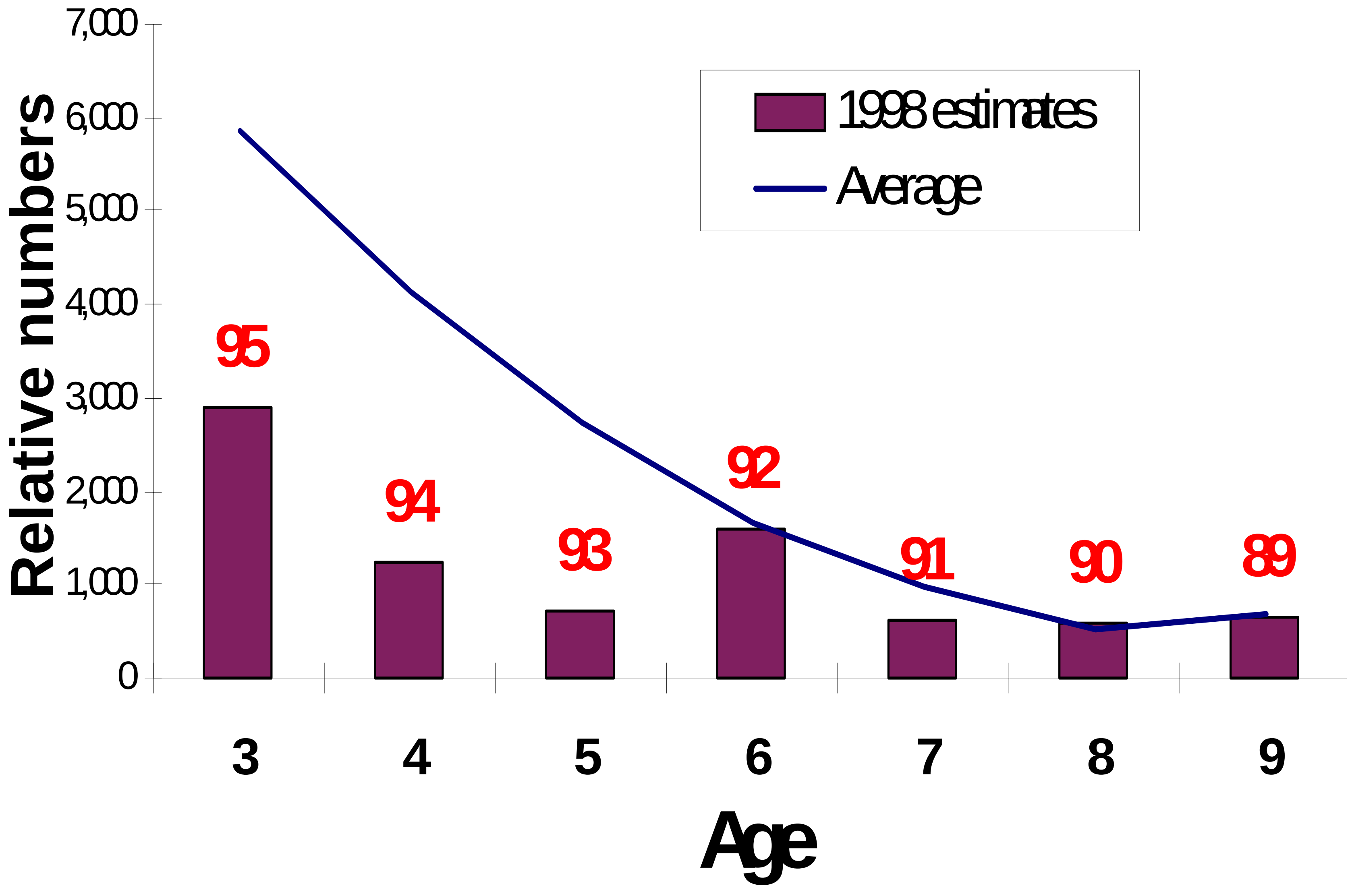


Figure 8. Projected 1998 age distribution (year classes noted on top of bars) and long-term average (solid line) for eastern Bering Sea pollock.

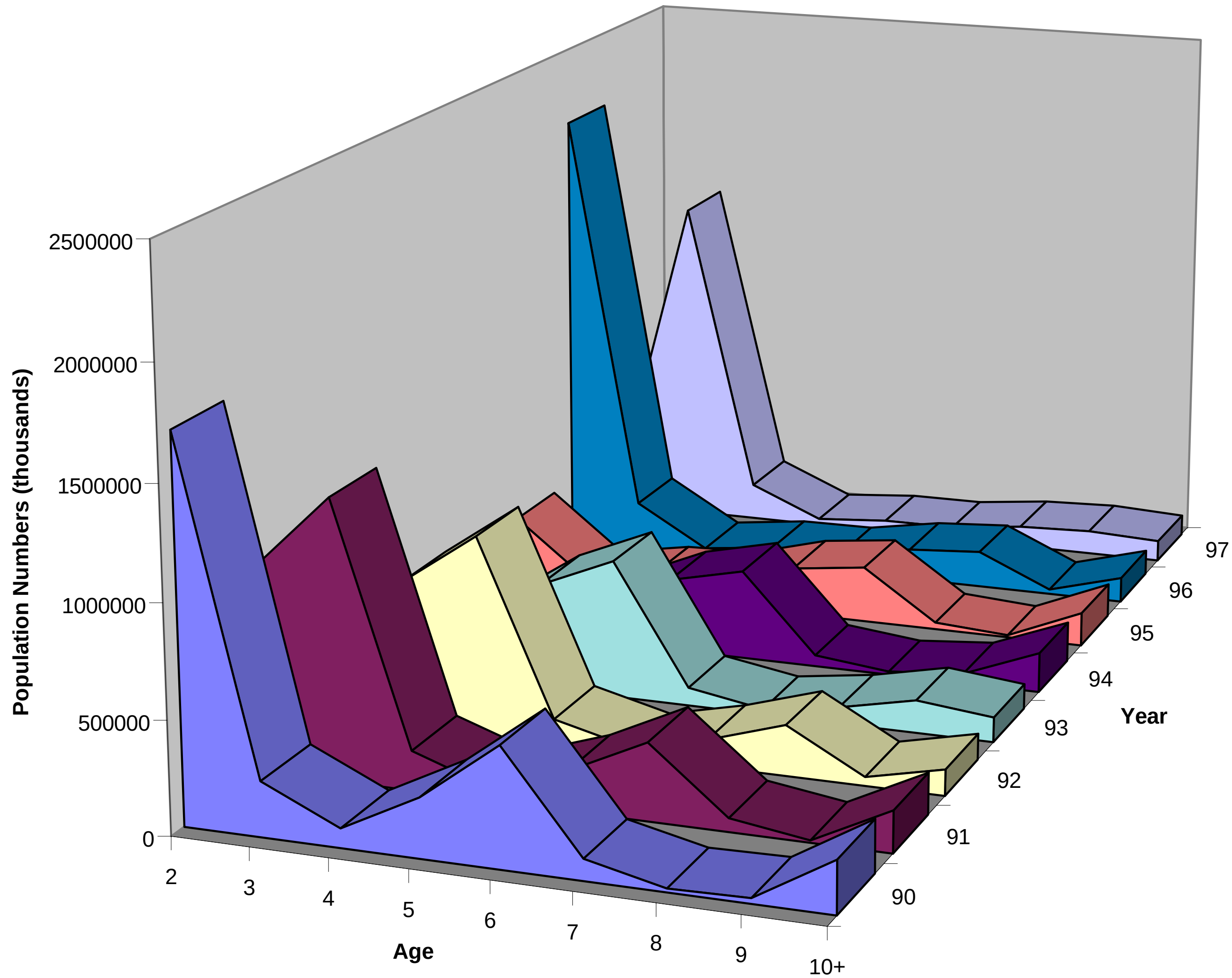


Figure 9. Estimated population numbers at age for walleye pollock in the western and central regulatory areas of the Gulf of Alaska, 1990 through 1997.

