UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
West Coast Region
1201 NE Lloyd Boulevard, Suite 1100
PORTLAND, OR 97232-1274

Refer to NMFS No:
WCRO-2020-02569

May 3, 2024

Julie K. Turner
Manager
Pacific Northwest Site Office
U.S. Department of Energy
P.O. Box 350, K9-42
Richland, Washington 99352

Re: Endangered Species Act Section 7(a)(2) Biological Opinion, Conference Opinion, and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the Pacific Northwest National Laboratory Research Activities Programmatic (PNNL RAP)

Dear Ms. Turner:

Please find below the Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion, Section 7(a)(4) conference opinion, and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat (EFH) Response for PNNL Sequim Bay and Strait of Juan de Fuca Research Activities Programmatic Consultation (PNNL RAP).

In this opinion, we conclude that the proposed programmatic action is not likely to jeopardize the continued existence of Puget Sound (PS) Chinook salmon (*Oncorhynchus tshawytscha*), Hood Canal summer-run (HCSR) chum (*O. keta*), PS steelhead (*O. mykiss*), Puget Sound/Georgia Basin (PS/GB) yelloweye rockfish (*Sebastes ruberrimus*), PS/GB bocaccio (*S. paucispinis*), southern distinct population segment (DPS) of green sturgeon (*Acipenser medirostris*), southern DPS of eulachon (*Thaleichthys pacificus*), southern resident killer whales (SRKW) (*Orcinus orca*), and Central America or Mexico DPSs of humpback whales (*Megaptera novaeangliae*), and will not result in the destruction or adverse modification to the applicable critical habitats.

The NMFS has not yet promulgated an ESA section 4(d) rule prohibiting take of threatened southern DPS of eulachon (hereafter, "eulachon"). However, consultation under section 7(a)(2) of the ESA is still required to evaluate whether or not the Federal action is likely to jeopardize the continued existence of listed species, or result in the destruction or adverse modification of designated critical habitat.

This programmatic opinion also includes a conference opinion (ESA Section 7(a)(4)) evaluating the effects of the proposed program of activities on sunflower sea stars (*Pycnopodia helianthoides*)[1]

[1] https://www.federalregister.gov/documents/2023/03/16/2023-05340/proposed-rule-to-list-the-sunflower-sea-star-as-threatened-under-the-endangered-species-act

We also reviewed the likely effects of the proposed action on EFH, pursuant to section 305(b) of the Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. 1855(b)). We concluded that the action would adversely affect the EFH of Pacific Coast groundfish, coastal pelagic species, and Pacific Coast salmon. Therefore, we have included the results of that review in Section 3 of this document.

Sincerely,

Kim W. Kratz. Ph.D
Assistant Regional Administrator
Oregon Washington Coastal Office

cc: Ioana Bociu, PNNL
Tom McDermott, PNNL
Corey A Duberstein, PNNL

Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion, Section (a)(4) Conference Opinion, and Magnuson–Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the

Pacific Northwest National Laboratory
Research Activities Programmatic
(PNNL RAP)

NMFS Consultation Number: WCRO-2020-02569

Action Agency: U.S. Department of Energy

Affected Species and NMFS' Determinations:

ESA-Listed Species	Status	Is Action Likely to Adversely Affect Species?	Is Action Likely to Jeopardize the Species?	Is Action Likely to Adversely Affect Critical Habitat?	Is Action Likely to Destroy or Adversely Modify Critical Habitat?
Puget Sound Steelhead	Threatened	Yes	No	N/A	N/A
Puget Sound Chinook salmon	Threatened	Yes	No	Yes	No
Hood Canal Summer-run Chum salmon	Threatened	Yes	No	Yes	No
Puget Sound/Georgia Basin Yelloweye Rockfish	Threatened	Yes	No	Yes	No
Puget Sound/Georgia Basin Bocaccio	Endangered	Yes	No	Yes	No
Eulachon, Southern DPS	Threatened	Yes	No	N/A	N/A
Green Sturgeon, Southern DPS	Threatened	Yes	No	Yes	No
Southern Resident Killer whale	Endangered	Yes	No	Yes	No
Humpback Whale Central American DPS	Endangered	Yes	No	N/A	N/A
Humpback Whale Mexico DPS	Threatened	Yes	No	N/A	N/A
Conference					
Sunflower sea star	Proposed	Yes	No	N/A	N/A

Fishery Management Plan That Identifies EFH in the Project Area	Does Action Have an Adverse Effect on EFH?	Are EFH Conservation Recommendations Provided?
Pacific Coast Salmon	Yes	Yes
Pacific Groundfish	Yes	Yes
Coastal Pelagic Species	Yes	Yes

Consultation Conducted By: National Marine Fisheries Service
West Coast Region

Issued By:

Kim W. Kratz, Ph.D.
Assistant Regional Administrator
Oregon Washington Coastal Office

Date: May 3, 2024

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1. INTRODUCTION

This Introduction section provides information relevant to the other sections of this document and is incorporated by reference into Sections 2 and 3, below.

1.1 Background

The National Marine Fisheries Service (NMFS) prepared this programmatic biological opinion, conference opinion, and incidental take statement (ITS) portion of this document in accordance with section 7(b) of the Endangered Species Act (ESA) of 1973 (16 U.S.C. 1531 et seq.), and implementing regulations at 50 CFR 402, as amended.

Per 50 CFR § 402.10, we have also completed a conference opinion on the sunflower sea star as it is currently a species proposed for listing under the ESA. An opinion issued at the conclusion of the conference may be adopted as the biological opinion when the species is listed or critical habitat is designated, but only if no significant new information is developed (including that developed during the rulemaking process on the proposed listing or critical habitat designation) and no significant changes to the Federal action are made that would alter the content of the opinion. Hereafter, the combination of the biological opinion and conference opinion are referred to as a singular “Opinion”.

We also completed an essential fish habitat (EFH) consultation on the proposed action, in accordance with section 305(b)(2) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) (16 U.S.C. 1801 et seq.) and implementing regulations at 50 CFR Part 600.

For many years, NMFS has completed programmatic ESA and EFH consultations to address collections of routine activities that may affect listed species and critical habitat in the Pacific Northwest. These programmatic consultations have addressed activities such as habitat restoration, transportation projects such as road-stream crossing improvement, and the construction, replacement, or repair of over-water structures. The activity categories covered by programmatic consultations must be clearly described and their implementation subject to specific performance and design criteria such that their aggregate effects are predictable. Otherwise, NMFS cannot do a meaningful analysis to support conclusions made in these programmatic consultations. Indeed, with all consultations, NMFS must be able to reliably ascertain effects but, with programmatic consultations, the fact that we do not know the site-specific details of all the activities that will occur makes it especially important that the parameters of the programmatic are clear and well understood, i.e., what falls within the action and what does not. That clarity allows us to reliably predict and then analyze the effects of activities that fall within the covered activity categories.

During development of programmatic consultations, NMFS typically works with the action agency, providing technical assistance on the development of the specific performance and design criteria for the covered activity categories. These criteria function to describe and limit the activities and their effects to those that are well understood and predictable and thus allow for a meaningful analysis. The criteria are what make the programmatic suite of activities appropriate for ESA/MSA consultation.

We completed pre-dissemination review of this document using standards for utility, integrity, and objectivity in compliance with applicable guidelines issued under the Data Quality Act (DQA) (section 515 of the Treasury and General Government Appropriations Act for Fiscal Year 2001, Public Law 106-554). The document will be available at the NOAA Library Institutional Repository [https://repository.library.noaa.gov/welcome]. A complete record of this consultation is on file at Oregon Washington Coastal Office.

1.2 Consultation History

On January 27, 2016, NMFS issued a letter of concurrence (WCR-2015-3761) for a minor suite of research activities within Sequim Bay. Between 2015 and 2022 multiple addendums to WCRO-2015-3761 and separate, but related, activity consultations have been completed (Dungeness Spit Mapping WCRO-2018-8853, Clallam Bay Mapping WCRO-2018-10566, Aquatic Sound Source WCRO-2018-11181, and Triton Initiative WCRO-2020-01218).

On May 31, 2019, NMFS and the Department of Energy's (DOE) Pacific Northwest National Laboratory (PNNL) met in NMFS Lacey Office to discuss a potential programmatic once the WCRO-2015-3761 consultation had run its five-year course.

On September 16, 2020, PNNL requested formal consultation. Over several meetings DOE/PNNL, U.S. Fish and Wildlife Service (FWS), and NMFS worked together to describe the proposed activities project performance and design criteria. On August 24, 2023, PNNL resubmitted a more inclusive programmatic biological assessment to NMFS. The action agency determined that activities carried out under PNNL Research Activities Programmatic (RAP) may affect and are likely to adversely affect (LAA), not likely to adversely affect (NLAA), or no effect (NE), the following listed species and critical habitat:

1. Puget Sound (PS) Chinook salmon (*Oncorhynchus tshawytscha*)
    a. Species: LAA
    b. Critical habitat: NLAA
2. Hood Canal summer-run (HCSR) chum salmon (*O. keta*)
    a. Species: LAA
    b. Critical habitat: NLAA
3. PS steelhead (*O. mykiss*)
    a. Species: LAA
    b. Critical habitat: NE
4. North American Green Sturgeon (*Acipenser medirostris*)
    a. Species: LAA
    b. Critical habitat: NLAA
5. Pacific Eulachon (*Thaleichthys pacificus*)
    a. Species: LAA
    b. Critical habitat: NE
6. Puget Sound/Georgia Basin (PSGB) yelloweye rockfish (*Sebastes ruberrimus*)
    a. Species: LAA
    b. Critical habitat: NLAA

7. PSGB bocaccio (*S. paucispinis*)
    a. Species: LAA
    b. Critical habitat: NLAA
8. Southern Resident Killer Whales (SRKW) (*Orcinus orca*)
    a. Species: LAA
    b. Critical habitat: NLAA
9. Humpback Whale (*Megaptera novaeanrliae*) (both DPSs)
    a. Species: LAA
    b. Critical habitat: NLAA
10. Conference: Sunflower sea stars (*Pycnopodia helianthoides*)
    a. Species: NLAA
    b. Critical habitat: Not designated

The NMFS presents its effects determinations in the table above, on the cover page of this opinion. On December 5, 2023, consultation was initiated. The No Effect critical habitats are not included for analysis in this document. NMFS did not concur with the NLAA determinations on critical habitat for yelloweye, bocaccio, SRKW, or the humpback DPSs.

On July 5, 2022, the U.S. District Court for the Northern District of California issued an order vacating the 2019 regulations that were revised or added to 50 CFR part 402 in 2019 ("2019 Regulations," see 84 FR 44976, August 27, 2019) without making a finding on the merits. On September 21, 2022, the U.S. Court of Appeals for the Ninth Circuit granted a temporary stay of the district court's July 5 order. On November 14, 2022, the Northern District of California issued an order granting the government's request for voluntary remand without vacating the 2019 regulations. The District Court issued a slightly amended order two days later on November 16, 2022. As a result, the 2019 regulations remain in effect, and we are applying the 2019 regulations here. For purposes of this consultation and in an abundance of caution, we considered whether the substantive analysis and conclusions articulated in this programmatic opinion and incidental take statement would be any different under the pre-2019 regulations. We have determined that our analysis and conclusions would not be any different.

1.3 Proposed Federal Action

Under the ESA, "action" means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by federal agencies (50 C.F.R. 402.02). Under MSA, federal action means any action authorized, funded, or undertaken, or proposed to be authorized, funded or undertaken by a federal agency (50 CFR 600.910). For purposes of this programmatic consultation, the Action Agency is the DOE, and the activities are those proposed by applicants seeking authorization under ESA and MSA.

The DOE, through PNNL, proposes to perform 13 categories of research activity related to renewable energy development and its impacts on marine life, development of technologies and systems to monitor changes in the marine environment, underwater materials detection technology development, marine and coastal resources, environmental chemistry, water resources modeling, ecotoxicology, biotechnology, and national security. Research activities would occur within Sequim Bay and the adjacent portion of the Strait of Juan de Fuca between Dungeness Spit and Protection Island. The research areas are described in more detail in Section

2.3, below. Potential research activities include placement of instruments on the water surface, water column, or substrate; sampling of environmental media; development of detection and monitoring technologies based on acoustics and LiDAR; use of autonomous vehicles for sample collection and monitoring; and testing, evaluation, and monitoring of small-scale hydrokinetic devices.

The PNNL RAP is a program developed by NMFS and the DOE for programmatic ESA and MSA consultation. Programmatic consultations include a set of activity categories and specifies performance and design criteria for those activities that, when implemented: (1) help avoid and minimize adverse effects of activities that fall in the covered categories on listed species and their critical habitat; (2) provide parameters for eligible activities and their effects to enable the agencies to provide an analysis of the effects of these activities that is predictable and foreseeable; and (3) ensure that activities, authorized or carried out, either individually or in total, do not jeopardize the continued existence of species listed under the ESA, adversely modify their designated critical habitat, and to minimize the adverse effects on EFH to the maximum extent practicable.

Projects covered by the PNNL RAP are limited to specific categories of activities. Further, this coverage only applies to projects if they comply with the Overarching Performance Criteria (OPC), associated activity specific project design criteria (PDC) and performance criteria/limits, and general construction measures (GCMs). Activities covered include temporary[2] installation of in-water or over-water structures (i.e., buoys, floats, seabed installations, etc.) and in-water and over-water research activities (autonomous vehicles, sediment sampling, acoustic research, etc.).

The proposed action for the PNNL RAP does *not* cover projects that result in a long-term loss of nearshore habitat function to ESA listed species and their designated critical habitat. One-way project proponents ensure their proposed project does not result in a long-term loss of habitat function is by calculating conservation offsets using NMFS' PNNL Habitat Conservation Calculator (Calculator or Conservation Calculator) for certain activity types.

The PNNL calculator is an abbreviated version of the Nearshore Conservation Calculator. The calculators design and values were derived from scientific literature and best available information, as required by ESA. The Nearshore Calculator underwent and independent peer review in 2023. The independent peer review found that the Nearshore Calculator is well-founded and analytically sound, and based on best available science. Results of that peer review can be found on NOAA's webpage titled "Independent Peer Review of NOAA Fisheries' Puget Sound Nearshore Calculator".

The PNNL RAP is a streamlined regulatory option available to provide ESA and MSA review of proposed projects that will proceed under the auspices of PNNL. Individual proposals are reviewed to determine they meet the parameters of the program, and if all elements are met, NMFS provides a verification document. This allows each project's review to be narrow, while providing regulatory certainty, expedited documentation of ESA and EFH coverage, and best stewardship outcomes for protected resources. If project elements are not able to conform to the

[2] Up to 2 years - though some projects may take place over multiple years, which will require re-verification every 2 years.

program criteria herein, their proposed actions will be evaluated as an individual ESA consultation and/or EFH analysis.

Various types of proposed research activities are individually highlighted in the following section. The PDCs, performance criteria/limits, and implementation criteria are listed for each activity. An individual research project may fit under multiple activity types (e.g., an autonomous underwater vehicle could collect sediment samples and use an acoustic modem for communication and navigation, or an instrument package deployed on the seabed could use LiDAR and have substrate-mounted electrical cables). If a project falls under multiple activity types, all PDC and limits related to those activity types will be met, including verification and/or notification and mitigation requirements, as necessary. Any activities that do not fit within the existing PDCs or limits will require individual consultation or future modification of this programmatic. Modifications may occur on an annual basis when DOE, FWS, and NMFS discuss this programmatic document and potential revisions, including the review of monitoring results and modifications to monitoring and/or activities (Section 1.3.3).

The following information is divided into three sections: Project Criteria for 13 Covered Activities (Section 1.3.1), General Construction Measures (Section 1.3.2), and Program Administration (Section 1.3.3).

1.3.1 Project Criteria for 13 Covered Activities

All activities described in detail below will be subject to the following OPC.

Required OPCs applicable to all projects:

1. All devices and associated structures will be removed at the project end.
2. No alteration of the shoreline will occur for/from deployed structures/devices.
3. No deployments will occur in submerged aquatic vegetation (SAV), with exception of "Seagrass Macroalgae and Intertidal Research", "Seabed Installations" and “Benthic Characterization Surveys” for the explicit purpose of SAV research, described below.
4. Anchors will be placed in a way to avoid scour (e.g., the use of midline floats and/or tensile materials that do not produce looping during slack tidal conditions).
5. Projects requiring anchors will use helical screw anchors when possible.
6. Non-toxic, corrosion resistant materials will be used (e.g., encapsulated polyethylene foam, aluminum, fiberglass, or wood (as allowed in GCM #3).
7. Any activities in contact with the seabed surface that will encounter sunflower sea stars will remove the specimens by hand (if they do not move away freely) and relocate them beyond the area of disturbance, to the maximum extent practicable.
8. All work will comply with all federal, state and local regulations, including U.S. Coast Guard (USCG) requirements for visibility, marking and filing a Local Notice to Mariners or other appropriate navigational requirements.
9. If any project activities result in impacts to an individual of any protected species (e.g., **behavior changes, attraction to project sites, area avoidance, mortalities**), the project proponent must notify PNNL’s Biological Resources subject matter expert who will in turn notify the FWS and NMFS.

Activity Specific PDC and Implementation Criteria

Table 1, below, gives an overview of the thirteen separate activities and their corresponding limits and notification, verification, or verification/mitigation requirements. Following the table is an in-depth review of the activities.

Table 1. Activity and PDC List. Note: Not every limit/design criterion is listed in this table. See detailed write up below.