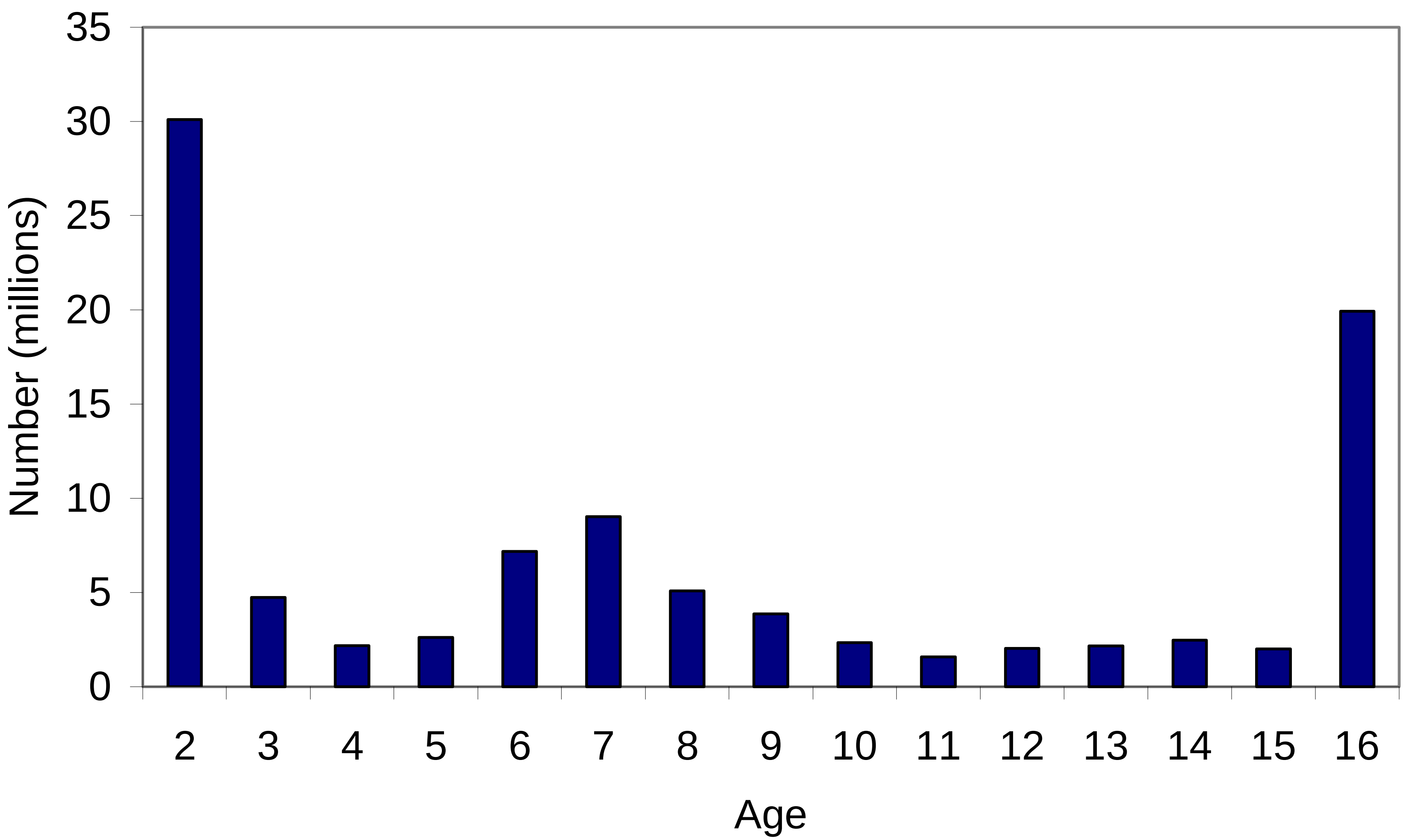


Figure 10. Estimated numbers (in millions) of sablefish at age in 1997. Ages 2 through 16+ are shown as these ages represent the recruited population, for which the best estimates of abundance exist.

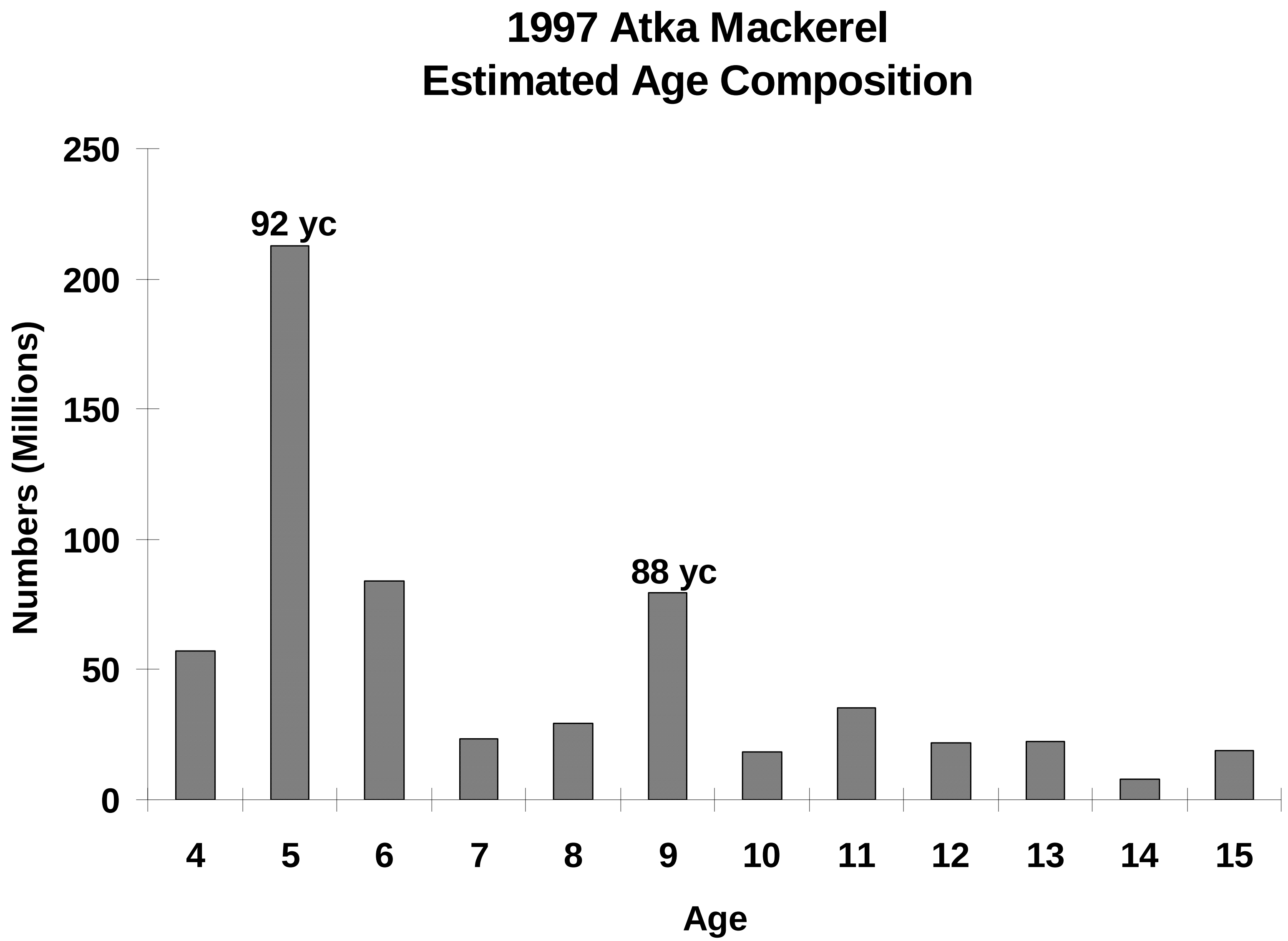


Figure 11. Estimated age composition of Bering Sea and Aleutian Islands Atka mackerel, 1997.