No.	Activity	Activity subcategory, if applicable	Size/Make	Distance Apart	Max # per yr. (Max at one time)	Days: 14 or less	Days: 15-45	Days: greater than 45 (in WW)	Days: greater than 60 (outside WW)
1	Floats and Buoys	**1A**: up to 100 ft^2 solid buoy	≤100 ft^2 solid buoy	10 ft	25 (15)	N	N	V	V/M
		1B: up to 400 ft^2 grated float	≤ 400 ft^2 grated float	10 ft	25 (5)	N	N	V	V/M
		1C: up to 400 ft^2 solid float	≤ 400 ft^2 solid float	10 ft	25 (3)	N	V	V	V/M
2	Dock Installations		≤ 6 ft^2	-	40 (20)	N	N	N	N
3	Seabed Installations	**3A**: Equipment and sensors	≤ 50 ft^2	2 ft	35 (15)	N	V	V	V/M
		3B: subsurface probes, markers, targets	≤ 20 ft^2 multiple, ≤ 6 ft^2 individual	1.5 ft	(150)	V	V	V	V
4	Autonomous Vehicle Surveys	**4A**: ASV/AUV (Surface/Underwater)	-	-	30 (10)	N	N	N	N
		4B: UAS (Aerial)	-	-	150 (10)	N	N	N	N
5	Benthic Surveys	**5A**: Benthic Sediment Sampling	-	80 ft (30 ft for 1 ft^2 or less)	30 per yr. (27 ft^3/survey) (810 ft^3/ per yr.)	N	N	N	N

No.	Activity	Activity subcategory, if applicable	Size/Make	Distance Apart	Max # per yr. (Max at one time)	Days: 14 or less	Days: 15-45	Days: greater than 45 (in WW)	Days: greater than 60 (outside WW)
		5B: Benthic Characterization Surveys *Non-Intrusive	-	crawlers - 3ft apart, not in FF WW w/o survey	Dependent on accompanying Activity PDC	N	N	N	N
		5C: Benthic Characterization Surveys *Intrusive	-	80 ft apart, and not same site in 1 yr.	Dependent on accompanying Activity PDC	V	V	V	V
6	Water Column Sampling	-	-	-	30	N	N	N	N
7	Dye and Particulate Releases	-	-	-	30	N	N	N	N
8	Seagrass, Macroalgae, and Intertidal Research	-	-	-	108 ft^2 SB, 108 ft^2 SJdF, <10% of total seagrass area	N	N	N	N
9	Light Emitting Devices	**9A**: Eye Safe	-	-	-	N	N	N	N
		9B: Non-Eye Safe	-	MMMP	(5)	V	V	V	V
10	Acoustic Device Operations	**10A**: Outside hearing range	-	-	-	N	N	N	N
		10B: In hearing Range	-	MMMP	(1 per species hearing range at a time)	V	V	V	V
11	Electromagnetic Field Operations	**11A**: Devices	Structure: Activity 1 or 3, EMF: 1.25 Tesla max	15 ft	(10)	N	N	N	V

No.	Activity	Activity subcategory, if applicable	Size/Make	Distance Apart	Max # per yr. (Max at one time)	Days: 14 or less	Days: 15-45	Days: greater than 45 (in WW)	Days: greater than 60 (outside WW)
		11B: Cables	-	leave open unaffected corridors	40 bundles (each 1 ft wide)	N	N	N	V
12	Community and Research Scale Marine Energy Devices	**12A**: with BMPs	≤ 400 ft^2	10 ft	150 (150 is total for both 12A & 12B)	N	N	V	V/M
		12B: without BMPs	≤ 400 ft^2	10 ft	150 (150 is total for both 12A & 12B)	V	V	V	V/M
13	Tidal Turbines	-	See Table 20 & Table 21	MMMP	1	V	V	V	V/M

N = notification, V= verification, V/M = verification/mitigation, ASV = autonomous surface vehicles, AUV = Autonomous underwater vehicles, UAS = Unmanned aerial systems, FF = forage fish (January 15 to October 14 for surf smelt, May 1 to January 14 for Pacific herring and May 2 to October 14 for Pacific Sand Lance), WW = work window (July 16 – February 15), SB = Sequim Bay action area, SJdF = Strait of Juan ds Fuca action area, BMP = best management practices, MMMP = marine mammal monitoring plan

Activity 1: Buoys and Floating Platforms

Subcategory 1A: Buoys
Buoys are defined as solid structures that provide buoyancy in water, which may or may not be accompanied by sensors/instruments and moorings as part of their structure. Though a majority of PNNL projects use buoys with dimensions under eight square feet (sqft), the maximum dimensions of buoys evaluated under this Activity are 100 sqft to account for the potential deployment of larger oceanographic buoys. Buoys larger than 100 sqft will be evaluated as platforms[3].

Subcategory 1B: Grated Floats
Grated platforms are in-water structures with floats (e.g., encapsulated foam) providing buoyancy on the bottom of generally flat, walkable surfaces of up to 400 sqft. Areas above the floats, accounting for up to 50 percent of the total surface can be solid (e.g., metal or wood sheets/planks), whereas the remaining walkable, 50 percent semi-solid (grated) areas include materials with at least 60 percent open space to allow for light penetration to the water column.

Subcategory 1C: Solid Floats
Solid platforms are in-water structures (e.g., photovoltaic panels, buoys over 100 sqft), no larger than 400 sqft with floats (e.g., encapsulated foam) providing buoyancy which shade 100 percent of their surface area. Floating platforms and buoys would generally float at the surface, but some floats or devices could be staged at mid-water column with surface markings if needed.

Floating platforms or buoys would be temporary and deployed for up to two years (projects will require re-verification every 2 years), and removed when the project is over. In some cases, the platforms, buoys, string of buoys, or other structure may be designed to be free floating during the research or testing. Multiple mooring lines may be used to keep structures in a more stable position.

Activity 1 Performance Criteria/Limits:

a) A minimum distance of 10 ft will be maintained between floating platforms and buoys.
b) A maximum of 15 buoys, 5 grated platforms and 3 solid platforms being deployed at one time across the entire action area.
c) A maximum of 25 deployments per year.

Activity 1 PDC:

a) Platforms will be constructed to let ample light penetration to the water column using grating or other light penetrating materials. Surfaces will be a minimum of 50 percent grated and all grating must have a minimum of 60 percent open space, unless PNNL documents the functional grating percentages above are being met in structure design, incorporating the same light penetration to the water column as the percentages above or permitted as a solid (non-grated platform).
b) Structure designs that involve non-biofouling light-penetrating materials would be preferred.

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[3] Community/research scale marine energy devices (Activity 12) which inherently function as buoys (i.e., shape, structure, operation and impact) will be considered as buoys. All other community/research-scale marine energy devices will be evaluated under Section 2.13.

c) Structure materials (e.g., plexiglass) that initially would allow light penetration but that are subject to eventual biofouling would only be used for short-term deployments. Periodicity will depend on biofouling rate relative to light penetration. Once functional grating percentages are not met, the structure will be removed or cleaned to fulfill functional grating requirements.
d) Platforms would be constructed of corrosion resistant, non-toxic materials such as encapsulated polyethylene foam, aluminum, fiberglass, or wood (as allowed in GCM #3).
e) Floating platforms and buoys would be anchored using diver-installed helical anchors (preferred), concrete or corrosion resistant metal anchors.
f) Anchors will be chosen to minimize seabed disturbance. If necessary, mid-line floats would be added to keep mooring lines from scouring the bottom or create line entanglement.
g) Verification for any activities deployed between February 16 and July 15 for 60 days or more would require compensatory mitigation using the modified PNNL Habitat Conservation Calculator and conservation credit resources (NOAA NMFS 2023). The timeframe reflects time worked outside the July 16 – February 15 Tidal Reference Area 10 (Port Townsend) in water work window.

Table 2. Activity 1 (buoys and floats) Implementation Criteria

Duration	**Subcategory 1A: Buoy (max 100 ft^2 [9 ft diameter])**	**Subcategory 1B: Grated Platform (max 400 ft^2 [20ft x 20ft])**	**Subcategory 1C: Solid Platform (max 400 ft^2 [20ft x 20ft])**
1-14 Days	Notification	Notification	Notification
15-45 Days	Notification	Notification	Verification
Greater than 45 Days	Verification	Verification	Verification
Greater than 60 Days, and Outside Work Window	Verification/Mitigation	Verification/Mitigation	Verification/Mitigation

Activity 2: PNNL-Sequim Dock Installations

Installation of in-water scientific instruments/equipment and support cabling onto or from the PNNL-Sequim dock (pier, ramp and floating dock), pilings, or adjacent shoreline may be required for various research activities. Such deployments of scientific instruments (e.g., light sensors, water quality sensors, coupons for biofouling studies, etc.) may be done for research data collection or for testing instrument integrity or pretests of instruments prior to research deployment at other locations in or near Sequim Bay. Attachment of instruments to pilings will be achieved by hand or diver installation to support placement above the seabed and fixed to pilings using materials such as cable ties, hose clamps, webbing, or straps. Installation and operation of scientific equipment to the PNNL-Sequim pier and/or floating dock would be temporary (usually days to months) for most projects, with the exception of continuous monitoring activities which could be for more than a year.

Activity 2 Performance Criteria/Limits:

a) The maximum surface area per device would be 6 sqft (limited to sensor supporting structures (i.e., cage to hold multiple sensors)).
b) Maximum of 40 deployments per year.
c) No more than 20 being deployed at any given time.

Activity 2 PDC:

a) Installations are limited to PNNL-Sequim pier, ramp or floats that extend into the water column.
b) Instruments will be installed by hand and would not disturb the benthos.

Table 3. Activity 2 (PNNL-Sequim Dock Installations) Implementation Criteria

Duration	**Dock Installations (max 6 ft^2)**
1-14 Days	Notification
15-45 Days	Notification
Greater than 45 Days	Notification
Greater than 60 Days, and Outside Work Window	Notification

Activity 3: Seabed Installations

Seabed installations throughout Sequim Bay and the Strait of Juan de Fuca will include a variety of structures, from inert targets for detection, such as scuba tanks, to larger benthic landers housing multiple instruments.

Subcategory 3A: Equipment and Sensors
Examples of equipment and instruments that may be placed on the seabed include, but are not limited to:

- Grid framework or plot frames for benthic and underwater surveys
- Benthic landers
- Housings for equipment arrays
- Mounts for video equipment, lights, cameras, sensors, or acoustic devices
- Autonomous underwater vehicle (AUV) docking and charging stations

The deployments will be temporary for the duration of the project (1day to 2 years - projects will require re-verification every 2 years). Docking systems for AUVs are used to charge devices between missions. These systems would be installed on the seabed, at the PNNL-Sequim pier, or attached to buoys or platforms and installed near the water surface or mid-water column. Power sources for docking stations could include cabling to shore, marine energy devices, solar panels, or batteries. Navigation of the AUV will be achieved through methods such as ultra-short baseline positioning, long baseline positioning, or other active acoustics.

Activity 3A Performance Criteria/Limits:

a) The maximum footprint of such devices would be approximately 50 sqft, excluding associated cabling size.

b) A maximum of 35 per year, and no more than 15 deployed at any given time across both areas.
c) The devices must be at least two feet apart.

Activity 3A PDC:

a) The equipment and instruments could be anchored to the seabed using diver-installed screw or helical anchors or tethered to concrete or corrosion resistant metal mooring. Surface water marking of underwater research equipment locations will be added if required by the USCG based on the relief or profile of the device extending vertically from the seabed into the water column.
b) Seabed installations for purposes of "Seagrass Macroalgae and Intertidal Research" will be allowed by following multiple PDC requirements (Activities 3 and 8).
c) Verification for any activities deployed between February 16 and July 15 for 60 days or more would require compensatory mitigation using the modified PNNL Habitat Conservation Calculator and conservation credit resources (NOAA NMFS 2023). The timeframe reflects time worked outside the July 16 – February 15, Tidal Reference Area 10 (Port Townsend) in water work window.

Table 4. Activity 3A (Equipment and Instrument Seabed Installation) Implementation Criteria

Duration	**Subcategory 3A: Seabed installations (max 50 ft^2)**
1-14 Days	Notification
15-45 Days	Verification
Greater than 45 Days	Verification
Greater than 60 Days, and Outside Work Window	Verification/ Mitigation

Subcategory 3B: Subsurface Probes, Markers, and Targets

Measurement probes (e.g., dissolved oxygen, pH, temperature, conductivity, etc.), and other devices such as sediment cameras would be installed either on the substrate surface or within the substrate to depths up to approximately 7 ft. Instruments would be installed subsurface by divers using hand tools or with the aid of a water jet.

Some research may be aimed at developing technologies to detect objects such as placards, inert unexploded ordinance, or other objects, either on or buried in the substrate. To test these technologies, assorted inert targets (such as scuba tanks, crab pots, aluminum cylinders, and other metallic objects with high acoustic reflectivity for system reference (e.g., “Lincoln Hats”, etc.)) would either be set on the substrate surface or buried up to 5 ft in the substrate. The targets would either be connected via ropes, or the locations would be recorded with high accuracy underwater global positioning system (GPS) or acoustic tags. The targets would typically remain one to six months but in some cases may be in place for a year or more.

Activity 3B Performance Criteria/Limits:

a) Probes, markers, and/or targets will be spaced at least 1.5 ft apart.
b) A maximum of 150 being deployed at any given time.
c) No probes, markers or targets will be in place for more than 2 years.

d) A 20 sqft maximum if tied together, and 6 sqft for individual targets.

Activity 3B Design Criteria:

a) Burial within the substrate would be performed by divers using hand tools or with the aid of a water jet.

Table 5. Activity 3B (sub surface probes, makers, targets) Implementation Criteria

Duration	Subcategory 3B: Subsurface Probes, Markers, and Targets
1-14 Days	Verification
15-45 Days	Verification
Greater than 45 Days	Verification
Greater than 60 Days, and Outside Work Window	Verification

Activity 4: Autonomous Vehicle Surveys

Subcategory 4A: Water Vehicles

Autonomous underwater vehicles (AUVs), which include remotely operated as well as fully autonomous vehicles, and autonomous surface vehicles (ASVs) may be deployed from shore, vessels, platforms, or underwater charging stations within the research areas and will be electronically tracked while in use. AUVs are mobile, pre-programmed or remote-controlled, platforms that can carry a wide variety of instruments over a range of different depths. ASVs are surface vessels that operate without an operator onboard and may also carry or deploy a wide variety of instruments and sensors. AUVs/ASVs may be used for surveying and mapping, or other environmental monitoring tasks based on the sensor payload. AUVs/ASVs may also be used to deliver components from the surface to a specified location or underwater docking platform. AUVs and ASVs may use acoustic navigation (DiveNet system), a propeller and fins for steering and diving, and use GPS for navigation and tracking from the surface. AUVs and ASVs that communicate to shore via acoustic signals and may also carry or deploy a wide variety of instruments and sensors, include acoustic navigation and/or other acoustic equipment. In some cases, AUV underwater charging stations may be tested. A variety of equipment may be operated by the AUV/ASV and/or mounted on or near the docking stations including standard oceanographic equipment (CTD, ADCP), acoustic modem (~10-30 kHz), optical modem, sonars (frequencies vary by type), hydrophones, cameras, lights, Doppler Velocity Log (DVL), magnetic homing elements (has a short range of ~1m), wireless inductive charging (50 W–2 kW power transfer), and releasable acoustic beacons.

Subcategory 4B: Aerial Vehicles

Unmanned aerial systems (UAS) are systems where three components are combined for flight: a person with or without an automatic/autonomous algorithm control, communication, and a drone. UAS may be deployed from the shoreline, floating platforms, or vessels. The systems may be used to deploy various sensors such as LiDAR for bathymetry measurements, video, hyperspectral and RGB photography, and physical sensors.

Activity 4 Performance Criteria/Limits:

a) A maximum of 30 AUVs/ASVs could be deployed within a given year, with a maximum of 10 being deployed at any given time.
b) A maximum of 150 UAS deployments will occur within a given year, with a maximum of 10 being deployed at any given time.

Activity 4 PDC:

c) Vehicles will include standard automatic identification systems.
d) Systems will be under observation during daily deployments.
e) Marine grade or appropriately encased drones will be used.
f) All PNNL projects are bound by the Federal Aviation Administration (FAA) regulations. All pilots will hold or obtain a pilot's license before operating a drone, as per FAA regulations.
g) As per 14 CFR § 107.3, small, unmanned aircraft are those weighing less than 55 pounds on takeoff, including payload or attached devices to the aircraft.
h) Flights will adhere to [14 CFR § 107.51 – Operating Limitations for Small Unmanned Aircraft] (< 400 ft) over the water surface. An FAA exemption would be needed to operate outside the limit.
i) NMFS guidance for marine areas to avoid flying drones near marine wildlife will be followed (NMFS 2023).
j) Flights within 200 yards from Protection Island and the boundary drawn around Dungeness Spit are not allowed (PNNL 2023).

Table 6. Activity 4 (Autonomous Vehicle Survey) Implementation Criteria

Duration	Subcategory A-B: Autonomous Vehicles (AUVs, ASVs and UAS)
1-14 Days	Notification
15-45 Days	Notification
Greater than 45 Days	Notification
Greater than 60 Days, and Outside Work Window	Notification

Activity 5: Benthic Surveys

Surveys of habitat and aquatic species may be necessary at all locations by methods including, but not limited to, diver surveys, underwater video, or sonar. Surveys and sampling may be onetime analyses for targeted sampling or could occur at a location over a period of time in a monitoring capacity. Likely survey targets include sediments, macroalgae and kelp.

Subcategory 5A: Benthic Sediment Sampling Surveys

Sediment sampling is the removal or collection of substrate by mechanical or manual methods. Sediment sampling would occur with a grab sampler, coring device, or trowel. Examples of grab samplers include Eckman, Ponar, VanVeen-type sampler, box-core, or similar devices used for surface sediments. Most sampling devices would be deployed from a research vessel or research platform. Sampling can also be conducted in other ways. For example, divers may collect small samples underwater using trowels or similar hand tools.

Activity 5A Performance Criteria/Limits:

a) The longest bore coring device would be a gravity corer with a sample size of 10 ft long with a 4-inch diameter.
b) A maximum of 30 surveys.
c) A maximum limit of 27 cubic feet per survey, across both sites (whole action area).
d) A maximum of 810 cubic feet per year, across both sites (whole action area).

Activity 5A PDC:

a) Sediment samples would be spaced at least 80 feet apart, or 30 feet apart if devices are limited to one sqft or less of surface sediment disturbance.
b) A maximum volumetric limit of 27 cubic feet per survey

Table 7. Activity 5A (Sediment Sampling) Implementation Criteria

Duration	Subcategory 5A: Sediment Collection Surveys
1-14 Days	Notification
15-45 Days	Notification
Greater than 45 Days	Notification
Greater than 60 Days, and Outside Work Window	Notification

Subcategory 5B and C: Benthic Characterization Surveys (No Sediment Sampling)

The applicant will characterize benthic conditions through a variety of methods, resulting in a better understanding of the environment, not limited to examples detailed in the current section. For example, cameras or other vessel-based characterization of benthos not in direct contact with sediment are not included in this Activity Subcategory as impact to benthos will not occur. On the other hand, a sediment-profile imaging and plan view (SPI/PV) imaging system may be deployed to map benthic habitats and will be in contact with the benthos. The SPI/PV imaging system consists of a camera attached to a metal frame that is lowered by a vessel to the seabed. Once the frame reaches the seabed, an internal camera prism assembly is lowered to penetrate the sediment to collect a cross-sectional image of the sediment column in profile. The camera prism can descend approximately 15 cm below the sediment surface and has a surface area of approximately 500 square centimeters.

Non-intrusive benthic characterization: Typically, from a vessel, a portable free fall penetrometer (PFFP) may be deployed to assess sediment behavior in terms of shear strength and pore pressure response in the upper meter of the seafloor surface. The device also measures accelerations and ambient pressure onboard. A representative PFFP that may be used is the BlueDrop by BlueCDesigns. It is deployable and retrievable by hand with a weight of 8 kg and a length of 63 cm. The deployed probe creates an 8 cm diameter hole extending to <1 m depth in soft mud and <0.3 m depth in sands and gravels. It can be deployed from larger kayaks and skiffs to full size research vessels and platforms. The PFFP does not emit sounds, expel fluids, or introduce items or substances. A typical research project may include several hundred drops along multiple miles of transects.

Intrusive sediment characterization: Seabed characterization could also be performed using fully autonomous amphibious bottom crawlers such as the Otter or SeaOx Surf Zone Crawlers. These crawlers can operate to depths of 100 m through high current and up onto land. The Otter is 45 kg, and the maximum dimensions are 1 m long by 55 cm wide by 25 cm high. The SeaOx is larger at approximately 133 kg with dimensions of 122 cm long by 122 cm wide and 30 cm tall. These crawlers can potentially tow cameras and/or a Flex EMI sled that uses an electromagnetic induction array to detect objects on the seabed.

Activity 5B & C Performance Criteria/Limits:

Benthic characterization survey activity (intrusive and non-intrusive) has no limits, per se. Limits are based on accompanying Design Criteria.

Activity 5B & C PDC:

a) Non-intrusive benthic characterization surveys equipment (e.g., benthic crawlers) would be spaced at least 3 ft apart and would require notification only.
b) Intrusive sediment characterization events (e.g., PFFP) would be spaced at least 80 ft apart and would not sample within the same area within the same year.
c) Benthic research for purposes of "Seagrass Macroalgae and Intertidal Research" will be allowed by following this Activity's PDC along with Activity 8 PDC, GCMs, and the OPCs.
d) Substrate crawlers would not be used in forage fish spawning areas outside Tidal Reference Area 10 work windows (currently January 15 to October 14 for surf smelt, May 1 to January 14 for Pacific herring and May 2 to October 14 for Pacific Sand Lance); unless a forage fish survey is conducted, documenting the absence of forage fish in the project area (valid for 2 weeks, as stipulated by WDFW). Species-specific forage fish spawning areas near the Sequim Campus can be found on the Washington Department of Wildlife and Fisheries forage fish survey map[4].