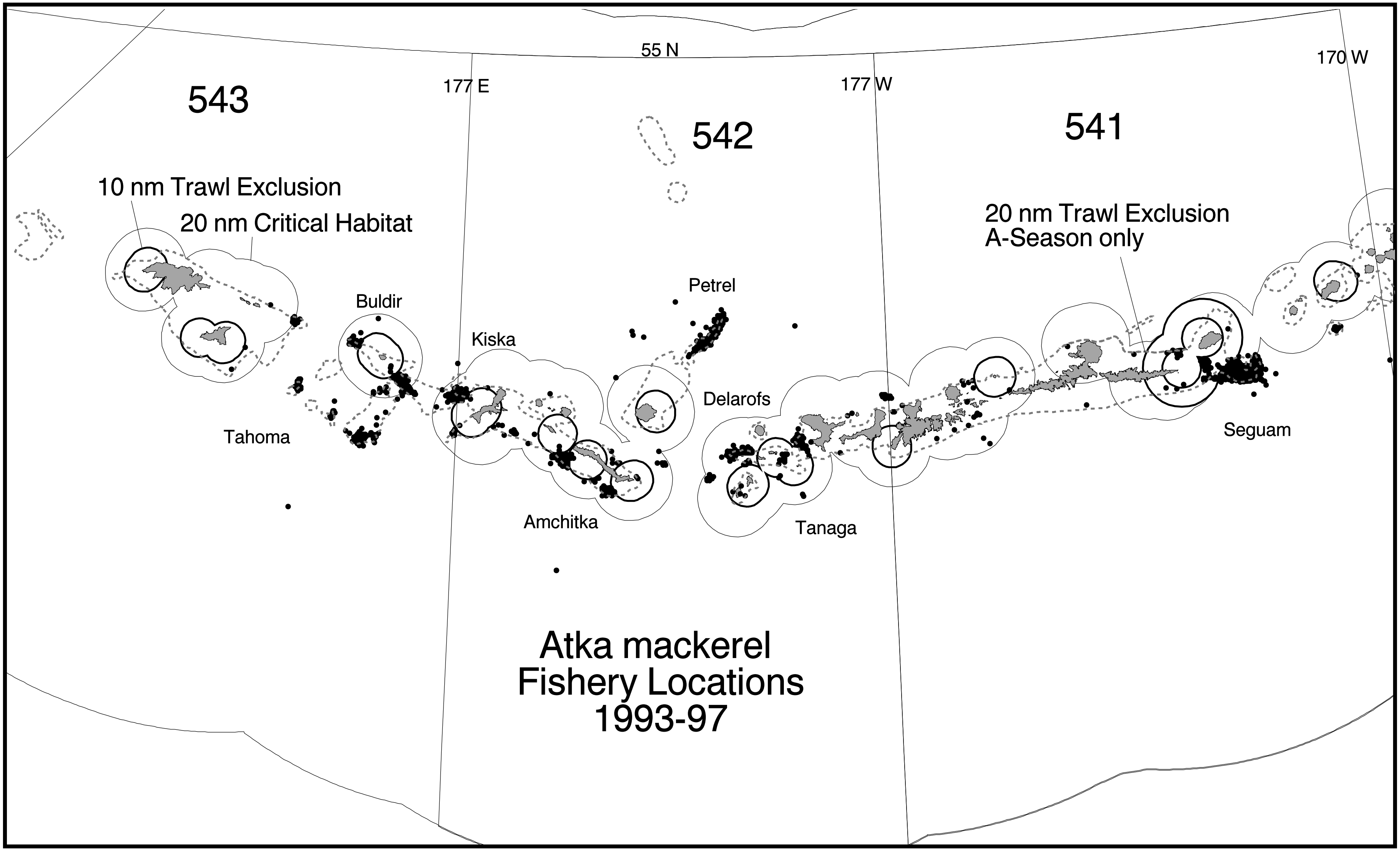


Figure 7. Atka mackerel fishery locations in the Aleutian Islands region in 1993-97. Trawl exclusion zones, Steller sea lion critical habitat zones around rookeries and haulouts, the 200 m isobath, management areas 541-543, and names of locations used by the fishery are shown.

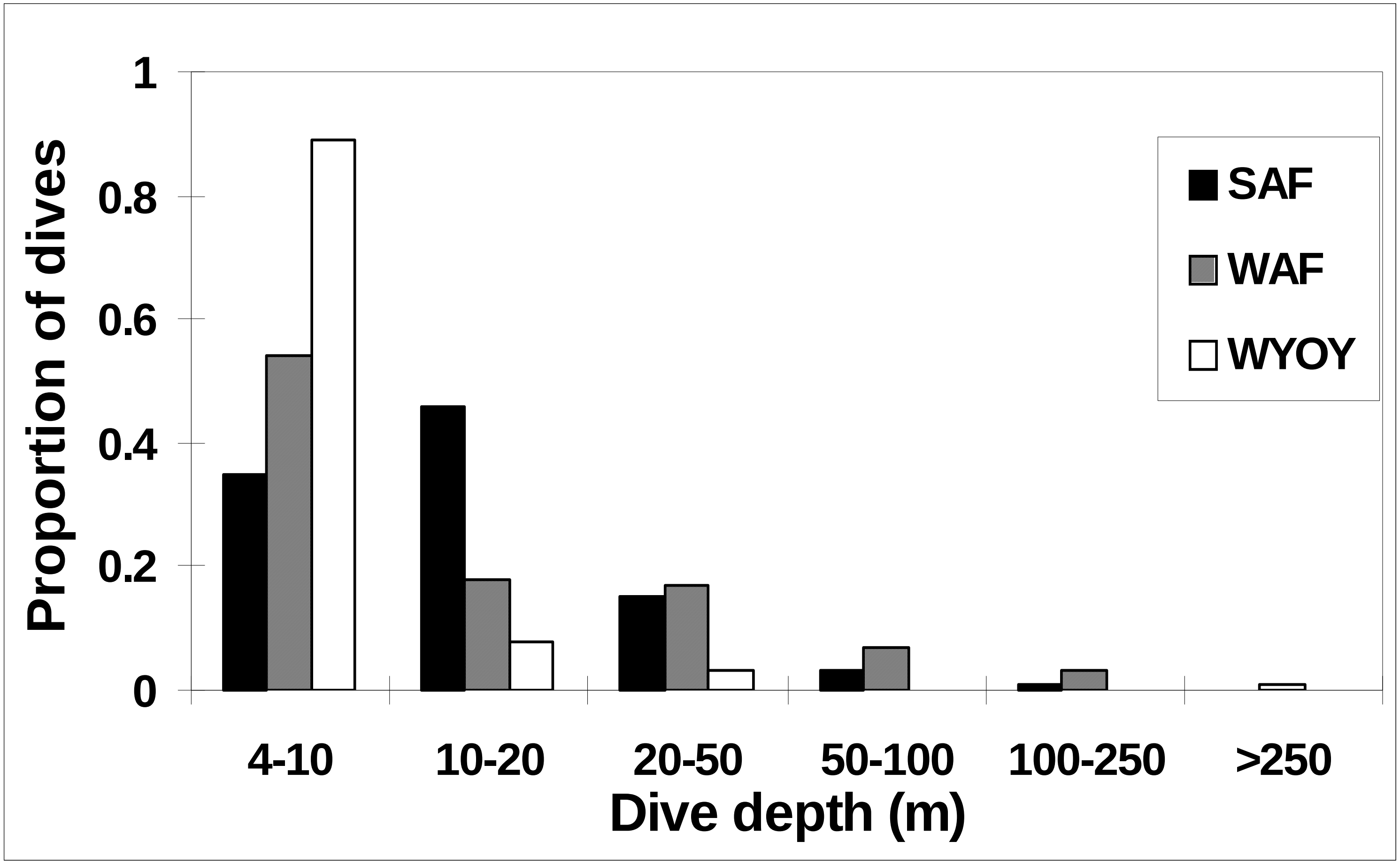


Figure 13. Proportion of dives by depth range for young-of-the-year (WYOY) and adult female Steller sea lions in summer (SAF) and winter (WAF) tracked during 1990-1993 (from Merrick and Loughlin 1997).

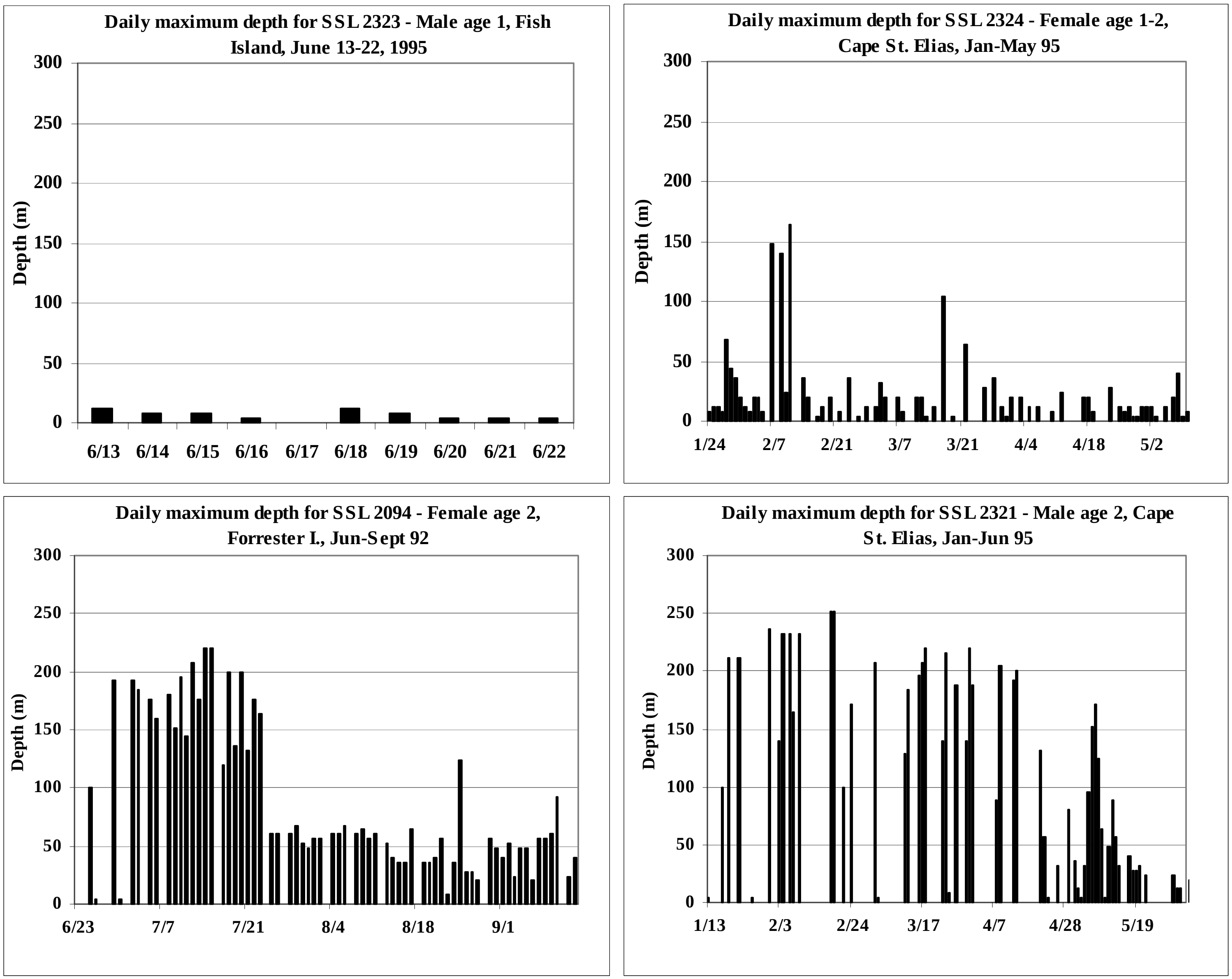


Figure 14. Maximum daily dive depths for four juvenile Steller sea lions (based on data from U. Swain, Alaska Department of Fish and Game).