Table 8. Activity 5 B & C (Benthic Characterization Survey) Implementation Criteria

Duration	Subcategory 5B: Non-intrusive surveys and intrusive events with distances > 3 ft apart	Subcategory 5C: Intrusive characterization events > 80 ft apart
1-14 Days	Notification	Verification
15-45 Days	Notification	Verification
Greater than 45 Days	Notification	Verification
Greater than 60 Days, and Outside Work Window	Notification	Verification

Activity 6: Water Column Sampling

Plankton, and invertebrate species sampling may occur as one-time collections or multiple times in either one or multiple locations to monitor an area. Sampling may involve hand collection by divers, diver held sampling devices, or by research vessel, platform, buoy, AUV, or previously deployed research equipment. Invertebrates or plankton sampled from the water column or water

4 https://wdfw.maps.arcgis.com/home/webmap/viewer.html?webmap=19b8f74e2d41470cbd80b1af8dedd6b3&extent=-126.1368,45.6684,-119.6494,49.0781

surface would be collected using gear with mesh sizes designed to collect plankton and invertebrates (e.g., Neuston net, sweep netting).

Water column sampling for additional parameters may occur for marine microbes, analysis of nutrients, minerals, or other targeted abiotic substances. Like plankton or invertebrate sampling, collection of parameters may occur by divers using handheld samplers, or by deployment of sampling equipment from a boat, platform or buoy, AUV, or other research equipment previously deployed.

Activity 6 Performance Criteria/Limits:

a) A maximum of 30 water, plankton, and invertebrate species sampling events could take place within a year.

Activity 6 PDC:

a) Vertebrate biota would be returned to the water if incidentally captured.

Table 9. Activity 6 (Water Sampling) Implementation Criteria

Duration	Water Column Sampling
1-14 Days	Notification
15-45 Days	Notification
Greater than 45 Days	Notification
Greater than 60 Days, and Outside Work Window	Notification

Activity 7: Dye and Particulate Releases

Florescent dye tracers have been used to study dispersion and transport in many aqueous environments (Clark et al. 2014). Optical fluorometers measurement techniques can be combined with dye release protocols to accurately measure relevant conditions at the site. This on-site collection can be achieved by manual sampling or through autonomous collection and detection techniques. In addition, remote sensing with dye enhancers and tracers can help provide greater spatial data than in situ sampling for further analysis. Laser stimulated fluorescence using bathymetric lidar systems has been used to create three dimensional maps of tracer concentrations in clear open ocean waters (Sundermeyer et al. 2007). For these related efforts, materials and methods may include dyes such as Rhodamine water tracing (WT) dye (<20ppb) and detection using instruments such as a Cyclops turbidity sensor collocated with a WETlabs WETStar Rhodamine WT fluorometer or similar devices. Analogous dye types and/or diatoms may be utilized in these studies. The hardware may be mounted on a surface vessel, an autonomous float, AUV, towed behind a vessel, or mounted on the substrate in the waterway.

Activity 7 Performance Criteria/Limits:

a) Rhodamine WT dye will be below a 20ppb concentration.

Activity 7 PDC:

a) Follow manufacturers use guidelines and limit to minimum concentrations needed for application.

b) Measurement devices used will not exceed dimensions listed within other Activity PDCs and limits (for example, PDC's and limits on Activity 3 seabed installations or Activity 1B grated floats).

Table 10. Activity 7 (Dye and Particulates) Implementation Criteria

Duration	Dye and Particulate Releases
1-14 Days	Notification
15-45 Days	Notification
Greater than 45 Days	Notification
Greater than 60 Days, and Outside Work Window	Notification

Activity 8: Seagrass, Macroalgae, and Intertidal Research

Research and survey activities in and around SAV including seagrasses, kelp, and other macroalgae are performed to determine ecological attributes of these communities and to facilitate testing of technologies under diverse habitat conditions and to gain better understanding of how these habitats function. Divers perform underwater experiments on eelgrass and macroalgae, as well as associated water and substrate, to understand sediment-nutrient dynamics that influence growth. Examples of research activities include transplanting of eelgrass shoots and rhizomes, installation of equipment and sensors, and the deployment of equipment designed to specifically collect data in and around these habitats. Samples of eelgrass, macroalgae, water, or associated sediment may be collected from shore during low tide, by divers, or via research vessels in deeper water habitat. These specimens would be analyzed in the laboratory for metabolites, biomass, carbon, organisms, and other ecological indicators relevant to ongoing research activities.

Activities in the tidelands and marsh habitats at PNNL-Sequim will support research relevant to biogeochemical and ecosystem processes. Installation of scientific equipment within these areas may include instruments to measure greenhouse gas flux, light, sediment accretion, hydrology, and photosynthetic response. To prevent instrumentation from moving or being lost due to tides and currents, equipment would be secured using garden stakes or staples, t-posts, PVC piping, rebar, cinder blocks, or something similar. Sediment cores (approximately 7 ft deep and 4 in diameter) would be collected and groundwater wells (approximately 2 in diameter) would be inserted into the space cleared by the sediment coring process. The small groundwater wells would be fit with sensors to collect data relevant to water-soil-nutrient processes. For greenhouse gas measurements, PVC collars would be inserted into the sediment in order to interface with flux chambers. Sediment cores would be collected at select locations to inform research relevant to carbon sequestration of marsh habitats. Periodic surveys of elevation and vegetation cover are expected, and samples of the sediment and vegetation may be collected. Likewise, push point samplers (hollow metal rods) will be periodically used to collect porewater samples for chemical analyses.

Activity 8 Performance Criteria/Limits:

a) A total of up to 216 sqft area, including SAV, could be disturbed (including collection) in the project areas within a given year.
   a. 108 sqft in the Sequim Bay Research Area

b. 108 sqft in the Strait of Juan de Fuca Research Area.

b) PNNL will not collect more than 10 percent of the eelgrass in any given collection area (e.g., 1.08 sqft out of 10.8 sqft or 0.1 square meter out of 1 square meter).
c) Sediment cores would be limited to 2 cubic ft in volume and 4-inch diameter.
d) For greenhouse gas measurements, in the Tidal Marsh Area, PVC collars would be no more than 1 ft diameter inserted 4 inches into the sediment in order to interface with flux chambers.
e) Push point samplers (hollow metal rods) will be limited to no more than 1-inch diameter and 1 cubic ft of total volume disturbance.

Activity 8 PDC:

a) Transplants and/or SAV specimens will be collected by hand in shallow water or with a small research vessel at deep-water habitats.
b) PNNL will record the number of plants removed and document locations with a GPS or alternative means (e.g., mapping).
c) Research projects will not significantly alter the habitats that are being investigated.

Table 11. Activity 8 (Seagrass, Macroalgae, and Intertidal Research) Implementation Criteria

Duration	108 ft^2 in Sequim Bay, 108 ft^2 Strait of Juan de Fuca, <10% of total seagrass area
1-14 Days	Notification
15-45 Days	Notification
Greater than 45 Days	Notification
Greater than 60 Days, and Outside Work Window	Notification

Activity 9: Light Emitting Devices

Activity 9 is divided into two subcategories: *9A (Eye Safe Light Emitting Devices)* and *9B (Eye Safe Light Emitting Devices)*.

Photography or video may be required for documentation or monitoring purposes. Underwater photography may use ambient light or require illumination from an artificial source such as flood lights or strobes. Intermittent light illuminators such as optical camera strobes may be used as an artificial source. Continuous light illuminators for biofouling prevention or research may also be used.

LiDAR systems may be used to detect, identify, and track animals in the vicinity of hydrokinetic devices or other equipment, for bathymetry studies, and for surface applications such as wind measurements and habitat assessments.

Underwater detection systems may use either a red laser, green laser, or both. The red laser system is eye-safe for both humans and marine animals and is functional out to approximately 33 feet, depending on water clarity; it is used for fine scale tracking and object identification. The green laser is not eye-safe for humans or marine animals at near distances, but it is functional to approximately 66 feet from the source. It is used to detect animals (of a specific size) approaching the system, then automatically turns off once the animal or object is 33 feet from the source. The Unobtrusive Multi-static Serial LiDAR Imager (UMSLI) system incorporates both red and green laser systems with specifications for each described in Table 12.

Table 12. UMSLI Red and Green Laser Specifications

Specification	Green Laser	Red Laser
Wavelength (nm)	532	638
Type	Nd:YAG	Laser diode
Class	3B	3B
Pulse Duration (ns)	1	3.9-4.8
Pulse repetition frequency (kHz)	10 – 200 variable	80 typical
Beam diameter at scanner (mm)	2.0	2.4
Beam divergence	Diffraction limited	Diffraction limited
Energy per pulse	5 μJ	13 μJ
Beam distribution	Gaussian	Gaussian
Beam profile	Slightly elliptical	Elliptical
Assumed attenuation coefficient in sea water (m-1)	0.4 – 0.7	0.8 – 1.1
Eye-safe in air?	**No**	**Yes**
Eye-safe in sea water?	**No**	**Yes**

Bathymetry can be measured by blue-green LiDAR, usually 532 nm, either from a system deployed underwater on a tow fish or AUV, or from a system deployed above the water on an UAV. Examples of aerial bathymetry systems are the Leica Chiroptera 4X that can penetrate to a depth of 82 feet, or the Leica Hawkeye 4X that penetrates to depths of 164 feet. These are all certified for safe human use as a commercial product.

LiDAR systems are also likely to be used above the surface of the water. These can be used for wind measurements, habitat assessment, or target detection. For wind applications, an upward looking LiDAR would be placed either on the ground or on a type of platform/buoy on the surface of the water, facing upward. An example of this is a WINDCUBE LiDAR. These have a range up to 656 feet and are safety compliant to Class 1M IEC/EN 60825-1. For habitat assessment or target detection, a LiDAR would be flown in an aircraft or drone/UAV, pointing downwards. This could use a system similar to the Phoenix mini RANGER-UAV. This is an eye safe (Class 1) LiDAR at 905 nm, with a range of 820 feet at 60 percent reflectivity.

Activity 9 Performance Criteria/Limits:

a) No maximum limit for eye safe light emitting devices.
b) A maximum of five non-eye safe light emitting device projects at one time.
c) Non-eye safe light emitting devices require a MMMP, Section 1.3.3 and Appendix B.

Activity 9 PDC:

a) Spotlights and strobes for monitoring, photography, etc. will be intermittent and not continuous.
b) Continuous lighting used to prevent biofouling, typically associated with sensors, will be shrouded, and not interfere with the surrounding water column.
c) Any observed effects on fish/marine mammals by eye-safe lasers and LiDAR sources shall be reported, as applicable (Appendix D).

d) Non-eye safe laser (e.g., green laser) operation will use Protected Species Observers (PSOs) (Appendix B).
e) Discontinuation of operation of non-eye-safe lasers if a protected species (SRKWs or humpback whales) is within 50 m for in-water work.
f) Non-eye safe devices with automated shutdown capability would also have that capability enabled during deployment.
g) Additionally, the PSO will scan areas prior to and during use of aerial LiDAR if non-eye-safe and discontinue operations if marine mammals are in the survey area.
h) The PSO will report observed effects on protected fish and marine mammals) (Appendix D).

Table 13. Activity 9 (Light Emitting Device) Implementation Criteria

Duration	Subcategory 9A: Eye Safe Light Emitting Devices	Subcategory 9b: Non-Eye Safe Light Emitting Devices
1-14 Days	Notification	Verification
15-45 Days	Notification	Verification
Greater than 45 Days	Verification	Verification
Greater than 60 Days, and Outside Work Window	Verification	Verification

Activity 10: Acoustic Device Operation

Activity 10 is divided into two subcategories: *10A (Acoustic Emissions Outside Hearing Range of Marine Mammals and Fish)* and *10B (Acoustic Emissions Within Hearing Range of Marine Mammals and Fish)*.

Active acoustic generating devices may be used as sources for acoustic detectors, for object or biota detection/identification, or communications. Target or equipment simulation may be necessary to test detection by different acoustic devices or sensors. Simulated sounds could include mimicking those made by marine mammals, fish and invertebrates (e.g., dolphin clicks, snapping shrimp) or underwater infrastructure for marine renewable energy devices such as rotating underwater turbines.

Technicians use equipment such as echosounders and sub-bottom profilers to detect animals in the water column or objects located on or within the substrate. Acoustic modems and guidance systems are used for underwater communications, often with AUVs.

Sound emission devices may be deployed, depending on study objective, using a variety of approaches. Examples of deployment approaches include tethered to the PNNL pier, installed on the substrate, moored in the water column, bundled with other instrumentation, towed by boat or AUV, carried by divers, or on free- floating drift buoys.

Table 14 provides examples of the range of sound emitting devices that could be used for PNNL related research that are within hearing range of marine mammals or fish, along with some physical parameters of the generated sounds. Additional acoustic technologies may be used in PNNL related research. These include single and multibeam echosounders, sonars, and acoustic cameras. Most of these instruments operate at frequencies that are above the hearing range of fish (generally less than 3 kHz), birds (generally less than 10 kHz), and marine mammals (generally less than 160 kHz).

Table 14. Examples of Sound Emitting Devices, Operation Frequencies, Source Levels, and Duty Cycles of Acoustic Devices used in PNNL Research (all are considered non-impulsive sources)

Device	Operating Frequency	Max Source Level (dB re 1 µPa at 1 m)	Duty Cycle
Vemco V13 fish tag	69, 180, 307 kHz	150	1 coded pulse (<< 1 s)
DiveNET Autonomous Smart Buoys (ASB)	10–30 kHz	170	5% (203 ms signal every 4 s)
OceanSonics icTalk LF	200 Hz –2.2 kHz	130	user-configurable
OceanSonics icTalk HF	10–200 kHz	140	user-configurable
Surface Acoustic Pingers (SAP)	8–15 kHz	190	1 pulse (<<1 s) every 2 s
EdgeTech eBOSS subbottom profiler2,3	3–30 kHz	195	32%
APL Custom Transmitter3	3–30 kHz	180	32%
Benthos ATM 900 underwater modem2	22–27 kHz	178	0.001s ping at 100Hz (10%)
Kongsberg Underwater Positioning System2	2230 kHz	189	0.031 s ping at 2 Hz (6%)
Stationary 38 kHz echosounder2, 4	38 kHz	215	~ 0.1%
Navy J11 projector2	30 Hz –10 kHz	158	continuous sound
Bluefin-21 SAS Sonar5 4	4–24 kHz	200	50%
Benthowave spherical transducer6	20–200 kHz	180-200	Up to 50%
Benthowave piston transducer7	3.5–100 kHz	180-200	Up to 50%
Single beam echosounder	above 160 kHz	*NA due to operation frequency outside hearing range*	
Single beam echosounder	10–160 kHz	less than 120 dB	
Multibeam echosounder	above 200 kHz	*NA due to operation frequency outside hearing range*	
Acoustic camera	900 kHz, 2250 kHz	*NA due to operation frequency outside hearing range*	
RDI DVL	600 kHz	*NA due to operation frequency outside hearing range*	
EdgeTech 2205	1600 kHz	*NA due to operation frequency outside hearing range*	
Acoustic Doppler Current Profilers	300 kHz–6 MHz	*NA due to operation frequency outside hearing range*	

Activity 10 Performance Criteria/Limits:

a) Time limits for use of sound sources with injury isopleths greater than 20 m or behavioral isopleths greater than 50 m (applicable to marine mammals or fish, or a combination of these):
    - 8 hour/day (a day is 12:00:00 to 11:59:59)
    - 5 day/week (a week is Monday to Sunday)
    - 2 week/month (a month is any calendar month)
    - 6 month/year (max consecutive months of activity is 4)
    - Total allowable hours of sound emission activity per year is 480 hours or 5.5 percent of a year.

b) Max of 1 per species hearing range at a time.

Activity 10 PDC:

a) Sound and pressure levels above thresholds emitted by instruments operating at frequencies within the hearing range of protected species will be mapped as effect isopleths.
b) PNNL determines effect isopleths (distance from the sound source to where the sound pressure level attenuates to below the reference effect threshold) for sound emissions by using an Acoustic Effects Calculator.
c) For potential marine mammal and fish injury and behavioral effects, PSOs and vessel staff will be employed to survey affected areas based on distance, as outlined in MMMP Appendix B.
d) Operation will discontinue when a marine mammal is observed in the surveyed area.
e) Tidal work windows will be followed to the maximum extent possible for devices operating at frequencies within the hearing range of fish and at sound pressure levels that exceed fish injury thresholds.

Table 15. Activity 10 (Acoustic Device) Implementation Criteria

Duration	Subcategory 10A: Acoustic Emissions Outside Hearing Range (Marine Mammals and Fish)	Subcategory 10B: Acoustic Emissions Within Hearing Range (Marine Mammals and Fish)
1-14 Days	Notification	Verification
15-45 Days	Notification	Verification
Greater than 45 Days	Notification	Verification
Greater than 60 Days, and Outside Work Window	Notification	Verification

Activity 11: Electromagnetic Field (EMF) Operations

Subcategory 11A: EMF Devices

EMF devices used in PNNL research will produce variable levels of EMF up to 1.25 Tesla (T) at the surface of the source (which is similar to an off-the-shelf Neodymium magnet). Generation of EMF emissions may be necessary for research projects focused on determining detection capabilities of various instruments as well as research aimed at testing different technologies and monitoring of marine resources near an operating instrument. EMF emission systems or cables may be deployed on the seabed surface or in the water column and could include either alternating current (AC) or direct current (DC) configurations. Research-related devices generating EMF usually will not be buried, but will rest on the seabed, be suspended in the water column, or float at the surface.

Activity 11A Performance Criteria/Limits:

a) Devices must be 15 feet apart.
b) Maximum 10 devices at a time.
c) Individual device has a maximum of 1.25 Tesla.

Activity 11A PDC:

a) Devices with automated shutdown capability would also have that capability enabled during deployment.
b) The project will report any observed effects on protected species (i.e., fish and marine mammals).

Table 16. Activity 11A (EMF Devices) Implementation Criteria

Duration	Subcategory 11A: EMF Devices
1-14 Days	Notification
15-45 Days	Notification
Greater than 45 Days	Notification
Greater than 60 Days, and Outside Work Window	Verification

Subcategory 11B: EMF Cables

Deployed cables operate at a lower threshold with fields up to 5 mT (the strength of a common refrigerator magnet). These fields are similar to those generated by common in-water equipment such as electric motors and loudspeakers. Electrical cables may or may not be connected to various deployment types, not limited to seabed installations, and the cable may power/charge devices and/or provide data transfer and communications. Divers and/or boats would be utilized to run cable from points on the existing pier/floating dock or other shoreline locations into the water near the PNNL-Sequim shoreline facilities and out to the deployed device/equipment. Research-related cables generating EMF usually will not be buried, but will rest on the seabed, be suspended in the water column, or float at the surface. Divers would most likely attach the cable to the substrate using small hand-installed helical anchors to avoid scour by the cable along the seabed and displacement of equipment, but in some cases small concrete blocks or similar anchoring devices could be used. Alternatively, partial burial of cables would be considered for longer term deployments. If a specific site is identified for multiple projects that would require several cables or repeated cable installation, a conduit may be installed on or within the substrate to allow installation and removal of cables without divers in order to avoid repeated disturbance of the substrate. Cable installation elsewhere could be required for devices including hydrophones, water quality sensors, underwater cameras, and navigation aids. Installations would be temporary for the duration of the project (up to two years - projects will require re-verification every 2 years).

Activity 11B Performance Criteria/Limits:

a) Any singular cable diameter will not exceed one foot.

b) A maximum of 40 cables will be deployed in research areas at any given time.
c) Cables coverage (square footage) is not included in PDC 3, seabed installations, category limit.