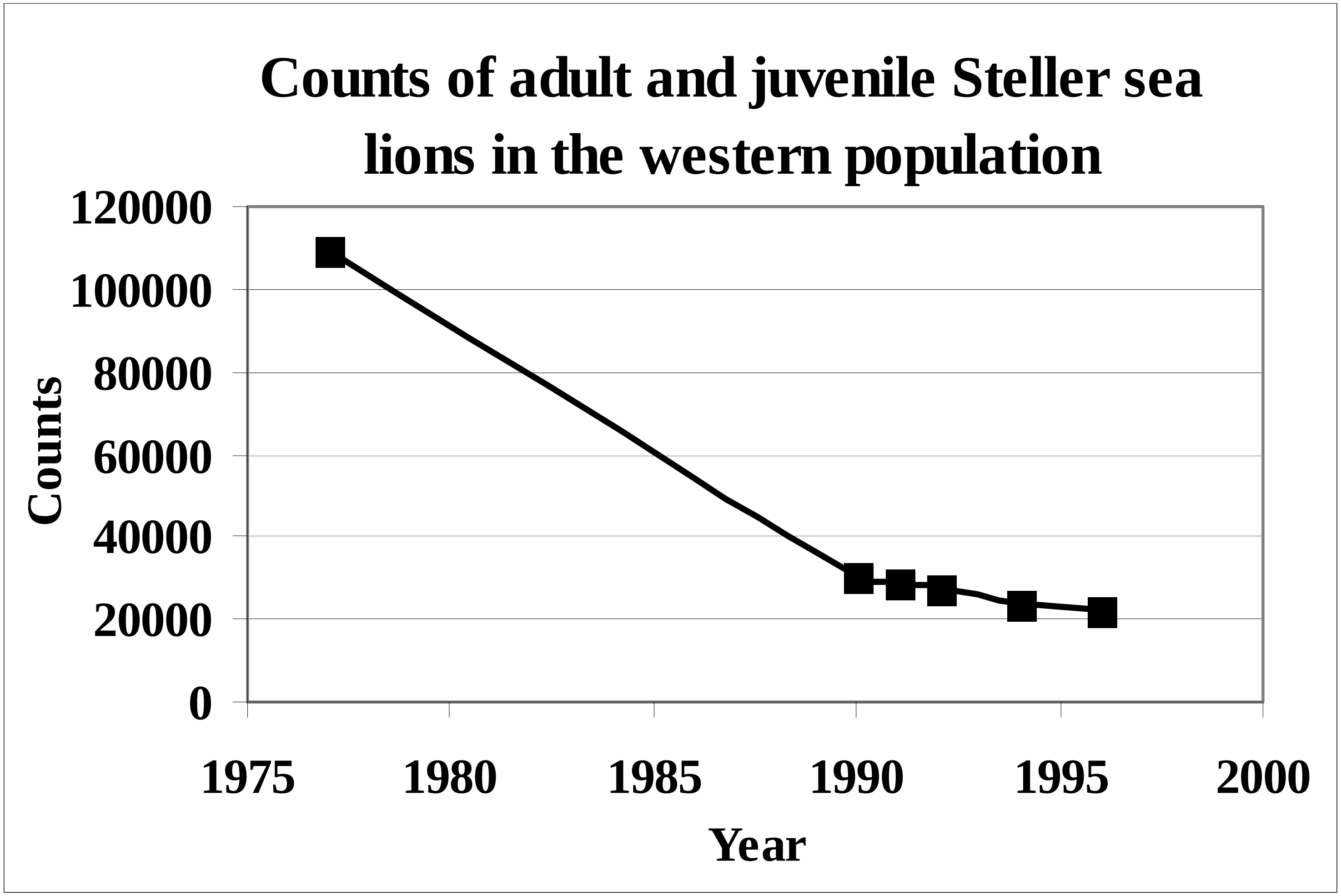


Figure 15. Counts of adult and juvenile Steller sea lions in the western population.

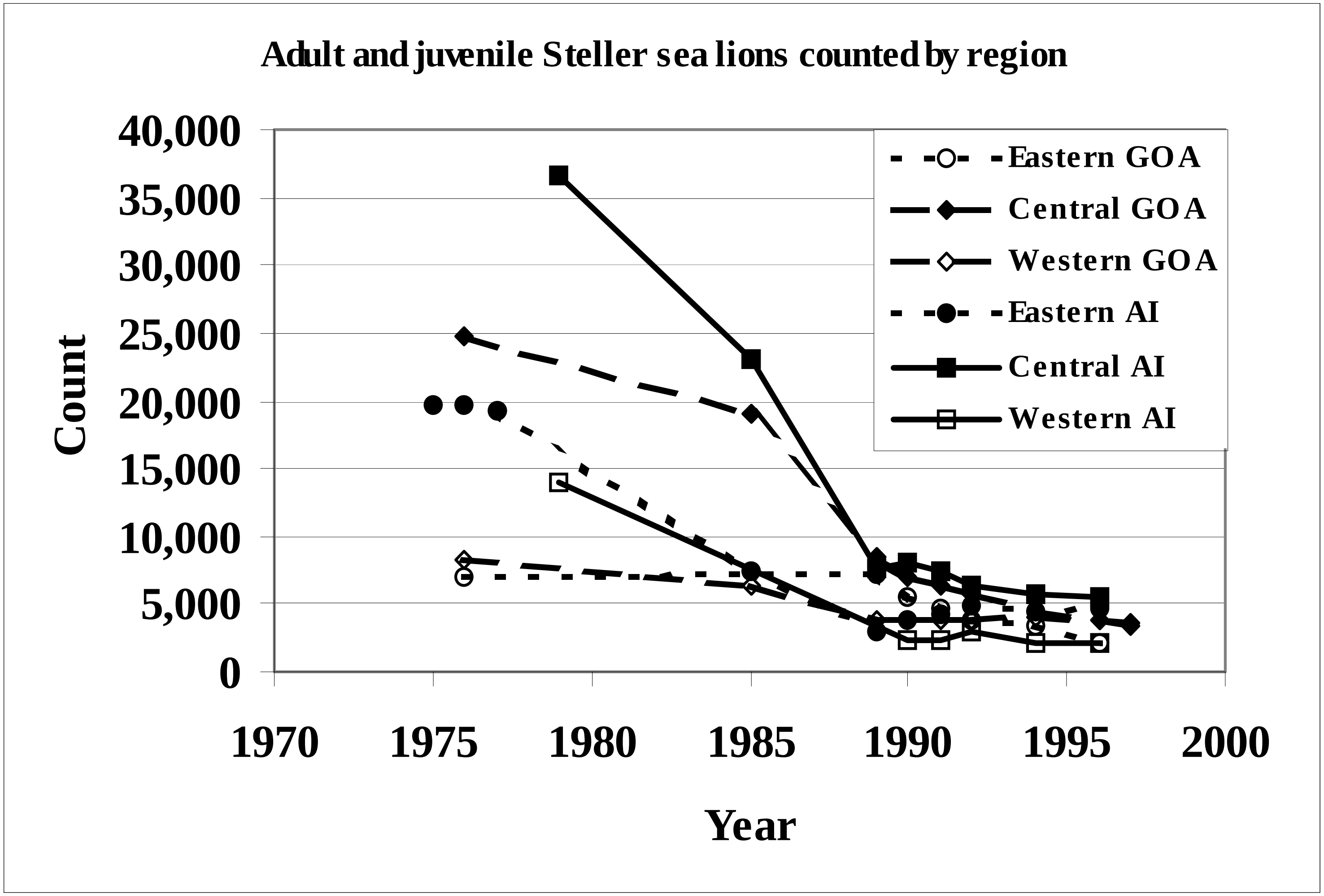
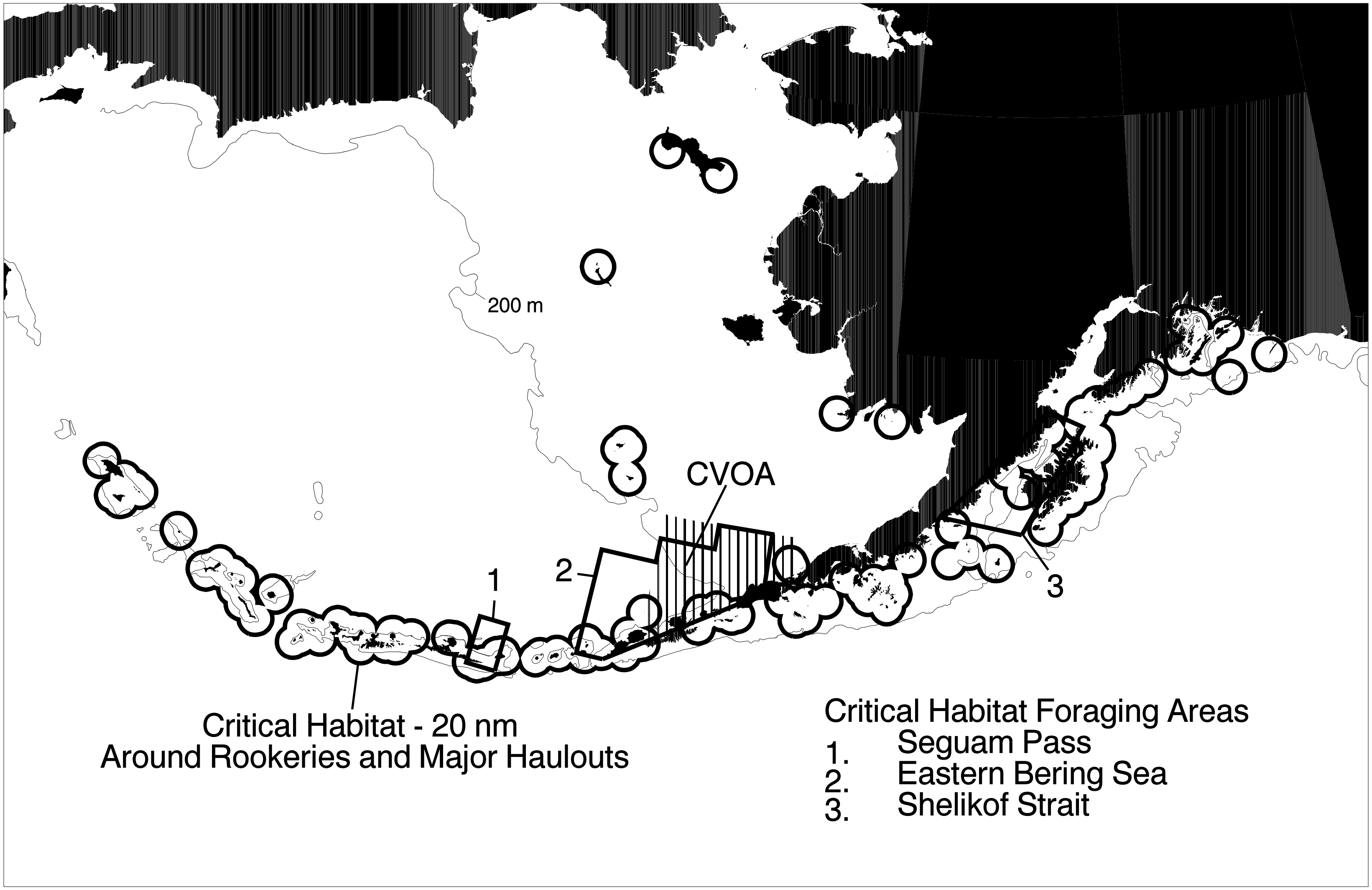


Figure 16. Counts by region of adult and juvenile Steller sea lions in the western population.



200 m
CVOA
1
2
3
Critical Habitat - 20 nm
Around Rookeries and Major Haulouts
Critical Habitat Foraging Areas
1. Seguam Pass
2. Eastern Bering Sea
3. Shelikof Strait

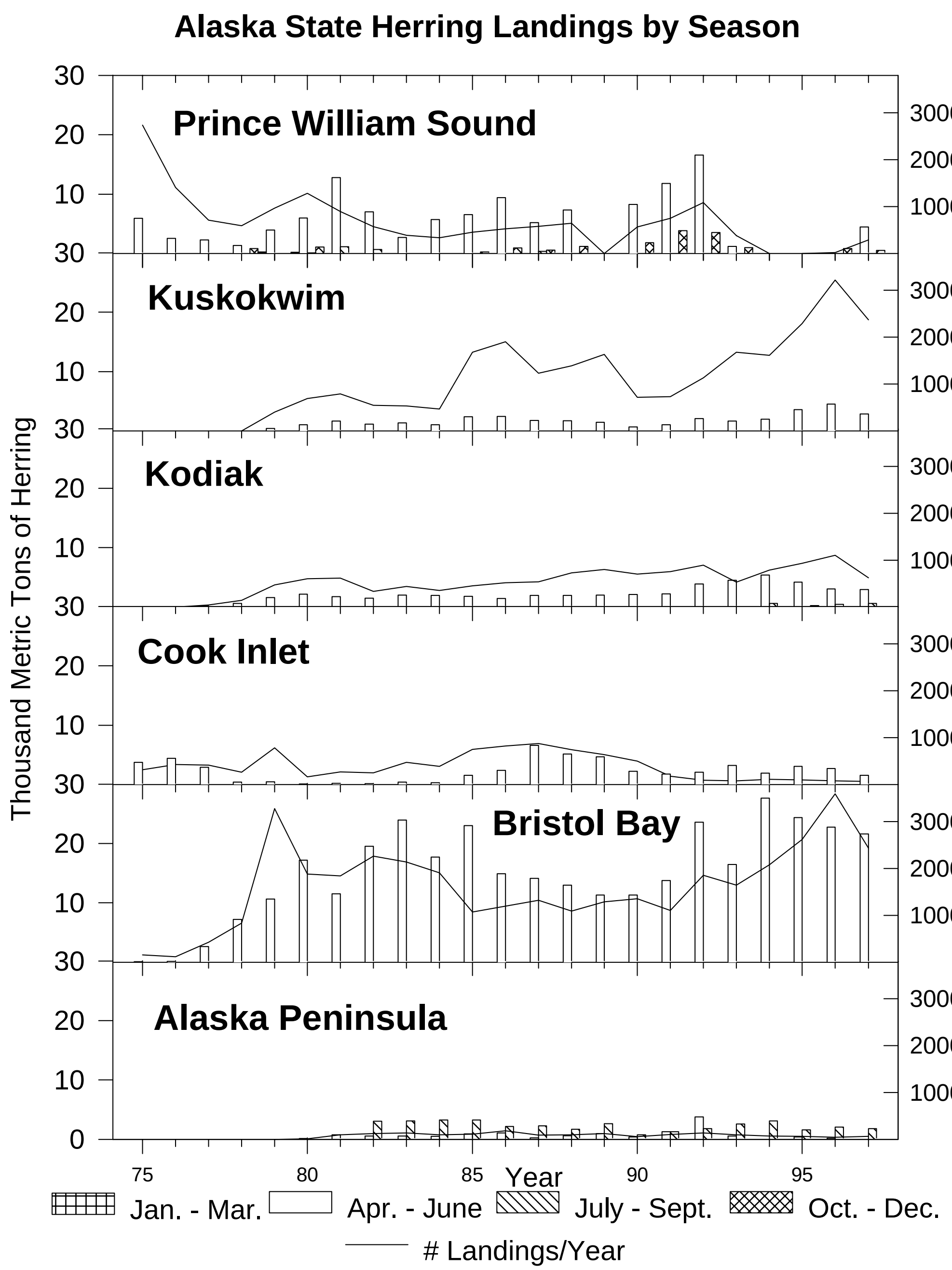


Figure 18a. Seasonal commercial catch of herring and annual number of landings in Alaska State waters. Bars indicate harvest amounts by 3-month seasons. The line indicates the number of landings/year (right axis), based on fish ticket data from the Alaska Department of Fish and Game.