Activity 11 B PDC:

a) Cables could be anchored to the seabed using diver-installed screw or helical anchors, small concrete blocks or corrosion resistant metal mooring.
b) Cables will be either housed together or spaced appropriately to avoid entanglement and clutter.
c) Cables will be spaced to allow corridors for species to travel, unobstructed or influenced.
d) Projects will route cables to minimize cable length needed.
e) Project will utilize common cable pathways to the extent practicable.
f) Cables, up to 1 ft in diameter or grouped together to make no more than a 1 ft wide seabed footprint to propagate a habitat corridor.
g) Area in-between groupings/1 ft cable will allow for an 800 sqft or more of unaffected buffer area per 50 ft of cable.
h) Cable installations for purposes of "Seagrass Macroalgae and Intertidal Research" will be allowed by following relevant PDCs in Activity 3 and Activity 8, applicable GCMs, and OPCs.

Table 17. Activity 11B (EMF Cables) Implementation Criteria

Duration	Subcategory 11B: EMF Cables
1-14 Days	Notification
15-45 Days	Notification
Greater than 45 Days	Notification
Greater than 60 Days, and Outside Work Window	Verification

Activity 12: Community and Research Scale Marine Energy Devices (excluding tidal turbines)

Marine energy devices are structures which can harness energy from ocean waves, currents, tides, salinity gradients and temperature changes; thus, converting the energy into power. This Activity excludes tidal turbines, which are described in the Activity 13. PNNL research activities around marine energy devices are generally focused on applications that seek to understand device design and performance as well as developing approaches for understanding the interaction of devices and protypes with the environment. At the community and research scale, the power produced by devices (e.g., kinetic energy) is not typically delivered to the U.S. power grid and would be limited to up to hundreds of kW of power generation. Deployments can occur in both the Sequim Bay and Strait of Juan de Fuca Research Areas and could power microgrids.

Wave energy converters (WEC) tend to have fewer moving parts than tidal turbines which could interact with marine life. These devices capture kinetic energy by moving up and down or by rocking with the waves. Devices can include, but are not limited to: point absorbers, wave overtopping reservoirs, attenuators, oscillating water columns, inverted pendulums, submerged pressure differential and rotating mass (Figure 1). Point absorbers convert the movement of the buoyancy device into power. Wave overtopping reservoirs rely on the movement of water through the center of the storage reservoir to move a low head turbine. An attenuator uses the motion generated from waves to capture energy. Oscillating water columns rely on the pressure differential between the rising and falling water within the headspace of the device. Inverted pendulums act as paddles and rely on the horizontal movement of waves to push a paddle-type structure.

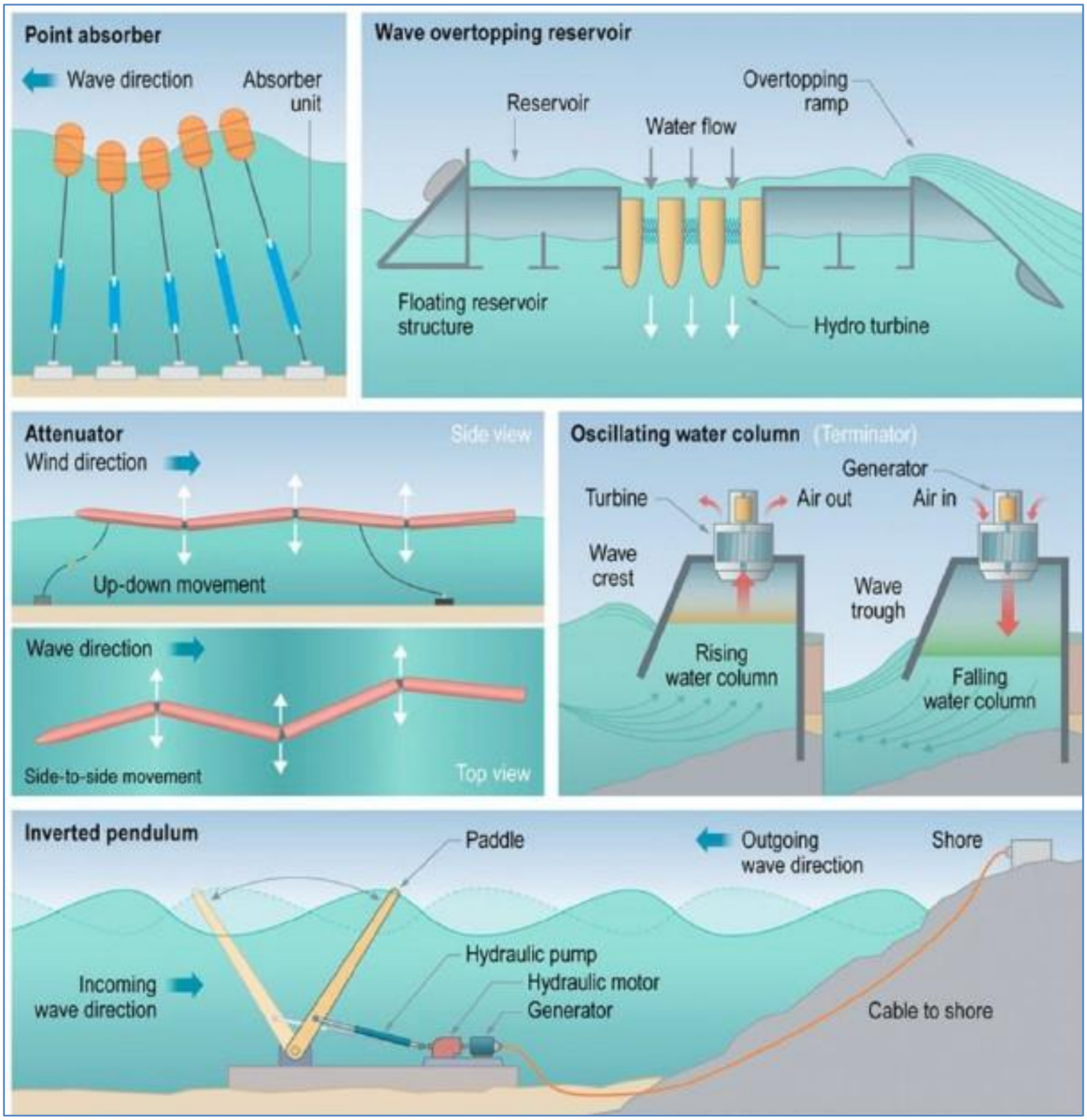


Figure 1. Examples of types of marine energy devices and movement style (Augustine et al. 2012).

Activity 12 Performance Criteria/Limits:

a) Devices may not provide delivery of electrical power to the U.S. power grid.
b) Marine Energy Devices must be placed at least 10 feet apart.

c) A maximum of 150 deployments of Marine Energy Devices is in place for any given year of this program (for both subcategories 12A and 12B combined).

Activity 12 PDC (required for both categories 12A and 12 B):

a) Devices would be anchored using diver-installed helical anchors (preferred), concrete or corrosion resistant metal anchors.
b) Anchors will be chosen to minimize seabed disturbance. If necessary, mid-line floats would be added to keep mooring lines from scouring the bottom or create line entanglement.
c) Marine Energy Devices must be no larger than 400 sqft.
d) Verification for any activities deployed between February 16 and July 15 for 60 days or more would require compensatory mitigation using the modified PNNL Habitat Conservation Calculator and conservation credit resources (NOAA NMFS 2023). The timeframe reflects time worked outside the July 16 – February 15 Tidal Reference Area 10 (Port Townsend) in water work window.

Subcategory 12A: Marine Energy Devices with BMPs (excluding tidal turbines)
In addition to the OPCs and Activity 12 PDCs Above, the specific PDC- applicable design criteria listed below must be included to qualify for subcategory 12A (Community and Research Scale Marine Energy Devices with best management practices (BMPs)).

a) Exposed rotating parts will operate at a speed of 10 m/s or less.
b) Wave overtopping reservoirs will be designed in a way to allow for a minimum of 50 percent water exchange between surface water and reservoir water.
c) Species monitoring as depicted in Appendix B. If protected species are seen within 50 m of the device, stop work and continue operation 30 minutes after the protected species have left the project vicinity.
d) NMFS approved screens will be used around parts open to both the environment and generator/turbine and will be of mesh size sufficient to omit life stages of all protected species that could enter into the device.
e) Divers will confirm anchoring on unconsolidated habitat.
f) Generators/turbines and/or exposed rotating parts will be housed in a manner to prevent impingement or areas of entrapment.
g) New and/or novel products/technologies of quality sufficient to avoid impacts to protected species, documented in a biological review.

Table 18. Activity 12A (Marine Energy Devices with BMPs) Implementation Criteria

Duration	Subcategory 12A: Community and Research Scale Marine Energy Devices (with BMPs)
1-14 Days	Notification
15-45 Days	Notification
Greater than 45 Days	Verification
Greater than 60 Days, and Outside Work Window	Verification/Mitigation

Subcategory 12B: Marine Energy Devices without BMPs (excluding tidal turbines)
For projects not following all applicable BMPs (*PDC 12A*), minor modifications of the BMPs might be allowed. The modification must be explained in the verification request. All projects not following all applicable PDCs will require verification regardless of duration.

Table 19. Activity 12B (Marine Energy Devices without BMPs) Implementation Criteria

Duration	Subcategory 12B: Community and Research Scale Marine Energy Devices (without BMPs)
1-14 Days	Verification
15-45 Days	Verification
Greater than 45 Days	Verification
Greater than 60 Days, and Outside Work Window	Verification/Mitigation

Activity 13: Tidal Turbine Research

The proposed tidal turbine research is designed to support future marine energy research and development that could involve deployment of various turbine types and numbers under various operational scenarios. There are various types of turbine devices to consider, including: axial flow or horizontal axis turbines with circular cross-sections and crossflow turbines, typically in a vertical orientation as vertical- axis turbines with prismatic cross-sections. Either type of turbine can be mounted on the bottom substrate or attached to a floating platform. However, other types of turbine concepts, such as oscillating hydrofoil, venturi effect, Archimedes screws, and tidal kites may also be considered.

The PNNL would not install tidal turbines for the purpose of connecting to the U.S. power grid but could install various types of tidal turbines for research purposes over the consultation period. Research could be focused on testing turbine concepts (including tidal kites) to improve efficiency or performance, microgrid research or it could be directed at monitoring technologies that would test and measure the environmental impacts of the devices.

The maximum dimensions of turbines that are technically feasible to deploy at a site includes the clearance distance between the top of a turbine and the surface at low water conditions. A reasonable turbine top to surface clearance for bottom mounted systems is 3 m, as determined from coordination with USCG to allow sufficient clearance for vessels passing overhead. Estimates of the maximum potential size for tidal turbines at four representative locations were made based on the available water depth and clearance considerations (Figure 3).

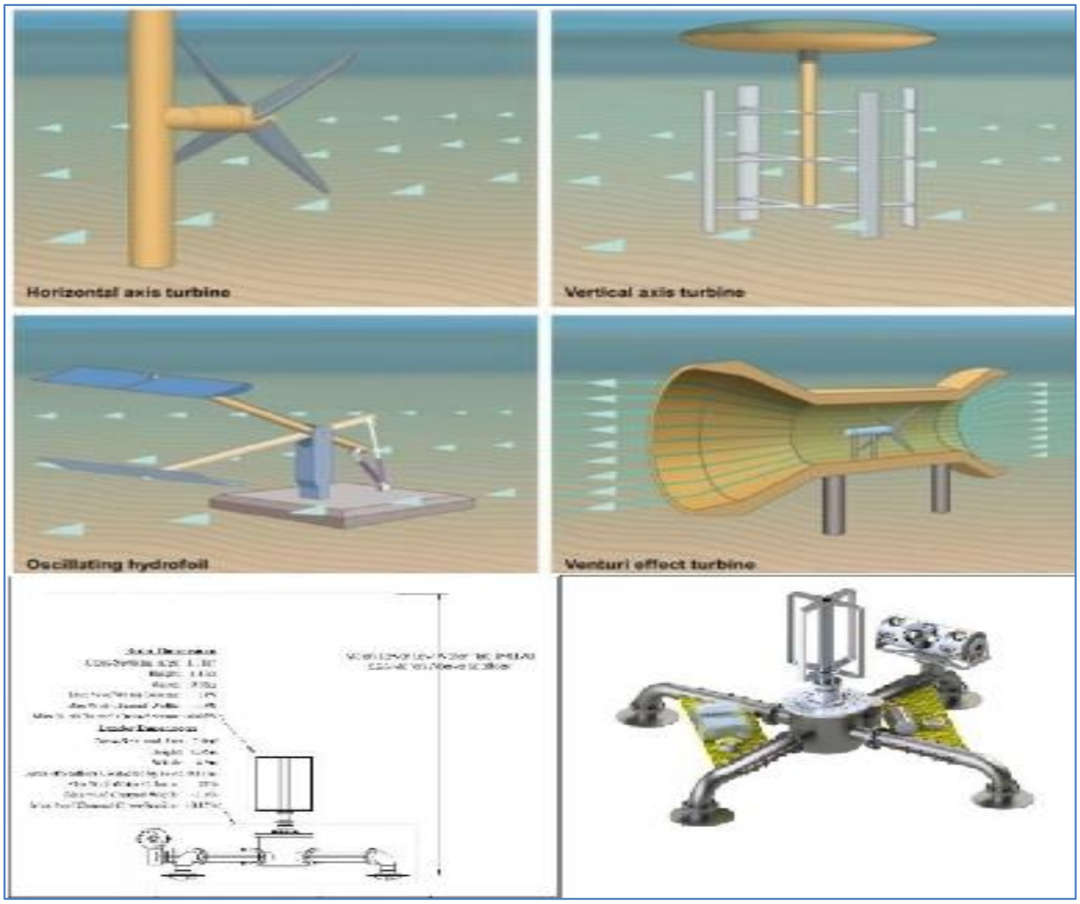
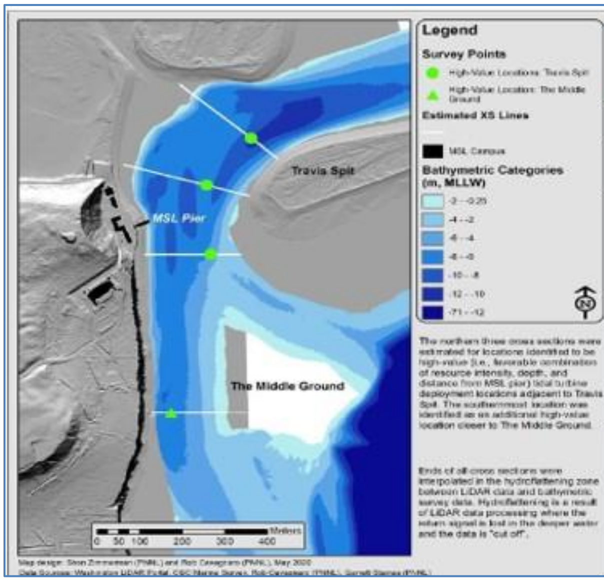


Figure 2. Tidal Turbine Examples

The maximum potential size for horizontal axis and vertical axis turbines at each location is provided in Table 20 and Table 21. The depth, flow speeds, size, and proximity to shoreside infrastructure make the inlet to Sequim Bay a suitable location for testing small to medium-scale tidal turbines. The site is not suitable for full-scale utility grid turbines or large arrays of research-scale turbines. There are limited areas within the inlet where turbines are likely to be deployed. These correspond to locations with sufficient depth, adequate resource intensity (speed), and close proximity to the PNNL-Sequim facility. Deployments at other locations within the Sequim Bay or the Strait of Juan de Fuca project areas would need to be assessed in a similar fashion and may be subject to additional monitoring.



Site >	North	Central	South	Middle Ground
Latitude	48.08118	48.08006	48.07839	48.07456
Longitude	-123.042	-123.043	-123.043	-123.044
Water Depth MMLW (m)	-10.06	-6.86	-5.28	-7.23
Channel Cross Section Area (m^2)	1916	1878	1125	851
Max Current Speed (m/s)	2.8	2.5	2.5	2.3

Figure 3. Location of Four Representative High-Value Turbine Locations within the Sequim Bay Inlet Channel

Table 20. Maximum Size, Power, and Speed of **Horizontal-Axis** Turbines at Four Representative Locations

Site	Max Turbine Diameter (m)	Max Area (m2)	Max % Channel Occupied	Max Power (kW)	Peak Speed (rpm)	Tip -Speed Ratio
North	5.3	22	1.1	49	40	5
Central	2.9	6.6	0.4	15	73	5
South	1.7	2.3	0.2	5.8	129	5
Middle Ground	3.2	7.9	0.9	13	60	5

Table 21. Maximum Size, Power, And Speed of **Vertical-Axis** Turbines at Four Representative Locations

Site	Max Turbine Height	Max Turbine Diameter (m)	Max Area (m2)	Max % Channel Occupied	Max Power (kW)	Peak Speed (rpm)	Tip -Speed Ratio
North	5.3	10.6	56	2.9	110	10	2.5
Central	2.9	5.8	16.7	0.9	33	18	2.5
South	1.7	3.4	5.8	0.5	13	32	2.5
Middle Ground	3.2	6.3	20	2.4	29	15	2.5

The ratio of turbine cross-sectional area to total channel cross-section at low water was calculated to provide a measure of the scale of these machines relative to the scale of the body of water for the largest technically feasible devices. This percentage for each site and turbine form factor is provided in Tables 20 and 21, above. Four representative stations have been selected for further analysis: three are close to Travis Spit and one is close to The Middle Ground. Characteristics of these four locations are presented in Figure 3 and Tables 20 and 21. Nevertheless, deployments could occur throughout the Sequim Bay and Strait of Juan de Fuca areas.

Additionally, tidal turbine rotation is dictated by current flow; therefore, turbine blades will typically not operate at all times during a 24-hour cycle. Turbine rotation speed is best and most often described in terms of tip-speed ratio, the ratio of the blade's tangential velocity to that of the surrounding fluid. It is therefore the apparent (relative) speed of the blade as experienced by organisms or debris moving with the flow. That is, even when the turbine is spinning faster during peak current flow in an absolute sense, its speed relative to the flow is unchanged if operated at the same tip-speed ratio, as would be typical for maintaining maximum efficiency. Large wind turbines, typically many meters in diameter, operate at peak performance at tip-speed ratios of 5 or higher. Tidal turbines operate at peak performance between tip-speed ratios of 1.5-5. For reference, at a flow speed of 2 m/s (about 4.5 mph), an 86 cm diameter turbine's blade would have an absolute tangential speed of 4 m/s (9 mph) at a tip-speed ratio of 2.

Further, with regard to operation, 1) peak efficiency operating speed (PEOS) may be less than maximum possible speed, 2) PEOS may exceed a tip-speed ratio of 2.5, and 3) breaking a system to below PEOS (e.g., to restrict tip-speed ratio to no greater than 2.5), although possible, is not a realistic mode of operation. Peak operating efficiency is most desirable for commercial energy production. Optimizing energy production is also a target of research, where turbines will operate over a range of speeds to determine peak operating efficiency. Braking unnecessarily increases electrical and/or mechanical wear and tear on components; thus, reduces component longevity and in certain cases can create unsafe circumstances due to potential catastrophic failure. Therefore, turbine manufacturers are unlikely to support/fund an unrealistic PNNL-Sequim research proposal that mandates a mechanical brake as part of a turbine design, as turbines are slowed down by their generator and control system and can be seen as standard braking operation.

Instead, PNNL-Sequim intends to conduct research based upon real-world deployment scenarios. While the scope of PNNL's efforts is focused on research and development, it is critical to emulate conditions relevant to real-world deployment scenarios of devices, including monitoring for impacts to the environment and evaluating novel developer designs (i.e., floating turbine designs). Though historically, the gravity-base mounted horizontal axis turbine is the most common design, accounted for over 70 percent of global research and development effort (Isaksson et al. 2020).