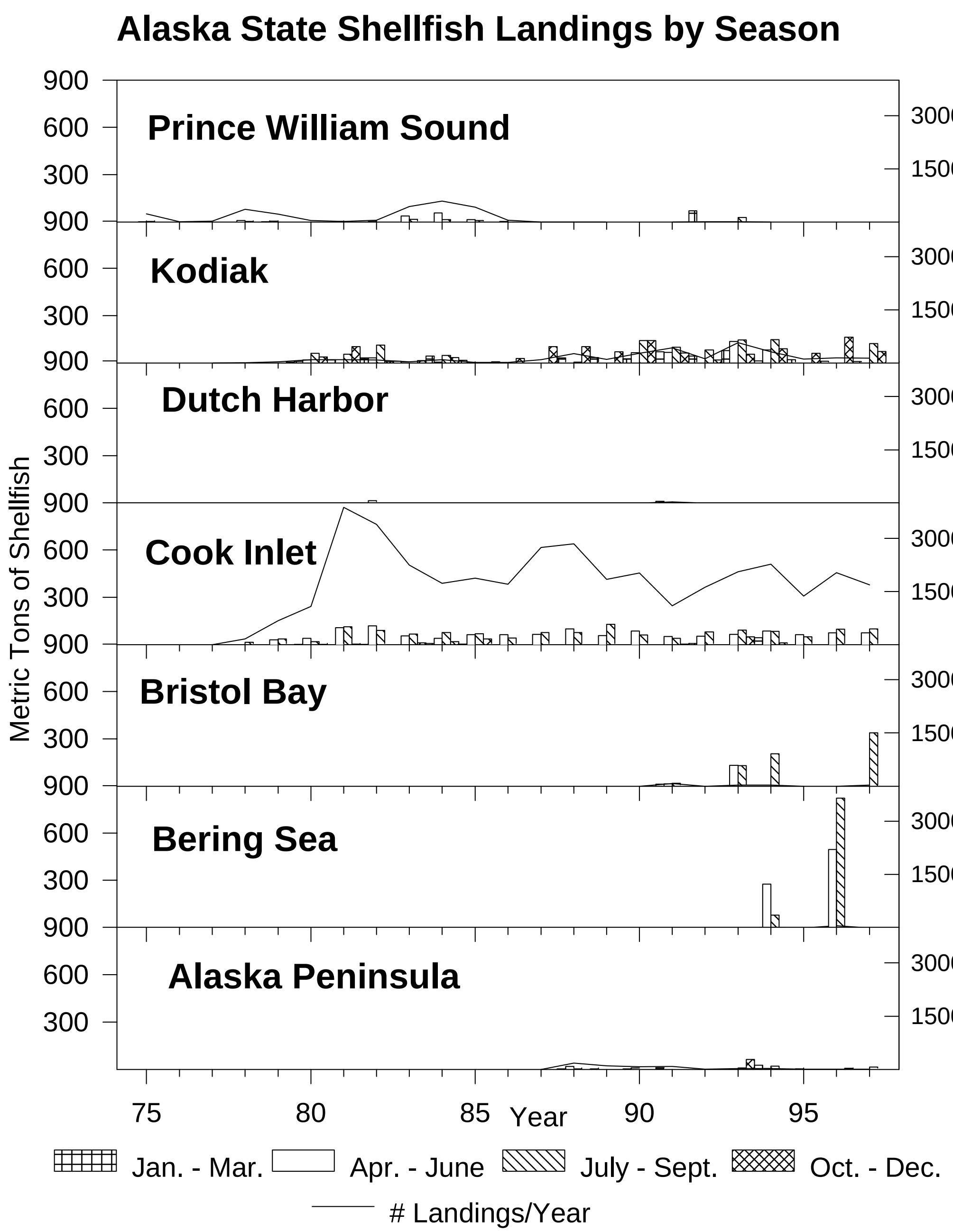


Figure 19a. Seasonal commercial catch of miscellaneous shellfish (excluding crab) and annual number of landings in Alaska State waters. Bars indicate harvest amounts by 3-month seasons. The line indicates the number of landings/year (right axis), based on fish ticket data from the Alaska Department of Fish and Game.

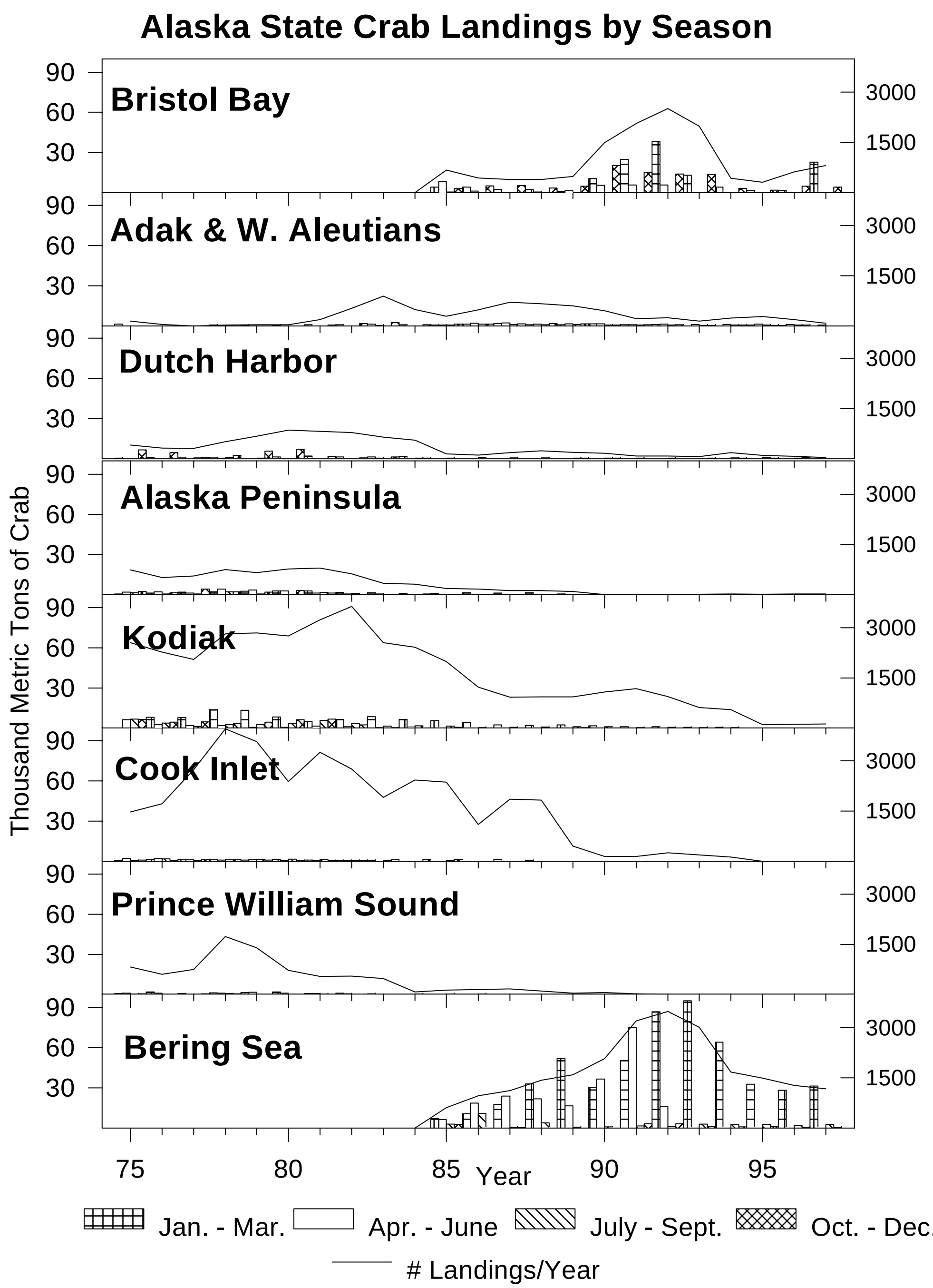


Figure 20a. Seasonal commercial catch of crab and annual number of landings in Alaska State waters. Bars indicate harvest amounts by 3-month seasons. The line indicates the number of landings/year (right axis), based on fish ticket data from the Alaska Department of Fish and Game.