The PNNL's current scope entails deployment of one tidal turbine at a time, and an adaptive approach to subsequent tidal turbine deployment involving adaptive management discussions with the FWS and NMFS including monitoring results during turbine deployment.

Activity 13 Performance Criteria/Limits:

a) A total of one tidal turbine allowed to be deployed at a time. As an adaptive management strategy, more turbines may be simultaneously deployed afterward, depending on performance and further collaboration with the FWS and NMFS.

b) Turbine coverage (square footage) is not included in Activity 1 (floats and buoys) or Activity 3 (seabed installations) category limits.

Activity 13 Design Criteria:

a) Underwater monitoring as detailed in MMMP, Appendix B, will be followed.
b) Any turbines and associated structures placed on the seafloor will be done so slowly, in a controlled manner, to minimize turbidity plumes.
c) PNNL will immediately contact the Services if underwater monitoring reveals collision of a possible protected species (i.e., seabird, marine mammal, fish).
d) Divers will confirm placement of turbines avoid rocky outcrops and SAV.
e) Verification for any activities deployed between February 16 and July 15 for 60 days or more would require compensatory mitigation using the modified PNNL Habitat Conservation Calculator and conservation credit resources (NOAA NMFS 2023). The timeframe reflects time worked outside the July 16 – February 15 Tidal Reference Area 10 (Port Townsend) in water work window.

Table 22. Activity 13 (Tidal Turbine Research) Implementation Criteria

Duration	Tidal Turbine Research
1-14 Days	Verification
15-45 Days	Verification
Greater than 45 Days	Verification
Greater than 60 Days, and Outside Work Window	Verification/Mitigation

1.3.2 General Construction Measures

Projects covered under PNNL RAP must comply with the following GCMs as applicable.

1. Isolation of Concrete Work

All concrete work (from powder to formed/hardened concrete) will be placed in the dry (e.g., isolated from water) or within confined waters (i.e., within a form or cofferdam) not connected to surface waters and will be allowed to cure a minimum of seven days before contact with surface water. Should new concrete technology develop which has a quicker curing rate, information must be provided as part of the project submittal and NMFS will evaluate whether a shorter cure time will be no more impactful than the cure time evaluated in this opinion.

2. Fish Screens

Whenever diverting or pumping water to/from an isolated area, a fish screen that meets the most recent revisions of NMFS' fish screen criteria will be installed prior to and during pumping activities and will be maintained in a condition that prevents fish movement through the barrier. Fish screen criteria can be found in Chapter 11 of NMFS Anadromous Salmonid Fish Facility manual or most recent version (NMFS 2022)[5]. If at any time fish screens have damage, pumping activities and in-water work shall cease until damaged fish screens are repaired.

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[5] https://media.fisheries.noaa.gov/2022-06/anadromous-salmonid-passage-design-manual-2022.pdf

3. Treated Wood

Inorganic arsenical pressure-treated wood (chromated copper arsenate (CCA) or ammoniacal copper zinc arsenate (ACZA)) that are sealed with a wrapping or a polyurea barrier may be used in PNNL RAP. Wrappings must meet the following criteria:

a. Wrappings are made from a pre-formed plastic such as polyvinyl chloride (PVC), a fiber glass-reinforced plastic or a high-density polyethylene (HDPE) with an epoxy fill or petrolatum saturated tape (PST) inner wrap in the void between the HDPE and the pile.
b. Wrapping material used for interior pilings must be a minimum of 1/10 of an inch thick, durable enough to maintain integrity, and have all joints sealed to prevent leakage.
c. Wrapping material used for exterior pilings that come into direct contact with ocean going vessels or barges must be HDPE pile wrappings with epoxy fill or PST inner wrap.
d. The tops of all wrapped piles must be capped or sealed to prevent exposure of the treated wood surface to the water column and to prevent preservative from dripping into the water.
e. Polyurea barrier systems must meet these additional criteria:
    i. The polyurea barrier must be an impact-resistant, biologically inert coating in accordance with American Wood Protection Association M 27 standard.
    ii. The polyurea barrier must be ultraviolet light resistant and a minimum of 250 mm (0.25 inch) thick in the area that is submerged (Morrell 2017).
    iii. Polyurea barriers must be installed on dry wood that are free of loose wood, splinters, sawdust or mechanical damage.
    iv. Wrappings or polyurea barriers will extend both above and below the portion of the wood that is in contact with the water.
    v. All operations to prepare wrappings or polyurea barriers for installation (cutting, drilling, and placement of epoxy fill) will occur in a staging area away from the waterbody.
    vi. All piles with wrappings or polyurea barriers must be regularly inspected and maintained to identify unobserved failures of the wrapping or polyurea barrier or anytime a wrapping or polyurea barrier breach is observed.

Pesticide and preservative-treated wood, such as ACZA treated wood, can only be used for substructures that are not in direct exposure to leaching by precipitation, overtopping waves, or submersion.

a. Treated wood shipped to the project area will be stored out of contact with standing water and wet soil and will be protected from precipitation.
b. Each load and piece of treated wood will be visually inspected and rejected for use in or above aquatic environments if visible residue, bleeding of preservative, preservative-saturated sawdust, contaminated soil, or other dispersible materials are present.
c. Offsite prefabrication will be used whenever possible to minimize cutting, drilling and field preservative treatment over or near water.
d. When upland on-site fabrication is necessary, all drilling, and field preservative treatment of exposed treated wood will be done above the plane of the High Tide Line to minimize discharge of sawdust, drill shavings, excess preservative and other debris. Tarps, plastic tubs, or similar devices will be used to contain the bulk of any fabrication debris, and any excess field preservative will be removed from the treated wood by wiping and proper disposal to prevent run-off to marine waters. Upland, on-site, cutting of treated wood shall occur 50 feet from open water.

e. Cutting of treated wood in nearshore areas shall include means of minimizing sawdust contamination, such as vacuum dust collectors or similar means of collecting dust.
f. Evaluate all wood construction debris removed during a project to ensure proper disposal of treated wood.
g. Ensure that no treated wood debris falls into the water or, if debris does fall into the water, remove it immediately.
h. After removal, place treated wood debris in an appropriate dry storage site protected from precipitation until it can be removed from the project area.
i. Treated wood debris shall not be left in the water or stacked at or below the High Tide Line.

4. Fish Capture and Release

a. If practicable, allow listed fish species to migrate out of the work area.
b. If the fish will not leave of its own ability, fish capture should be supervised by a qualified fisheries biologist, with experience in work area isolation and competent to ensure the safe handling of all fish.
c. Report any capture/release events to NMFS.

5. Use of tires or rubbers containing 6PPD-quinone (6PPDQ)

a. Tires or rubbers containing 6PPDQ will not be used in water, or near water where it is able to flow or leach, as bumpers, anchors, weights, etc.

1.3.3 Program Administration

1. Timeline and Revisions

The DOE, NMFS, and FWS will discuss any revisions or need for re-initiation during their Annual Coordination Meeting, concurrent with the signing of this programmatic.

2. PNNL Review

During the action agencies review of the activity proposed by a researcher, the DOE/PNNL will determine whether the proposed work meets the project design criteria covered above and is therefore appropriate for coverage under the programmatic opinion:

a. The proposed work falls within the description of an activity in the proposed action and meets all applicable OPCs, Activity specific PDCs and limits, and GCMs.
b. The proposed work conforms to all applicable Terms and Conditions (T&Cs) in the Incidental Take Statements (ITS) of the PNNL RAP consultation with NMFS.
c. The proposed work includes an individual response to the applicable EFH Conservation Recommendations accepted by the PNNL.
d. The proposed work does not include or cause actions (that would not occur but for the proposed action and are reasonably certain to occur) that are specifically excluded from the proposed action.
e. The proposed work includes sufficient conservation offsets and required documentation as described in Program Administration # 5 Conservation Offsets, below, where applicable, to address impacts to the nearshore and marine environment on ESA listed species and designated critical habitat.

3. Electronic Submission
After the PNNL conducts an initial review of the proposed project and deems it appropriate for consultation under the programmatic, PNNL will send a project request verification/notification to NMFS as detailed below:

a. NMFS Submission: Submit information to PNNL-wa.wcr@noaa.gov
b. Email Subject Line: PNNL RAP Verification Request (Activity #) or PNNL RAP Notification Only (Activity #).
c. Within 5 days of receipt, NMFS will provide the PNNL an email stating the request has been received. If PNNL has not received this email within 5 days, the PNNL will seek to confirm whether NMFS has received the submitted materials.
d. NMFS will endeavor to provide a response regarding verification to the PNNL within 30 days from the date of the email submittal. The PNNL must receive an affirmative decision from NMFS before verification is complete.
e. The "notification only" scenario does not require a response.
f. The email submission will include, at a minimum, the following information:
g. Project Name
h. Applicable Activity #(s)
i. Notification/verification form (Appendix C)
j. Project Drawings
k. PNNL Habitat Conservation Calculator and documentation of offsets, if required

4. NMFS Review and Verification
Consistent with Implementation Criteria Tables above, NMFS verification is required for the following activity categories:
a. Floats and Buoys: Activity 1A-C
b. Seabed Installations: Activity 3A-B
c. Benthic Surveys: Activity 5C
d. Light Emitting Devices: Activity 9B
e. Acoustic Device Operation: Activity 10B
f. EMF Devices/Cables: Activity 11A-B
g. Community and Research Scale Marine Energy Devices: Activity 12A-B
h. Tidal Turbine Research: Activity 13

NMFS verification is not required for "notification only" categories, unless that action is part of a larger action that does require notification. Consistent with Implementation Criteria Tables above, Stand-alone "notification only" activities categories include:
a. Dock Installations: Activity 2
b. Autonomous Vehicle Surveys: Activity 4A-B
c. Benthic Surveys: Activity 5A-B
d. Water Column Sampling: Activity 6
e. Dye and Particulate Releases: Activity 7
f. Seagrass, Macroalgae, and Intertidal Research: Activity 8
g. Light Emitting Devices: Activity 9A
h. Acoustic Device Operation: Activity 10A

For activities requiring NMFS verification, as mentioned above, PNNL will submit to NMFS project information and conservation offsets (if required) to show the programmatic requirements are met. NMFS will inform PNNL via email whether it agrees that the project meets the requirements (Appendix C). If NMFS determines that the project meets PNNL RAP's requirements, the email will identify that the project can be covered under the programmatic in the opinion of NMFS, and PNNL can proceed with the project. If the project does not meet the requirements in NMFS' opinion, the email will identify which aspects of the project do not meet the PNNL RAP conditions. The PNNL and the researchers may evaluate the project and resubmit it with additional explanation if they disagree; however, NMFS will make the final determination as to whether a project meets programmatic requirements.

Applicants of non-conforming projects may choose to either modify their project to meet PNNL RAP requirements or submit a Biological Assessment and request individual ESA/EFH consultation.

As an additional program-level check on the continuing effects of the action, the DOE and NMFS will meet at least annually to review implementation of the programmatic action and opportunities to improve conservation, or make the program overall more effective or efficient. Application of the proposed design criteria and the requirement to avoid net loss of habitat quality will ensure projects carried out under PNNL RAP will not lead to a long-term loss of conservation for listed species and critical habitat.

5. Conservation Offsets

A number of activities included in the proposed action can result in the loss of nearshore and marine habitat functions and values to ESA listed species and their designated critical habitat. To provide programmatic coverage for the effects of these activities under the ESA, the action agency must ensure that the loss of habitat functions and values, resulting from individual projects, does not meaningfully aggregate over space and time. To achieve this, project modification or conservation offsets are required for proposed activities resulting in loss of habitat functions and values for ESA-listed species and critical habitat. One way, project applicants can ensure their proposed project does not result in a long-term loss of habitat function by calculating conservation offsets utilizing NMFS' modified PNNL Nearshore Calculator (Calculator) for certain activity types (details in Appendix A).

The requirement to offset impacts 1) occurring during the time of peak salmon migration and 2) impacting SAV growth in the action area, is a key feature of PNNL RAP. The previously mentioned activities (1A-C, 3A, 12A-B, 13) *may* individually result in loss of habitat quality and thus *might* require conservation offsets.

The 'may' and the 'might' in the previous sentence relate to timing and duration. A project must trigger BOTH timing and duration criteria to warrant offsets. Timing refers to work outside of Tidal Reference Area 10's in water work window, meaning projects in or above the water February 16th through July 15th. Duration refers to the amount of time a project is in or above the water, in this case 60 days or more. Said another way, if a project is in the water over 60 days to 149 days (or 150 days during a leap year) between February 16th and July 15th, offsets are required (Figure 4)[6]. If a project is in the water for 60 days outside of the work window, no offsets required. If a project were to be in the water for 2 solid years (non leap years) then 298 days (149 days x 2 years) would need to be offset.

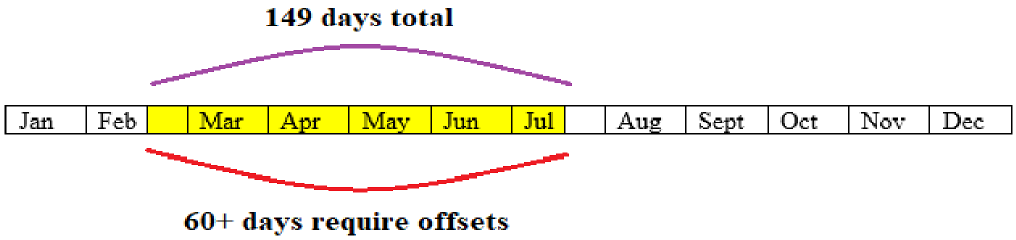

Figure 4. Non leap year offset requirement example

By requiring offsets, the PNNL RAP ensures no net-loss of habitat over time.

Activities required to have conservation offsets are likely to have some short-term impacts, but none of those impacts will have long-term adverse effects on listed species nor will they be severe enough to impair the ability of habitat to support species' conservation. The purchases of conservation bank or in-lieu fee programs credits will lead, over time, to improved habitat quality. The improvements will be off-site and possibly out-of-kind, but will remain in the Strait of Juan de Fuca Basin.

The NMFS will review each project requiring conservation offsets on a project by project basis using our Programmatic Implementations process. This check will ensure that the proposed offsets meet these requirements below and are sufficient to compensate for the associated adverse impact:

a. Conservation offsets are needed for the following activity categories:
    i. Activity #1A-C: Floats and Buoys
    ii. Activity #3A: Seabed Installations
    iii. Activity #12A-B: Community and Research Scale Marine Energy Devices
    iv. Activity #13: Tidal Turbine Research
b. Adverse effects on nearshore habitat, **over sixty days and outside of the work window**, must be offset with an equal (or greater) amount of conservation offsets (compared to project effects/debits).
    i. Purchase conservation credits from a NMFS-approved conservation bank, in-lieu fee program, and/or credit provider to support a within-basin restoration project that will improve nearshore or estuarine habitat
    ii. If PNNL purchases bulk credits from an approved conservation bank, in-lieu fee program, and/or crediting provider, and applies them to incoming projects, PNNL will keep a ledger documenting that all required offsets are covered. Purchase of the credits is between PNNL and applicants/researchers.
    iii. At the annual PNNL/NMFS/FWS meeting the ledger will be reviewed.

[6] If a project triggers both requirements, and mitigation is required, the *entire time in the water* will be calculated for offsets. Example: 3 months in work window + 3 months outside work window = 6 months in calculator.

6. Marine Mammals
Some in-water activities will shut down if marine mammals enter the zone of influence (Activities 9B, 10B, and 13). Research activities will not resume until all marine mammals have been cleared from the zone of influence and are observed to be moving away from the project site. See Appendix B for MMMP requirements.

a. Individual MMMPs will be reviewed by a NMFS biologist at time of verification of Activities 9B, 10B, and 13. The goal of a MMMP is to stop or not start work if a marine mammal is in the area where it may be affected by the project activity.
b. Guidance for developing an MMMP can be found on NOAA's website: http://www.westcoast.fisheries.noaa.gov/protected_species/marine_mammals/monitoring_plan_guidance.html

7. Monitoring and Reporting
After NMFS project verification/notification, all project notifications and reports are to be submitted electronically to NMFS at projectreports.wcr@noaa.gov (notice this a different email address than the PNNL inbox). This includes:

a. If applicable, conservation offset documentation must be provided to NMFS for each project to be completed under this programmatic consultation.
b. Annual Program Report. The PNNL will submit an Annual Report to the NMFS at PNNL-wa.wcr@noaa.gov each year. NMFS and the DOE/PNNL will develop the parameters of the report within six months of signature of this opinion for these programmatic consultations.
c. Annual Coordination Meeting. The Agencies will meet annually to discuss the Annual Report and any actions that can improve conservation, efficiency, or comprehensiveness under these programmatic consultations.

2. ENDANGERED SPECIES ACT CONFERENCE/BIOLOGICAL OPINION, AND INCIDENTAL TAKE STATEMENT

The ESA establishes a national program for conserving threatened and endangered species of fish, wildlife, plants, and the habitat upon which they depend. As required by section 7(a)(2) of the ESA, each federal agency must ensure that its actions are not likely to jeopardize the continued existence of endangered or threatened species, or adversely modify or destroy their designated critical habitat. Per the requirements of the ESA, federal action agencies consult with NMFS and section 7(b)(3) requires that, at the conclusion of consultation, NMFS provide an opinion stating how the agency's actions would affect listed species and their critical habitats. If incidental take is reasonably certain to occur, section 7(b)(4) requires NMFS to provide an ITS that specifies the impact of any incidental taking and includes reasonable and prudent measures (RPMs) and terms and conditions to minimize such impacts.

2.1 Analytical Approach

This opinion includes both a jeopardy analysis and an adverse modification analysis. The jeopardy analysis relies upon the regulatory definition of "jeopardize the continued existence of" a listed species, which is “to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species” (50 CFR 402.02). Therefore, the jeopardy analysis considers both survival and recovery of the species.

This opinion relies on the definition of “destruction or adverse modification,” which “means a direct or indirect alteration that appreciably diminishes the value of critical habitat as a whole for the conservation of a listed species” (50 CFR 402.02).

The designation(s) of critical habitat for (species) use(s) the term primary constituent element (PCE) or essential features. The 2016 critical habitat regulations (50 CFR 424.12) replaced this term with physical or biological features (PBFs). The shift in terminology does not change the approach used in conducting a “destruction or adverse modification” analysis, which is the same regardless of whether the original designation identified PCEs, PBFs, or essential features. In this opinion, we use the term PBF to mean PCE or essential feature, as appropriate for the specific critical habitat.

The 2019 regulations define effects of the action using the term “consequences” (50 CFR 402.02). As explained in the preamble to the regulations (84 FR 44977), that definition does not change the scope of our analysis and in this opinion, we use the terms “effects” and “consequences” interchangeably.

We use the following approach to determine whether a proposed action is likely to jeopardize listed species or destroy or adversely modify critical habitat:

- Evaluate the rangewide status of the species and critical habitat expected to be adversely affected by the proposed action.
- Evaluate the environmental baseline of the species and critical habitat.
- Evaluate the effects of the proposed action on species and their habitat using an exposure-response approach.
- Evaluate cumulative effects.
- In the integration and synthesis, add the effects of the action and cumulative effects to the environmental baseline, and, in light of the status of the species and critical habitat, analyze whether the proposed action is likely to: (1) directly or indirectly reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species, or (2) directly or indirectly result in an alteration that appreciably diminishes the value of critical habitat as a whole for the conservation of a listed species.
- If necessary, suggest a reasonable and prudent alternative to the proposed action.

The PNNL RAP requires projects authorized under this programmatic action do not result in a net-loss of habitat quality. The NMFS’ modified Habitat Calculator (Calculator) is an available tool which can be used to ensure no-net loss of habitat quality (Appendix A).

All of the Activities have a highly variable time range of “1 day to 2 years”, depending on the research needs. Though projects may take place over multiple years, projects will require re-verification every 2 years. For this analysis, we are assuming a short term of one day exposure and a longer-term, 2-year exposure. Both short-term and long-term exposures are analyzed for effects inside and outside of the work window.

The conference opinion evaluates anticipated adverse effects on sunflower sea stars in order to determine the risk of jeopardy to this species caused by the proposed actions.

2.2 Rangewide Status of the Species and Critical Habitat

This opinion examines the status of each species that would be adversely affected by the proposed action. The status is determined by the level of extinction risk that the listed species face, based on parameters considered in documents such as recovery plans, status reviews, and listing decisions. This informs the description of the species’ likelihood of both survival and recovery. The species status section also helps to inform the description of the species’ current “reproduction, numbers, or distribution” as described in 50 CFR 402.02. The opinion also examines the condition of critical habitat throughout the designated area, evaluates the conservation value of the various watersheds and coastal and marine environments that make up the designated area, and discusses the current function of the essential PBFs that help to form that conservation value.

One factor affecting the status of ESA-listed species considered in this opinion, and aquatic habitat at large, is climate change. Climate change is likely to play an increasingly important role in determining the abundance and distribution of ESA-listed species, and the conservation value of designated critical habitats, in the Pacific Northwest. These changes will not be spatially homogeneous across the Pacific Northwest. Major ecological realignments are already occurring in response to climate change (IPCC WGII, 2022). Long-term trends in warming have continued at global, national and regional scales. Global surface temperatures in the last decade (2010s) were estimated to be 1.09 °C higher than the 1850-1900 baseline period, with larger increases over land ~1.6 °C compared to oceans ~0.88 (IPCC WGI, 2021). The vast majority of this warming has been attributed to anthropogenic releases of greenhouse gases (IPCC WGI, 2021). Globally, 2014-2018 were the 5 warmest years on record both on land and in the ocean (2018 was the 4th warmest) (NOAA NCEI 2022). Events such as the 2013-2016 marine heatwave (Jacox et al. 2018) have been attributed directly to anthropogenic warming in the annual special issue of Bulletin of the American Meteorological Society on extreme events (Herring et al. 2018). Global warming and anthropogenic loss of biodiversity represent profound threats to ecosystem functionality (IPCC WGII 2022). These two factors are often examined in isolation, but likely have interacting effects on ecosystem function.

Updated projections of climate change are similar to or greater than previous projections (IPCC WGI, 2021). NMFS is increasingly confident in our projections of changes to freshwater and marine systems because every year brings stronger validation of previous predictions in both physical and biological realms. Retaining and restoring habitat complexity, access to climate refuges (both flow and temperature) and improving growth opportunity in both freshwater and marine environments are strongly advocated in the recent literature (Siegel and Crozier 2020).

Climate change is systemic, influencing freshwater, estuarine, and marine conditions. Other systems are also being influenced by changing climatic conditions. Literature reviews on the impacts of climate change on Pacific salmon (Crozier 2015, 2016, 2017, Crozier and Siegel 2018, Siegel and Crozier 2019, 2020) have collected hundreds of papers documenting the major themes relevant for salmon. Here we describe habitat changes relevant to Pacific salmon and steelhead, prior to describing how these changes result in the varied specific mechanisms impacting these species in subsequent sections.

Forests

Climate change will impact forests of the western U.S., which dominate the landscape of many watersheds in the region. Forests are already showing evidence of increased drought severity, forest fire, and insect outbreak (Halofsky et al. 2020). Additionally, climate change will affect tree reproduction, growth, and phenology, which will lead to spatial shifts in vegetation. Halofsky et al. (2018) projected that the largest changes will occur at low- and high-elevation forests, with expansion of low-elevation dry forests and diminishing high-elevation cold forests and subalpine habitats.

Forest fires affect salmon streams by altering sediment load, channel structure, and stream temperature through the removal of canopy. Holden et al. (2018) examined environmental factors contributing to observed increases in the extent of forest fires throughout the western U.S. They found strong correlations between the number of dry-season rainy days and the annual extent of forest fires, as well as a significant decline in the number of dry-season rainy days over the study period (1984-2015). Consequently, predicted decreases in dry-season precipitation, combined with increases in air temperature, will likely contribute to the existing trend toward more extensive and severe forest fires and the continued expansion of fires into higher elevation and wetter forests (Alizedeh 2021).

Agne et al. (2018) reviewed literature on insect outbreaks and other pathogens affecting coastal Douglas-fir forests in the Pacific Northwest and examined how future climate change may influence disturbance ecology. They suggest that Douglas-fir beetle and black stain root disease could become more prevalent with climate change, while other pathogens will be more affected by management practices. Agne et al. (2018) also suggested that due to complex interacting effects of disturbance and disease, climate impacts will differ by region and forest type.

Freshwater Environments

The following is excerpted from Siegel and Crozier (2019), who present a review of recent scientific literature evaluating effects of climate change, describing the projected impacts of climate change on instream flows:

Cooper et al. (2018) examined whether the magnitude of low river flows in the western U.S., which generally occur in September or October, are driven more by summer conditions or the prior winter's precipitation. They found that while low flows were more sensitive to summer evaporative demand than to winter precipitation, interannual variability in winter precipitation was greater. Malek et al. (2018), predicted that summer evapotranspiration is likely to increase in conjunction with declines in snowpack and increased variability in winter precipitation. Their results suggest that low summer flows are likely to become lower, more variable, and less predictable.

The effect of climate change on ground water availability is likely to be uneven. Sridhar et al. (2018) coupled a surface-flow model with a ground-flow model to improve predictions of surface water availability with climate change in the Snake River Basin. Projections using RCP 4.5 and 8.5 emission scenarios suggested an increase in water table heights in downstream areas of the basin and a decrease in upstream areas.

As cited in Siegel and Crozier (2019), Isaak et al. (2018), examined recent trends in stream temperature across the Western U.S. using a large regional dataset. Stream warming trends paralleled changes in air temperature and were pervasive during the low-water warm seasons of 1996-2015 (0.18-0.35°C/decade) and 1976-2015 (0.14-0.27°C/decade). Their results show how continued warming will likely affect the cumulative temperature exposure of migrating sockeye salmon *O. nerka* and the availability of suitable habitat for brown trout *Salmo trutta* and rainbow trout *O. mykiss*. Isaak et al. (2018) concluded that most stream habitats will likely remain suitable for salmonids in the near future, with some becoming too warm. However, in cases where habitat access is currently restricted by dams and other barriers salmon and steelhead will be confined to downstream reaches typically most at risk of rising temperatures unless passage is restored (FitzGerald et al. 2020, Myers et al. 2018).

Streams with intact riparian corridors and that lie in mountainous terrain are likely to be more resilient to changes in air temperature. These areas may provide refuge from climate change for a number of species, including Pacific salmon. Krosby et al. (2018), identified potential stream refugia throughout the Pacific Northwest based on a suite of features thought to reflect the ability of streams to serve as such refuges. Analyzed features include large temperature gradients, high canopy cover, large relative stream width, low exposure to solar radiation, and low levels of human modification. They created an index of refuge potential for all streams in the region, with mountain area streams scoring highest. Flat lowland areas, which commonly contain migration corridors, were generally scored lowest, and thus were prioritized for conservation and restoration. However, forest fires can increase stream temperatures dramatically in short time-spans by removing riparian cover (Koontz et al. 2018), and streams that lose their snowpack with climate change may see the largest increases in stream temperature due to the removal of temperature buffering (Yan et al. 2021). These processes may threaten some habitats that are currently considered refugia.

Marine and Estuarine Environments

Along with warming stream temperatures and concerns about sufficient groundwater to recharge streams, a recent study projects nearly complete loss of existing tidal wetlands along the U.S. West Coast, due to sea level rise (Thorne et al. 2018). California and Oregon showed the greatest threat to tidal wetlands (100%), while 68% of Washington tidal wetlands are expected to be submerged. Coastal development and steep topography prevent horizontal migration of most wetlands, causing the net contraction of this crucial habitat.

Rising ocean temperatures, stratification, ocean acidity, hypoxia, algal toxins, and other oceanographic processes will alter the composition and abundance of a vast array of oceanic species. In particular, there will be dramatic changes in both predators and prey of Pacific salmon, salmon life history traits and relative abundance. Siegel and Crozier (2019) observe that changes in marine temperature are likely to have a number of physiological consequences on fishes themselves. For example, in a study of small planktivorous fish, Gliwicz et al. (2018) found that higher ambient temperatures increased the distance at which fish reacted to prey. Numerous fish species (including many tuna and sharks) demonstrate regional endothermy, which in many cases augments eyesight by warming the retinas. However, Gliwicz et al. (2018) suggest that ambient temperatures can have a similar effect on fish that do not demonstrate this trait. Climate change is likely to reduce the availability of biologically essential omega-3 fatty acids produced by phytoplankton in marine ecosystems. Loss of these lipids may induce cascading trophic effects, with distinct impacts on different species depending on compensatory mechanisms (Gourtay et al. 2018). Reproduction rates of many marine fish species are also likely to be altered with temperature (Veilleux et al. 2018). The ecological consequences of these effects and their interactions add complexity to predictions of climate change impacts in marine ecosystems.

Perhaps the most dramatic change in physical ocean conditions will occur through ocean acidification and deoxygenation. It is unclear how sensitive salmon and steelhead might be to the direct effects of ocean acidification because of their tolerance of a wide pH range in freshwater (although see Ou et al. 2015 and Williams et al. 2019), however, impacts of ocean acidification and hypoxia on sensitive species (e.g., plankton, crabs, rockfish, groundfish) will likely affect salmon indirectly through their interactions as predators and prey. Similarly, increasing frequency and duration of harmful algal blooms may affect salmon directly, depending on the toxin (e.g., saxitoxin vs domoic acid), but will also affect their predators (seabirds and mammals). The full effects of these ecosystem dynamics are not known but will be complex. Within the historical range of climate variability, less suitable conditions for salmonids (e.g., warmer temperatures, lower streamflows) have been associated with detectable declines in many of these listed units, highlighting how sensitive they are to climate drivers (Ford 2022, Lindley et al. 2009, Williams et al. 2016, Ward et al. 2015). In some cases, the combined and potentially additive effects of poorer climate conditions for fish and intense anthropogenic impacts caused the population declines that led to these population groups being listed under the ESA (Crozier et al. 2019).

Climate change effects on salmon and steelhead

In freshwater, year-round increases in stream temperature and changes in flow will affect physiological, behavioral, and demographic processes in salmon, and change the species with which they interact. For example, as stream temperatures increase, many native salmonids face increased competition with more warm-water tolerant invasive species. Changing freshwater temperatures are likely to affect incubation and emergence timing for eggs, and in locations where the greatest warming occurs may affect egg survival, although several factors impact intergravel temperature and oxygen (e.g., groundwater influence) as well as sensitivity of eggs to thermal stress (Crozier et al. 2021). Changes in temperature and flow regimes may alter the amount of habitat and food available for juvenile rearing, and this in turn could lead to a restriction in the distribution of juveniles, further decreasing productivity through density dependence. For migrating adults, predicted changes in freshwater flows and temperatures will likely increase exposure to stressful temperatures for many salmon and steelhead populations, and alter migration travel times and increase thermal stress accumulation for ESUs or DPSs with early-returning (i.e. spring- and summer-run) phenotypes associated with longer freshwater holding times (Crozier et al. 2021, FitzGerald et al. 2020). Rising river temperatures increase the energetic cost of migration and the risk of *en route* or pre-spawning mortality of adults with long freshwater migrations, although populations of some ESA-listed salmon and steelhead may be able to make use of cool-water refuges and run-timing plasticity to reduce thermal exposure (Keefer et al. 2018, Barnett et al. 2020).

Marine survival of salmonids is affected by a complex array of factors including prey abundance, predator interactions, the physical condition of salmon within the marine environment, and carryover effects from the freshwater experience (Holsman et al. 2012, Burke et al. 2013). It is generally accepted that salmon marine survival is size-dependent, and thus larger and faster growing fish are more likely to survive (Gosselin et al. 2021). Furthermore, early arrival timing in the marine environment is generally considered advantageous for populations migrating through the Columbia River. However, the optimal day of arrival varies across years, depending on the seasonal development of productivity in the California Current, which affects prey available to salmon and the risk of predation (Chasco et al. 2021). Siegel and Crozier (2019) point out the concern that for some salmon populations, climate change may drive mismatches between juvenile arrival timing and prey availability in the marine environment. However, phenological diversity can contribute to metapopulation-level resilience by reducing the risk of a complete mismatch. Carr-Harris et al. (2018), explored phenological diversity of marine migration timing in relation to zooplankton prey for sockeye salmon *O. nerka* from the Skeena River of Canada. They found that sockeye migrated over a period of more than 50 days, and populations from higher elevation and further inland streams arrived in the estuary later, with different populations encountering distinct prey fields. Carr-Harris et al. (2018) recommended that managers maintain and augment such life-history diversity.

Synchrony between terrestrial and marine environmental conditions (e.g., coastal upwelling, precipitation and river discharge) has increased in spatial scale causing the highest levels of synchrony in the last 250 years (Black et al. 2018). A more synchronized climate combined with simplified habitats and reduced genetic diversity may be leading to more synchrony in the productivity of populations across the range of salmon (Braun et al. 2016). For example, salmon productivity (recruits/spawner) has also become more synchronized across Chinook populations from Oregon to the Yukon (Dorner et al. 2018, Kilduff et al. 2014). In addition, Chinook salmon have become smaller and younger at maturation across their range (Ohlberger 2018). Other Pacific salmon species (Stachura el al. 2014) and Atlantic salmon (Olmos et al. 2020) also have demonstrated synchrony in productivity across a broad latitudinal range.

At the individual scale, climate impacts on salmon in one life stage generally affect body size or timing in the next life stage and negative impacts can accumulate across multiple life stages (Healey 2011; Wainwright and Weitkamp 2013, Gosselin et al. 2021). Changes in winter precipitation will likely affect incubation and/or rearing stages of most populations. Changes in the intensity of cool season precipitation, snow accumulation, and runoff could influence migration cues for fall, winter and spring adult migrants, such as coho and steelhead. Egg survival rates may suffer from more intense flooding that scours or buries redds. Changes in hydrological regime, such as a shift from mostly snow to more rain, could drive changes in life history, potentially threatening diversity within an ESU (Beechie et al. 2006). Changes in summer temperature and flow will affect both juvenile and adult stages in some populations, especially those with yearling life histories and summer migration patterns (Crozier and Zabel 2006; Crozier et al. 2010, Crozier et al. 2019).

At the population level, the ability of organisms to genetically adapt to climate change depends on how much genetic variation currently exists within salmon populations, as well as how selection on multiple traits interact, and whether those traits are linked genetically. While genetic diversity may help populations respond to climate change, the remaining genetic diversity of many populations is highly reduced compared to historic levels. For example, Johnson et al. (2018), compared genetic variation in Chinook salmon from the Columbia River Basin between contemporary and ancient samples. A total of 84 samples determined to be Chinook salmon were collected from vertebrae found in ancient middens and compared to 379 contemporary samples. Results suggest a decline in genetic diversity, as demonstrated by a loss of mitochondrial haplotypes as well as reductions in haplotype and nucleotide diversity. Genetic losses in this comparison appeared larger for Chinook from the mid-Columbia than those from the Snake River Basin. In addition to other stressors, modified habitats and flow regimes may create unnatural selection pressures that reduce the diversity of functional behaviors (Sturrock et al. 2020). Managing to conserve and augment existing genetic diversity may be increasingly important with more extreme environmental change (Anderson et al. 2015), though the low levels of remaining diversity present challenges to this effort (Freshwater 2019). Salmon historically maintained relatively consistent returns across variation in annual weather through the portfolio effect (Schindler et al. 2015), in which different populations are sensitive to different climate drivers. Applying this concept to climate change, Anderson et al (2015) emphasized the additional need for populations with different physiological tolerances. Loss of the portfolio increases volatility in fisheries, as well as ecological systems, as demonstrated for Fraser River and Sacramento River stock complexes (Freshwater et al. 2019, Munsch et al. 2022).

Throughout Sections 2.2.1 and 2.2.2 below yellow highlight denotes species, populations, or physical and biological features of designated critical habitat affected by the proposed action.

2.2.1 Status of the Species

For Pacific salmon, steelhead, and certain other species, we commonly use the four "viable salmonid population" (VSP) criteria (McElhany et al. 2000) to assess the viability of the populations that, together, constitute the species. These four criteria (spatial structure, diversity, abundance, and productivity) encompass the species' "reproduction, numbers, or distribution" as described in 50 CFR 402.02. When these parameters are collectively at appropriate levels, they maintain a population's capacity to adapt to various environmental conditions and allow it to sustain itself in the natural environment.

Spatial structure" refers both to the spatial distributions of individuals in the population and the processes that generate that distribution. A population's spatial structure depends on habitat quality and spatial configuration, and the dynamics and dispersal characteristics of individuals in the population.

“Diversity” refers to the distribution of traits within and among populations. These range in scale from DNA sequence variation in single genes to complex life history traits (McElhany et al. 2000).

“Abundance” generally refers to the number of naturally produced adults (i.e., the progeny of naturally spawning parents) in the natural environment (e.g., on spawning grounds).

“Productivity,” as applied to viability factors, refers to the entire life cycle (i.e., the number of naturally-spawning adults produced per parent). When progeny replace or exceed the number of parents, a population is stable or increasing. When progeny fail to replace the number of parents, the population is declining. McElhany et al. (2000) use the terms “population growth rate” and “productivity” interchangeably when referring to production over the entire life cycle. They also refer to “trend in abundance,” which is the manifestation of long-term population growth rate.

For species with multiple populations, once the biological status of a species’ populations has been determined, we assess the status of the entire species using criteria for groups of populations, as described in recovery plans and guidance documents from technical recovery teams. Considerations for species viability include having multiple populations that are viable, ensuring that populations with unique life histories and phenotypes are viable, and that some viable populations are both widespread to avoid concurrent extinctions from mass catastrophes and spatially close to allow functioning as metapopulations (McElhany et al. 2000).

The summaries that follow describe the status of the ESA-listed species, and their designated critical habitats, that occur within the geographic area of this proposed action and are considered in this Opinion. More detailed information on the status and trends of these listed resources, and their biology and ecology, are in the listing regulations and critical habitat designations published in the Federal Register (Table 23).

Table 23. Listing status, status of critical habitat designations and protective regulations, and relevant Federal Register (FR) decision notices for ESA-listed species considered in this Opinion. Listing status: 'T' means listed as threatened; 'E' means listed as endangered.