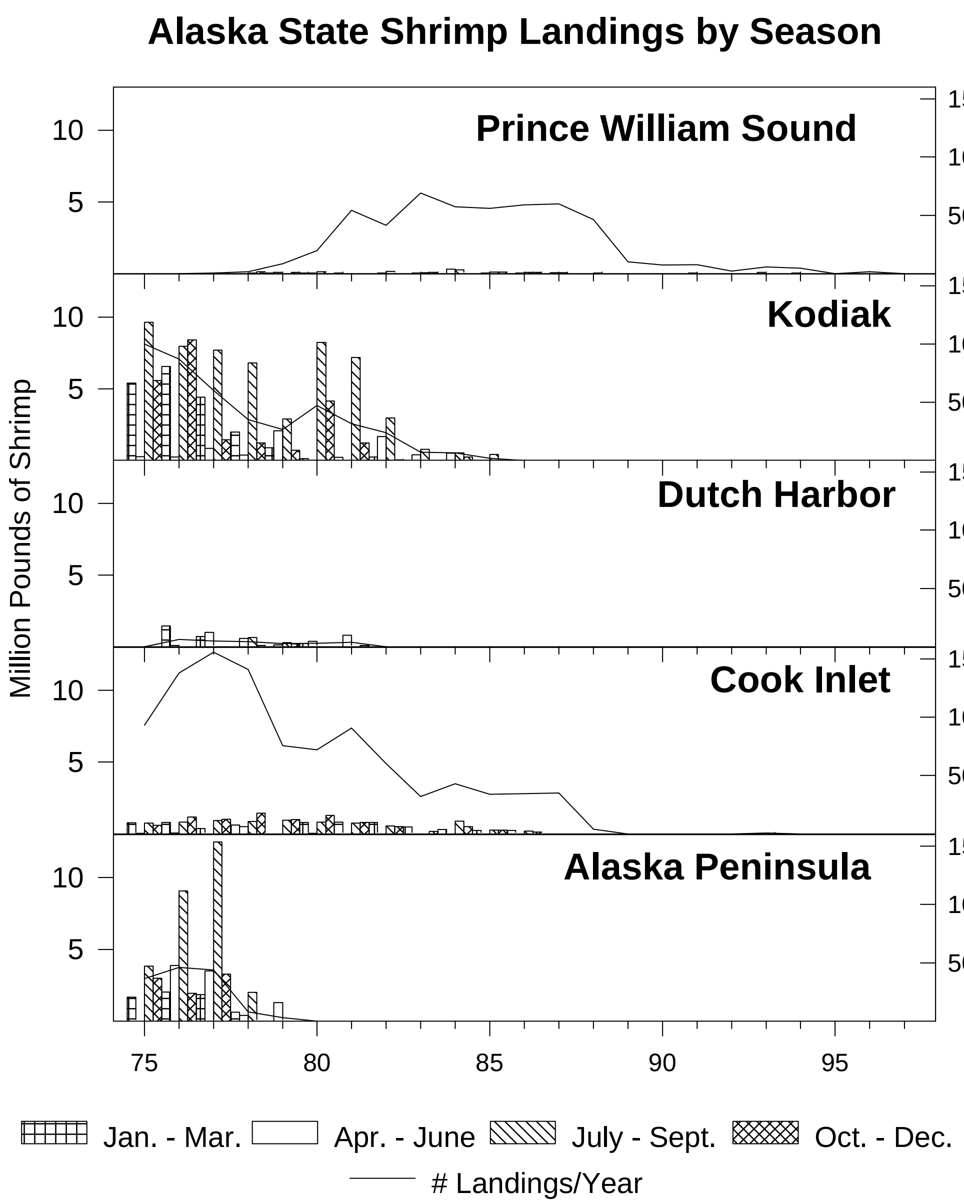


Figure 21a. Seasonal commercial catch of shrimp and annual number of landings in Alaskan waters other than in southeast Alaska or near Yakutat. Bars indicate harvest amounts by 3-month seasons. The line indicates the number of landings/year (right axis), based on fish ticket data from the Alaska Department of Fish and Game.

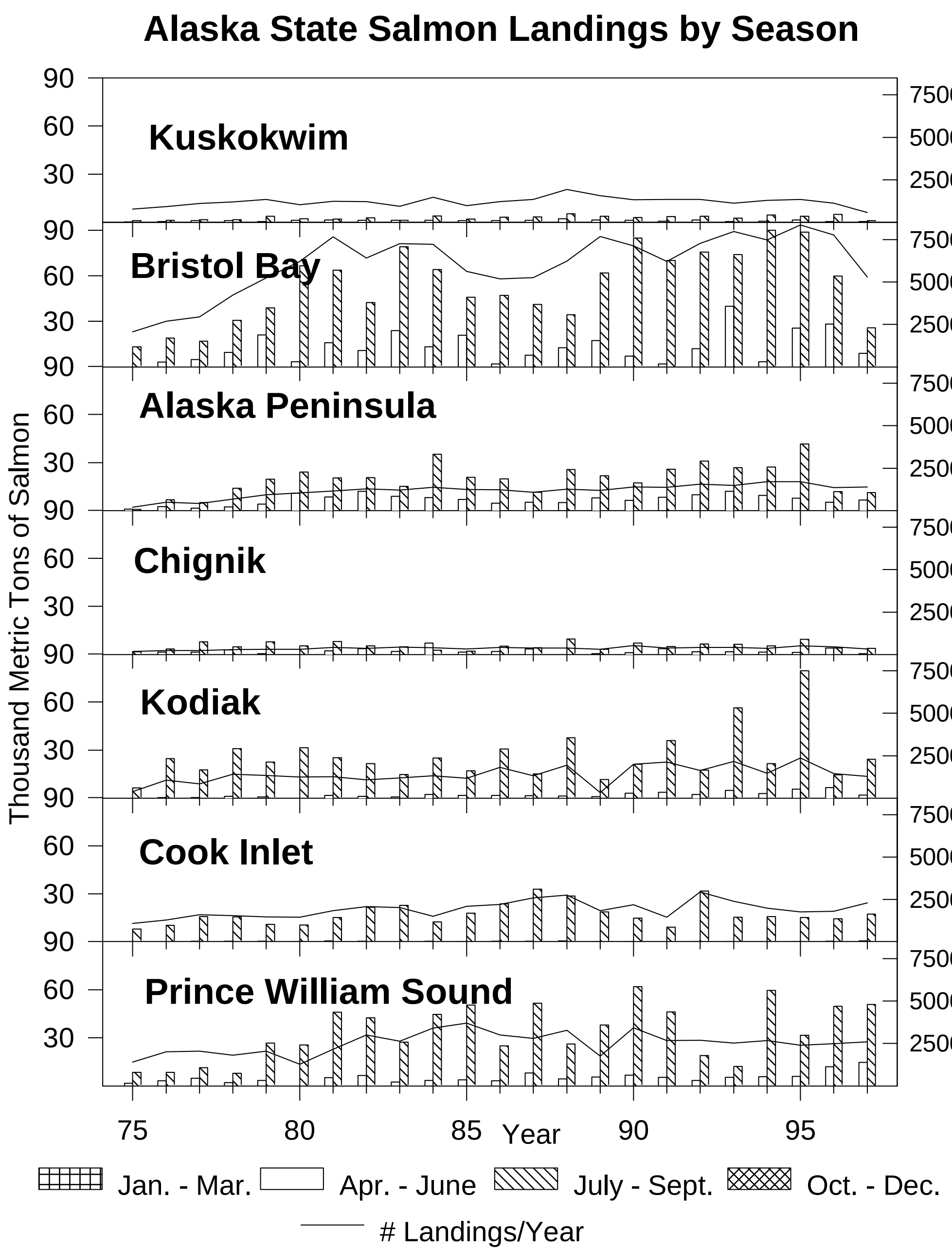


Figure 22a. Seasonal commercial catch of salmon and annual number of landings in Alaska State waters. Bars indicate harvest amounts by 3-month seasons. The line indicates the number of landings/year (right axis), based on fish ticket data from the Alaska Department of Fish and Game.