Species	Listing Status	Critical Habitat
PS Chinook salmon (*Oncorhynchus tshawytscha*)	T 6/28/05; 70 R 37160	9/02/05; 70 FR 52630
Hood Canal Summer Run Chum (*Oncorhynchus keta*)	T 6/28/05; 70 R 37160	9/02/05; 70 FR 52630
PS Steelhead (*Oncorhynchus mykiss*)	T 5/11/07; 72 FR 26722	2/24/16 81 FR 9252
PS/GB Yelloweye Rockfish (*Sebastes ruberrimus*)	T 4/28/10; 75 FR 22276	2/11/15; 79 FR 68401
PS/GB Bocaccio (*Sebastes paucispinis*)	T 4/28/10; 75 FR 22276	2/11/15; 79 FR 68401
Eulachon, Southern DPS (*Thaleichthys pacificus*)	T 3/18/10; 75 FR 13012	10/20/11; 76 FR 65324
Green Sturgeon, Southern DPS (*Acipenser medirostris*)	T 4/07/06; 71 FR 17757	10/09/09; 74 FR 52300
Southern Resident Killer whale (*Orcinus area*)	E 11/18/05; 70 FR 69903	11/29/06; 79 FR 69054 2/02/21; 86 FR 41668
Humpback Whale Central American DPS (*Megaptera novaeangliae*)	E 9/08/16; 81 FR 62259	4/21/21; 86 FR 21082
Humpback Whale Mexico DPS (*Megaptera novaeanrliae*)	T 9/08/16; 81 FR 62259	4/21/21; 86 FR 21082

Status of PS Chinook Salmon

The Puget Sound Chinook salmon evolutionarily significant unit (ESU) was listed as threatened on June 28, 2005 (70 FR 37160). We adopted the recovery plan for this ESU in January 2007. The recovery plan consists of two documents: the Puget Sound salmon recovery plan (Shared Strategy for Puget Sound 2007) and a supplement by NMFS (2006). The recovery plan adopts ESU and population level viability criteria recommended by the Puget Sound Technical Recovery Team (PSTRT) (Ruckelshaus et al. 2002). The PSTRT's biological recovery criteria will be met when all of the following conditions are achieved:

- The viability status of all populations in the ESU is improved from current conditions, and when considered in the aggregate, persistence of the ESU is assured;
- Two to four Chinook salmon populations in each of the five biogeographical regions of the ESU achieve viability, depending on the historical biological characteristics and acceptable risk levels for populations within each region;
- At least one population from each major genetic and life history group historically present within each of the five biogeographical regions is viable;
- Tributaries to Puget Sound not identified as primary freshwater habitat for any of the 22 identified populations are functioning in a manner that is sufficient to support an ESU-wide recovery scenario; Production of Chinook salmon from tributaries to Puget Sound

not identified as primary freshwater habitat for any of the 22 identified populations occurs in a manner consistent with ESU recovery; and

- Populations that do not meet the viability criteria for all VSP parameters are sustained to provide ecological functions and preserve options for ESU recovery.

Spatial Structure and Diversity. The Puget Sound Chinook salmon ESU includes all naturally spawning populations of Chinook salmon from rivers and streams flowing into Puget Sound including the Strait of Juan De Fuca from the Elwha River, eastward, including rivers and streams flowing into Hood Canal, South Sound, North Sound and the Strait of Georgia in Washington. The ESU also includes the progeny of numerous artificial propagation programs (NWFSC 2015; Ford 2022). The PSTRT identified 22 extant populations, grouped into five major geographic regions, based on consideration of historical distribution, geographic isolation, dispersal rates, genetic data, life history information, population dynamics, and environmental and ecological diversity. The PSTRT distributed the 22 populations among five major biogeographical regions, or major population groups (MPG), that are based on similarities in hydrographic, biogeographic, and geologic characteristics (Table 24. Extant PS Chinook salmon populations in each biogeographic region (Ford 2022)).

Between 1990 and 2014, the proportion of natural-origin spawners has trended downward across the ESU, with the Whidbey Basin the only MPG with consistently high fractions of natural-origin spawner abundance. All other MPG have either variable or declining spawning populations with high proportions of hatchery-origin spawners (Ford 2022).Overall, the new information on abundance, productivity, spatial structure and diversity since the 2010 status review supports no change in the biological risk category (Ford 2022).

Abundance and Productivity. Available data on total abundance since 1980 indicate that although abundance trends have fluctuated between positive and negative for individual populations, there are widespread negative trends in natural-origin Chinook salmon spawner abundance across the ESU (NWFSC 2015). Productivity remains low in most populations, and hatchery-origin spawners are present in high fractions in most populations outside of the Skagit watershed. Available data now shows that most populations have declined in abundance over the past 7 to 10 years. Further, escapement levels for all populations remain well below the technical recovery team (TRT) planning ranges for recovery, and most populations are consistently below the spawner-recruit levels identified by the TRT as consistent with recovery (Ford 2022).

Limiting Factors. Limiting factors for this species include:

- Degraded floodplain and in-river channel structure
- Degraded estuarine conditions and loss of estuarine habitat
- Riparian area degradation and loss of in-river large woody debris
- Excessive fine-grained sediment in spawning gravel
- Degraded water quality and temperature
- Degraded nearshore conditions
- Impaired passage for migrating fish
- Altered flow regime

Table 24. Extant PS Chinook salmon populations in each biogeographic region (Ford 2022). **Yellow highlight denotes area and population/s affected by the proposed action.**

Biogeographic Region	Population (Watershed)
Strait of Georgia	North Fork Nooksack River
	South Fork Nooksack River
Strait of Juan de Fuca	Elwha River
	Dungeness River
Hood Canal	Skokomish River
	Mid Hood Canal River
Whidbey Basin	Skykomish River
	Snoqualmie River
	North Fork Stillaguamish River
	South Fork Stillaguamish River
	Upper Skagit River
	Lower Skagit River
	Upper Sauk River
	Lower Sauk River
	Suiattle River
	Upper Cascade River
Central/South Puget Sound Basin	Cedar River
	North Lake Washington/ Sammamish River
	Green/Duwamish River
	Puyallup River
	White River
	Nisqually River

Status of Hood Canal Summer-run Chum Salmon

We adopted a recovery plan for HCSR chum salmon in May of 2007. The recovery plan consists of two documents: the Hood Canal and Eastern Strait of Juan de Fuca Summer Chum Salmon Recovery Plan (Hood Canal Coordinating Council 2005) and a supplemental plan by NMFS (2007). The recovery plan adopts ESU and population level viability criteria recommended by the PSTRT (Sands et al. 2007). The PSTRT's biological recovery criteria will be met when the following conditions are achieved:

- Spatial Structure: 1) Spawning aggregations are distributed across the historical range of the population. 2) Most spawning aggregations are within 20 km of adjacent aggregations. 3) Major spawning aggregations are distributed across the historical range of the population and are not more than approximately 40 km apart. Further, a viable population has spawning, rearing, and migratory habitats that function in a manner that is consistent with population persistence
- Diversity: Depending on the geographic extent and ecological context of the population, a viable population includes one or more persistent spawning aggregations from each of the two to four major ecological diversity groups historically present within the two populations (see also McElhany et al. 2000).

- Abundance and Productivity: Achievement of minimum abundance levels associated with persistence of HCSR Chum ESU populations that are based on two assumptions about productivity and environmental response (Table 25).

Table 25. HCSR chum ESU abundance and productivity recovery goals (Sands et al. 2007). **Yellow highlight denotes area and population affected by the proposed action.**

Population	Low Productivity Planning Target for Abundance (productivity in parentheses)	High Productivity Planning Target for Abundance (productivity in parentheses)
Strait of Juan de Fuca	12,500 (1.0)	4,500 (5.0)
Hood Canal	24,700 (1.0)	18,300 (5.0)

Despite substantive gains towards meeting viability criteria in the Hood Canal and Strait of Juan de Fuca summer chum salmon populations, the ESU still does not meet all of the recovery criteria for population viability at this time (Ford 2022).

Spatial Structure and Diversity. The ESU includes all naturally spawning populations of summer-run chum salmon in Hood Canal tributaries as well as populations in Olympic Peninsula rivers between Hood Canal and Dungeness Bay, Washington, as well as several artificial propagation programs. The PSTRT identified two independent populations for the HCSR chum, one which includes the spawning aggregations from rivers and creeks draining into the Strait of Juan de Fuca, and one which includes spawning aggregations within Hood Canal proper (Sands et al. 2009).

Spatial structure and diversity measures for the HCSR chum recovery program have included the reintroduction and sustaining of natural-origin spawning in multiple small streams where summer chum spawning aggregates had been extirpated. Supplementation programs have been very successful in both increasing natural spawning abundance in six of eight extant streams (Salmon, Big Quilcene, Lilliwaup, Hamma Hamma, Jimmycomelately, and Union) and increasing spatial structure due to reintroducing spawning aggregations to three streams (Big Beef, Tahuya, and Chimacum). Spawning aggregations are present and persistent within five of the six major ecological diversity groups identified by the PSTRT (Table 26). As supplementation program goals have been met in most locations, they have been terminated except in Lilliwaup/Tahuya, where supplementation is ongoing (Ford 2022). Spatial structure and diversity viability parameters for each population have increased and nearly meet the viability criteria.

Table 26. Seven ecological diversity groups as proposed by the PSTRT for the HCSR Chum ESU by geographic region and associated spawning aggregation. **Yellow highlight denotes area and populations affected by the proposed action.**

Geographic Region(population)	Proposed Ecological Diversity Groups	Spawning aggregations: Extant* and extinct**
Eastern Strait of Juan de Fuca	Dungeness	Dungeness River (unknown)
	Sequim-Admiralty	Jimmycomelately Creek*, Salmon Creek*, Snow Creek*, Chimacum Creek**
Hood Canal	Toandos	Unknown
	Quilcene	Big Quilcene River*, Little Quilcene River*
	Mid-West Hood Canal	Dosewallips River*, Duckabush River*
	West Kitsap	Big Beef Creek**, Seabeck Creek**, Stavis Creek**, Anderson Creek**, Dewatto River**, Tahuya River**, Mission Creek**, Union River*
	Lower West Hood Canal	Hamma Hamma River*, Lilliwaup Creek*, Skokomish River*

Abundance and Productivity. Smoothed trends in estimated total and natural population spawning abundances for both Hood Canal and Strait of Juan de Fuca populations have generally increased over the 1980 to 2014 time period. The Hood Canal population has had a 25 percent increase in abundance of natural-origin spawners in the most recent 5-year time period over the 2005-2009 time period. The Strait of Juan de Fuca has had a 53 percent increase in abundance of natural-origin spawners in the most recent 5-year time period.

Trends in population productivity, estimated as the log of the smoothed natural spawning abundance in year t minus the smoothed natural spawning abundance in year (t-4), have increasing over the past five years, and were above replacement rates in the 2012 and 2013. However, productivity rates have been varied above and below replacement rates over the entire time period up to 2014. Point No Point Treaty Tribes and WDFW (2014) provide a detailed analysis of productivity for the ESU, each population, and by individual spawning aggregation, and report that three of the eleven stocks exceeded the co-manager’s interim productivity goal of an average of 1.6 Recruit/Spawner over eight years. They also report that natural-origin Recruit/Spawner rates have been highly variable in recent brood years, particularly in the Strait of Juan de Fuca population. Only one spawning aggregation (Chimacum) meets the comanager’s interim recovery goal of 1.2 recruits per spawner in six of most recent eight years. Productivity of individual spawning aggregates shows only two of eight aggregates have viable performance. (Ford 2022).

Limiting factors. Limiting factors for this species include (Hood Canal Coordinating Council 2005):

- Reduced floodplain connectivity and function
- Poor riparian condition
- Loss of channel complexity (reduced large wood and channel condition, loss of side channels, channel instability)
- Sediment accumulation
- Altered flows and water quality

Status of PS Steelhead

The PS Steelhead TRT produced viability criteria, including population viability analyses, for 20 of 32 demographically independent populations (DIPs) and three MPGs in the DPS (Hard 2015). It also completed a report identifying historical populations of the DPS (Myers et al. 2015). The DIPs are based on genetic, environmental, and life history characteristics. Populations display winter, summer, or summer/winter run timing (Myers et al. 2015). The steelhead TRT concludes that the DPS is currently at "very low" viability, with most of the 32 DIPs and all three MPGs at "low" viability.

The designation of the DPS as "threatened" is based upon the extinction risk of the component populations. Hard 2015, identify several criteria for the viability of the DPS, including that a minimum of 40 percent of summer-run and 40 percent of winter-run populations historically present within each of the MPGs must be considered viable using the VSP-based criteria. For a DIP to be considered viable, it must have at least an 85 percent probability of meeting the viability criteria, as calculated by Hard (2015).

On December 27, 2019, NMFS published a recovery plan for PS steelhead (84 FR 71379) (NMFS 2019). The plan indicates that within each of the three MPGs, at least fifty percent of the populations must achieve viability, *and* specific DIPs must also be viable (Table 27).

Table 27. PS steelhead MPGs. **Yellow highlight denotes area and population affected by the proposed action.**

<table>
<tr><th>Geographic Region(population)</th><th>Subcategory</th><th colspan="2">Spawning aggregations</th></tr>
<tr><td rowspan="8">Central and South Puget Sound MPG</td><td rowspan="4"></td><td colspan="2">Green River Winter-Run</td></tr>
<tr><td colspan="2">Nisqually River Winter-Run</td></tr>
<tr><td colspan="2">Puyallup/Carbon Rivers Winter-Run</td></tr>
<tr><td colspan="2">White River Winter-Run</td></tr>
<tr><td rowspan="4">At least one additional DIP from this MPG</td><td colspan="2">Cedar River</td></tr>
<tr><td colspan="2">North Lake Washington/Sammamish Tributaries</td></tr>
<tr><td colspan="2">South Puget Sound Tributaries</td></tr>
<tr><td colspan="2">East Kitsap Peninsula Tributaries</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td rowspan="8">Hood Canal and Strait of Juan de Fuca MPG</td><td rowspan="2"></td><td colspan="2">Elwha River Winter/Summer-Run</td></tr>
<tr><td colspan="2">Skokomish River Winter-Run</td></tr>
<tr><td rowspan="3">One from the remaining Hood Canal populations</td><td colspan="2">West Hood Canal Tributaries Winter Run</td></tr>
<tr><td colspan="2">East Hood Canal Tributaries Winter-Run</td></tr>
<tr><td colspan="2">South Hood Canal Tributaries Winter Run</td></tr>
<tr><td rowspan="3">One from the remaining Strait of Juan de Fuca populations</td><td colspan="2">Dungeness Winter-Run</td></tr>
<tr><td colspan="2">Strait of Juan de Fuca Tributaries Winter-Run</td></tr>
<tr><td colspan="2">Sequim/Discovery Bay Tributaries Winter-Run</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td rowspan="5">North Cascades MPG: Of the eleven DIPs with winter or winter/summer runs, five must be viable</td><td>(1) One from the Nooksack River Winter-Run</td><td rowspan="5">Of the five summer-run DIPs in this MPG, three must be viable representing in each of the three major watersheds containing summer-run populations</td><td rowspan="2">South Fork Nooksack River Summer-Run</td></tr>
<tr><td>(2) One from the Stillaguamish River Winter-Run</td></tr>
<tr><td>(3) One from the Skagit River (either the Skagit River Summer-Run and Winter-Run or the Sauk River Summer-Run and Winter-Run)</td><td>One DIP from the Stillaguamish River (Deer Creek Summer-Run or Canyon Creek Summer-Run)</td></tr>
<tr><td>(4) One from the Snohomish River watershed (Pilchuck, Snoqualmie, or Snohomish/Skykomish River Winter-Run)</td><td rowspan="2">One DIP from the Snohomish River (Tolt River Summer-Run or North Fork Skykomish River Summer-Run)</td></tr>
<tr><td>(5) One other winter or summer/winter run from the MPG at large</td></tr>
<tr><td colspan="4"></td></tr>
</table>

Spatial Structure and Diversity. The PS steelhead DPS is the anadromous form of O. mykiss that occur in rivers, below natural barriers to migration, in northwestern Washington State that drain to Puget Sound, Hood Canal, and the Strait of Juan de Fuca between the U.S./Canada border and the Elwha River, inclusive. The DPS also includes six hatchery stocks that are considered no more than moderately diverged from their associated natural-origin counterparts: Green River natural winter-run; Hamma Hamma winter-run; White River winter-run; Dewatto River winter-run; Duckabush River winter-run; and Elwha River native winter-run (USDC 2014). Steelhead are the anadromous form of *Oncorhynchus mykiss* that occur in rivers, below natural barriers to migration, in northwestern Washington State (Ford 2011). Non-anadromous ''resident'' *O. mykiss* occur within the range of PS steelhead but are not part of the DPS due to marked differences in physical, physiological, ecological, and behavioral characteristics (Hard et al. 2007).

A DIP can include summer steelhead only, winter steelhead only, or a combination of summer and winter run timing (e.g., winter run, summer run or summer/winter run). Most DIPs have low viability criteria scores for diversity and spatial structure, largely because of extensive hatchery influence, low breeding population sizes, and freshwater habitat fragmentation or loss (Hard et al. 2007). In the Central and South Puget Sound and Hood Canal and Strait of Juan de Fuca MPGs, nearly all DIPs are not viable (Hard 2015). More information on PS steelhead spatial structure and diversity can be found in NMFS' technical report (Hard 2015).

Abundance and Productivity. Abundance of adult steelhead returning to nearly all Puget Sound rivers has fallen substantially since estimates began for many populations in the late 1970s and early 1980s. Smoothed trends in abundance indicate modest increases since 2009 for 13 of the 22 DIPs. Between the two most recent five-year periods (2005-2009 and 2010-2014), the geometric mean of estimated abundance increased by an average of 5.4 percent. For seven populations in the Northern Cascades MPG, the increase was 3 percent; for five populations in the Central & South Puget Sound MPG, the increase was 10 percent; and for six populations in the Hood Canal & Strait of Juan de Fuca MPG, the increase was 4.5 percent. However, several of these upward trends are not statistically different from neutral, and most populations remain small. Inspection of geometric means of total spawner abundance from 2010 to 2014 indicates that 9 of 20 populations evaluated had geometric mean abundances fewer than 250 adults and 12 of 20 had fewer than 500 adults. Between the most recent two five-year periods (2005-2009 and 2010-2014), several populations showed increases in abundance between 10 and 100 percent, but about half have remained in decline. Long-term (15-year) trends in natural spawners are predominantly negative (Ford 2022).

There are some signs of modest improvement in steelhead productivity since the 2011 review, at least for some populations, especially in the Hood Canal & Strait of Juan de Fuca MPG. However, these modest changes must be sustained for a longer period (at least two generations) to lend sufficient confidence to any conclusion that productivity is improving over larger scales across the DPS. Moreover, several populations are still showing dismal productivity, especially those in the Central & South Puget Sound MPG (Ford 2022).

Little or no data is available on summer-run populations to evaluate extinction risk or abundance trends. Because of their small population size and the complexity of monitoring fish in headwater holding areas, summer steelhead have not been broadly monitored.

Limiting factors. In our 2013 proposed rule designating critical habitat for this species (USDC 2013), we noted that the following factors for decline for PS steelhead persist as limiting factors:

- The continued destruction and modification of steelhead habitat

- Widespread declines in adult abundance (total run size), despite significant reductions in harvest in recent years
- Threats to diversity posed by use of two hatchery steelhead stocks (Chambers Creek and Skamania)
- Declining diversity in the DPS, including the uncertain but weak status of summer run fish
- A reduction in spatial structure
- Reduced habitat quality through changes in river hydrology, temperature profile, downstream gravel recruitment, and reduced movement of large woody debris
- In the lower reaches of many rivers and their tributaries in Puget Sound where urban development has occurred, increased flood frequency and peak flows during storms and reduced groundwater-driven summer flows, with resultant gravel scour, bank erosion, and sediment deposition
- Dikes, hardening of banks with riprap, and channelization, which have reduced river braiding and sinuosity, increasing the likelihood of gravel scour and dislocation of rearing juveniles

Status of Rockfishes

NMFS adopted a recovery plan for both PS/GB bocaccio and yelloweye rockfish in 2017. Extinction risk factors identified in the plan include loss of nearshore habitat. A 5-year review for yelloweye and bocaccio rockfish announced as being initiated in 2020 is pending completion.

There are no estimates of historic or present-day abundance of PS/GB yelloweye rockfish, or PS/GB bocaccio across the full DPSs area. In 2013, the WDFW published abundance estimates from a remotely operated vehicle survey conducted in 2008 in the San Juan Island area (Pacunski et al. 2013). This survey was conducted exclusively within rocky habitats and represents the best available abundance estimates to date for one basin of the DPS. The survey produced estimates of 47,407 (25 percent variance) yelloweye, and 4,606 (100 percent variance) bocaccio in the San Juan area (Tonnes et al., 2016).

Further, data suggest that total rockfish declined at a rate of 3.1 to 3.8 percent per year from 1977 to 2014 or a 69 to 76 percent total decline over that period. The listed species declined over-proportional compared to the total rockfish assemblage. Therefore, long-term population growth rate for the listed species was likely even lower (more negative) than that for total rockfish. Finally, there is little to no evidence of recent recovery of total rockfish abundance to recent protective measures.

Mature females of the listed species produce from several thousand to over a million eggs annually (Love et al. 2002). In rockfish, the number of embryos produced by the female increases with size. For example, female copper rockfish that are 20 cm in length produce 5,000 eggs while a female 50 cm in length may produce 700,000 eggs (Palsson 2009). These specific observations come from other rockfish, not the two listed species. However, the generality of maternal effects in *Sebastes* suggests that some level of age or size influence on reproduction is likely for all species.

Larval rockfish rely on nearshore habitat. The nearshore is generally defined as habitats contiguous with the shoreline from extreme high water out to a depth no greater than 98 feet (30 m) relative to mean lower low water. This area generally coincides with the maximum depth of the photic zone and can contain physical or biological features essential to the conservation of many fish and invertebrate species, including PS/GB bocaccio. Approximately 27 percent of Puget Sound's shoreline has been modified by armoring (Simenstad et al. 2011). Nearshore habitats throughout the greater Puget Sound region have been affected by a variety of human activities, including agriculture, heavy industry, timber harvest, and the development of sea ports and residential property (Drake et al. 2010).

The alteration of Puget Sound shorelines has been found to impact a variety of marine life, ranging from invertebrate fauna (Sobocinski 2003) to surf smelt egg viability (Rice 2006), but consequences of the alteration of Puget Sound shorelines on rockfish habitat such as kelp are less understood. Some areas around Puget Sound have shown a large decrease in kelp. Areas with floating and submerged kelp (families Chordaceae, Alariaceae, Lessoniacea, Costariaceae, and Laminaricea) support the highest densities of most juvenile rockfish species (Matthews 1989; Halderson and Richards 1987; Carr 1983; Hayden-Spear 2006). Kelp habitat provides structure for feeding, predation refuge, and reduced currents that enable energy conservation for juveniles.

A study of rockfish in Puget Sound found that larval rockfish appeared to occur in two peaks (early spring, late summer) that coincide with the main primary production peaks in Puget Sound. Both measures indicated that rockfish ichthyoplankton essentially disappeared from the surface waters by the beginning of November. Densities also tended to be lower in the more northerly basins (Whidbey and Rosario), compared to Central and South Sound (Greene and Godersky 2012).

Status of PS/GB Bocaccio

The PS/GB bocaccio DPS was listed as endangered on April 28, 2010 (75 FR 22276). In April 2016, NMFS completed a 5-year status review that recommended the DPS retain its endangered classification (Tonnes *et al*. 2016), and released a recovery plan in October 2017 (NMFS 2017b). Though PS/GB bocaccio were never a predominant segment of the multi-species rockfish population within the Puget Sound/Georgia Basin, their present-day abundance is likely a fraction of their pre-contemporary fishery abundance. Most PS/GB bocaccio within the DPS may have been historically spatially limited to several basins within the DPS. They were apparently historically most abundant in the Central and South Sound with no documented occurrences in the San Juan Basin until 2008. The apparent reduction of populations of PS/GB bocaccio in the Main Basin[7] and South Sound represents a further reduction in the historically spatially limited distribution of PS/GB bocaccio, and adds significant risk to the viability of the DPS.

The VSP criteria described by McElhany *et al*. (2000), and summarized at the beginning of Section 2.2, identified spatial structure, diversity, abundance, and productivity as criteria to assess the viability of salmonid species because these criteria encompass a species'

[7] The U.S. portion of the Puget Sound/Georgia Basin that is occupied by yelloweye rockfish and bocaccio can be divided into five areas, or Basins, based on the distribution of each species, geographic conditions, and habitat features. These five interconnected Basins are: (1) The San Juan/Strait of Juan de Fuca Basin, (2) Main Basin, (3) Whidbey Basin, (4) South Puget Sound, and (5) Hood Canal. 79 FR 68041: 11/13/2014

“reproduction, numbers, or distribution” as described in 50 CFR 402.02. These viability criteria reflect concepts that are well founded in conservation biology and are generally applicable to a wide variety of species because they describe demographic factors that individually and collectively provide strong indicators of extinction risk for a given species (Drake *et al*. 2010), and are therefore applied here for PS/GB bocaccio.

The life history of PS/GB bocaccio includes a larval/pelagic juvenile stage that is followed by a juvenile stage, subadult, and adult stages. As with other rockfish, PS/GB bocaccio fertilize their eggs internally and the young are extruded as larvae that are about 4 to 5 mm in length. Females produce from several thousand to over a million offspring per spawning (Love et al. 2002). The timing of larval parturition in PS/GB bocaccio is uncertain, but likely occurs within a five- to six-month window that is centered near March (Greene and Godersky 2012; NMFS 2017b; Palsson *et al*. 2009). Larvae are distributed by prevailing currents until they are large enough to actively swim toward preferred habitats, but they can pursue food within short distances immediately after birth (Tagal *et al*. 2002). Larvae are distributed throughout the water column (Weis 2004), but are also observed under free-floating algae, seagrass, and detached kelp (Love *et al*. 2002; Shaffer *et al*. 1995). Unique oceanographic conditions within Puget Sound likely result in most larvae staying within the basin where they are released rather than being broadly dispersed (Drake *et al*. 2010).

At about 3 to 6 months old and 1.2 to 3.6 inches long, juvenile PS/GB bocaccio gravitate to shallow nearshore waters where they settle and grow. Rocky or cobble substrates with kelp is most typical, but sandy areas with eelgrass are also utilized for rearing (Carr 1983; Halderson and Richards 1987; Hayden-Spear 2006; Love *et al*. 1991 & 2002; Matthews 1989; NMFS 2017b; Palsson *et al*. 2009). Young of the year rockfish may spend months or more in shallow nearshore rearing habitats before transitioning toward deeper water habitats (Palsson *et al*. 2009). As PS/GB bocaccio grow, their habitat preference shifts toward deeper waters with high relief and complex bathymetry with rock and boulder-cobble complexes (Love *et al*. 2002), but they also utilize non-rocky substrates such as sand, mud, and other unconsolidated sediments (Miller and Borton 1980; Washington 1977). Adults are most commonly found between 131 to 820 feet (Love *et al*. 2002; Orr *et al*. 2000). The maximum age of PS/GB bocaccio is unknown, but may exceed 50 years, and they reach reproductive maturity near age six.

<u>Spatial Structure and Diversity:</u> The PS/GB bocaccio DPS includes all PS/GB bocaccio from inland marine waters east of the central Strait of Juan de Fuca and south of the northern Strait of Georgia. The waters of Puget Sound and Straits of Georgia can be divided into five interconnected basins that are largely hydrologically isolated from each other by relatively shallow sills (Burns 1985; Drake *et al*. 2010). Although most individuals of the PS/GB bocaccio DPS are believed to remain within the basin of their origin, including larvae and pelagic juveniles, some movement between basins occurs, and the DPS is currently considered a single population.

<u>Abundance and Productivity:</u> The PS/GB bocaccio DPS exists at very low abundance and observations are relatively rare. No reliable range-wide historical or contemporary population estimates are available for the PS/GB bocaccio DPS. It is believed that prior to contemporary fishery removals, each of the major Puget Sound/Georgia Basin areas likely hosted relatively

large, though unevenly distributed, populations of PS/GB bocaccio. They were likely most common within the South Sound and Main Basin, but were never a predominant segment of the total rockfish abundance within the region (Drake *et al*. 2010). The best available information indicates that between 1965 and 2007, total rockfish populations have declined by about 70 percent in the Puget Sound region, and that PS/GB bocaccio have declined by an even greater extent (Drake *et al*. 2010; Tonnes *et al*. 2016; NMFS 2017b).

Limiting Factors: Factors limiting recovery for PS/GB bocaccio include:

- Fisheries Removals (commercial and recreational bycatch)
- Derelict fishing gear in nearshore and deep-water environments
- Degraded water quality (chemical contamination, hypoxia, nutrients)
- Climate change
- Habitat disruption

Status of PS/GB Yelloweye Rockfish

Spatial Structure. PS/GB Yelloweye rockfish occupy the waters of the Pacific coast from California to Alaska. Yelloweye rockfish in the waters of the Puget Sound/Georgia Basin were determined to be a DPS (75 Fed. Reg. 22276). The PS/GB DPS of yelloweye rockfish was listed as "threatened" under the ESA on April 28, 2010 (75 Fed. Reg. 22276). The DPSs include all yelloweye rockfish a found in waters of Puget Sound, the Strait of Georgia, and the Strait of Juan de Fuca east of Victoria Sill. Critical habitat was designated for all species of listed rockfish in 2014 under section 4(a)(3)(A) of the ESA (79 Fed. Reg. 68041, November 13, 2014).

Diversity. New collection and analysis of PS/GB yelloweye rockfish tissue samples reveal significant genetic differentiation between the inland DPS and coastal samples. These new data are consistent with and further support the existence of a population of PS/GB yelloweye rockfish that is discrete from coastal populations (Ford 2015; NMFS 2016). In addition, yelloweye rockfish from Hood Canal were genetically differentiated from other Puget Sound/Georgia Basin fish, indicating a previously unknown degree of population differentiation within the DPS (Ford 2015; NMFS 2016). Other genetic analysis has found that yelloweye rockfish in the Georgia Basin had the lowest molecular genetic diversity of a collection of samples along the coast (Siegle et al. 2013). Although the adaptive significance of such microsatellite diversity is unclear, it may suggest low effective population size, increased drift, and thus lower genetic diversity in the Puget Sound/Georgia Basin DPS.

Abundance. Yelloweye rockfish within the Puget Sound/Georgia Basin (in U.S. waters) are very likely the most abundant within the San Juan Basin of the DPS. Yelloweye rockfish spatial structure and connectivity is threatened by the apparent reduction of fish within each of the basins of the DPS. This reduction is probably most acute within the basins of Puget Sound proper. The severe reduction of fish in these basins may eventually result in a contraction of the DPS' range. In Puget Sound, catches of PS/GB yelloweye rockfish have declined as a proportion of the overall rockfish catch (Drake et al. 2010).

Productivity. Life history traits of PS/GB yelloweye rockfish suggest generally low levels of inherent productivity because they are long-lived, mature slowly, and have sporadic episodes of successful reproduction (Musick 1999; Tolimieri and Levin 2005). Yelloweye rockfish productivity may also be impacted by an Allee effect. This situation arises when reproductive adults are removed from the population and remaining individuals are eventually unable to encounter mates. This process then further reduces population density and can lead to extinction. Adult PS/GB yelloweye rockfish typically occupy relatively small ranges (Love et al. 2002), and the extent to which they may move to find suitable mates is unknown. However, there is insufficient information to determine that this is currently occurring for yelloweye rockfish and further research is needed (Hutchings and Reynolds 2004).

Limiting Factors: Factors limiting recovery for PS/GB yelloweye rockfish include:

- Fisheries Removals (commercial and recreational bycatch)
- Derelict fishing gear in nearshore and deep-water environments
- Degraded water quality (chemical contamination, hypoxia, nutrients)
- Climate change
- Habitat disruption

Status of Southern DPS Eulachon

Eulachon were listed as a threatened species on March 18, 2010 (75 FR 13012). NMFS adopted a final recovery plan for eulachon on September 6, 2017 (NMFS 2017c). On April 1, 2016, NMFS announced the results of a 5-year review of eulachon status. After completing the review, NMFS recommended the southern DPS of eulachon remain classified as a threatened species. A 5-year review of eulachon announced as being initiated in 2020 is pending completion.

The major threats to eulachon are impacts of climate change on oceanic and freshwater habitats (species-wide), fishery by-catch (species-wide), dams and water diversions (Klamath and Columbia subpopulations) and predation (species-wide) (NMFS 2017c). .

Spatial Structure and Diversity. The southern DPS of eulachon includes all naturally-spawned populations that occur in rivers south of the Nass River in British Columbia to the Mad River in California. Core populations for this species include the Fraser River, Columbia River and (historically) the Klamath River. Eulachon leave saltwater to spawn in their natal streams late winter through early summer, and typically spawn at night in the lower reaches of larger rivers fed by snowmelt. After hatching, larvae are carried downstream and widely dispersed by estuarine and ocean currents. Eulachon movements in the ocean are poorly known, although the amount of eulachon bycatch in the pink shrimp fishery seems to indicate that the distribution of these organisms overlap in the ocean. The southern DPS includes four major subpopulations: (1) Columbia, (2) Klamath, (3) Frazier, and (4) British Columbia. However, these subpopulations do not include all spawning aggregations within the DPS. For instance, spawning runs of eulachon have been noted in Redwood Creek and the Mad River in California, the Umpqua River and Tenmile Creek in Oregon, and the Naselle, Elwha, and Quinault rivers in Washington (NMFS 2017c).

Abundance and Productivity. In the early 1990s, there was an abrupt decline in the abundance of eulachon returning to the Columbia River with no evidence of returning to their former population levels since then (Drake et al. 2008). Persistent low returns and landings of eulachon in the Columbia River from 1993-2000 prompted the states of Oregon and Washington to adopt a Joint State Eulachon Management Plan in 2001 that provides for restricted harvest management when parental run strength, juvenile production, and ocean productivity forecast a poor return (WDFW and ODFW 2001). Despite a brief period of improved returns in 2001-2003, the returns and associated commercial landings have again declined to the very low levels observed in the mid-1990s (Joint Columbia River Management Staff 2009). Starting in 2005, the fishery has operated at the most conservative level allowed in the management plan Although eulachon abundance in monitored rivers has generally improved, especially in the 2013-2015 return years, recent poor ocean conditions and the likelihood that these conditions will persist into the near future suggest that population declines may be widespread in the upcoming return years. Therefore, it is too early to tell whether recent improvements in the southern DPS of eulachon will persist or whether a return to the severely depressed abundance years of the mid-late 1990s and late 2000s will recur (NMFS 2017c).

Limiting Factors. Limiting factors for this southern DPS of eulachon include (NMFS 2017a):

- Changes in ocean conditions due to climate change, particularly in the southern portion of the species' range where ocean warming trends may be the most pronounced and may alter prey, spawning, and rearing success.
- Climate-induced change to freshwater habitats
- Bycatch of eulachon in commercial fisheries
- Adverse effects related to dams and water diversions
- water quality
- Shoreline construction
- Over harvest
- Predation

Status of Southern DPS Green Sturgeon

The southern DPS of green sturgeon was listed as threatened on April 7, 2006 (71 FR 17757). NMFS completed a 5-year review for this DPS in 2015 and recommended the DPS retain its threatened classification. The recovery plan for this DPS was finalized in August, 2018 (NMFS 2018). A key recovery strategy is to reestablish additional spawning areas in currently occupied rivers in California. A 5-year review announced as being initiated in 2020 is pending completion.

Spatial Structure and Diversity. Two DPSs have been defined for green sturgeon (*Acipenser medirostris*), a northern DPS (spawning populations in the Klamath and Rogue rivers) and a southern DPS (spawners in the Sacramento River). Southern green sturgeon includes all naturally-spawned populations of green sturgeon that occur south of the Eel River in Humboldt County, California. Telemetry data and genetic analyses suggest that Southern DPS green sturgeon generally occur from Graves Harbor, Alaska to Monterey Bay, California (Moser and Lindley 2007; Lindley et al. 2008, 2011) and, within this range, most frequently occur in coastal waters of Washington, Oregon, and Vancouver Island and near San Francisco and Monterey bays (Huff et al. 2012). Within the nearshore marine environment, tagging and fisheries data indicate that Northern and Southern DPS green sturgeon prefer marine waters of less than a depth of 110 m (Erickson and Hightower 2007).

Abundance and Productivity. Recent studies are providing preliminary information on the population abundance of Southern DPS green sturgeon. The current estimate of spawning adult abundance is between 824-1,872 individuals (NMFS 2015c). The spawning population of the Southern DPS in the Sacramento River congregates in a limited area of the river compared to potentially available habitat. The reason for this is unknown. This is concerning given that a catastrophic or targeted poaching event impacting just a few holding areas could affect a significant portion of the adult population. No comparable data on holding area occupancy within the Sacramento River were available at the time of the last status review making it difficult to assess whether the current observations reflect an improvement or decline in the species status (NMFS 2015c).

Limiting Factors. The principal factor for the decline of southern green sturgeon is the reduction of its spawning area to a single known population limited to a small portion of the Sacramento River. It is currently at risk of extinction primarily because of elimination of freshwater spawning habitat, degradation of freshwater and estuarine habitat quality, water diversions, fishing, and other causes (USDC 2010). Adequate water flow and temperature are issues of concern. Water diversions pose an unknown but potentially serious threat within the Sacramento and Feather Rivers and the Sacramento River Delta. Poaching also poses an unknown but potentially serious threat because of high demand for sturgeon caviar. The effects of contaminants and nonnative species are also unknown but potentially serious. As mentioned above, retention of green sturgeon in both recreational and commercial fisheries is now prohibited within the western states, but the effect of capture/release in these fisheries is unknown. There is evidence of fish being retained illegally, although the magnitude of this activity likely is small (NOAA Fisheries 2011).

Status of Southern Resident Killer Whales (SRKWs)

The SRKW DPS, composed of J, K and L pods, was listed as endangered under the ESA on November 18, 2005 (70 FR 69903). A 5-year review under the ESA completed in 2016 concluded that Southern Residents should remain listed as endangered and includes recent information on the population, threats, and new research results and publications (NMFS 2016). This section summarizes the status of Southern Resident killer whales throughout their range based on information taken largely from the recovery plan (NMFS 2008), 5-year review (NMFS 2021), as well as new data that became available more recently.

Spatial Structure and Diversity/Geographic Range and Distribution. Southern Residents occur throughout the coastal waters off Washington, Oregon, and Vancouver Island and are known to travel as far south as central California and as far north as Southeast Alaska (NMFS 2008, Hanson et al. 2013) Southern Residents are highly mobile and can travel up to 86 miles in a single day (Baird 2000), with seasonal movements likely tied to the migration of their primary prey, salmon.

During the spring, summer, and fall months, the whales spend a substantial amount of time in the inland waterways of the Strait of Georgia, Strait of Juan de Fuca, and Puget Sound (Bigg 1982; Ford 2000; Krahn et al. 2002; Hauser et al. 2007). In general, the three pods are increasingly more present in May and June and spend a considerable amount of time in inland waters through September. Late summer and early fall movements of Southern Residents in the Georgia Basin are consistent, with strong site fidelity shown to the region as a whole and high occurrence in the San Juan Island area (Hanson and Emmons 2010, Hauser et al. 2007). All three pods generally remain in the Georgia Basin through October and make frequent trips to the outer coasts of Washington and southern Vancouver Island and are occasionally sighted as far west as Tofino and Barkley Sound (Ford 2000; Hanson and Emmons 2010, Whale Museum unpubl. data). Sightings in late fall decline as the whales shift to the outer coasts of Vancouver Island and Washington.

Although seasonal movements are generally predictable, there can be large inter-annual variability in arrival time and days present in inland waters from spring through fall, with late arrivals and fewer days present in recent years (Hanson and Emmons 2010; The Whale Museum unpubl. data). For example, K pod has had variable occurrence in June ranging from 0 days of occurrence in inland waters to over 25 days. Fewer observed days in inland waters likely indicates changes in their prey availability (i.e., abundance, distribution and accessibility). During fall and early winter, Southern Resident pods, and J pod in particular, expand their routine movements into Puget Sound, likely to take advantage of chum and Chinook salmon runs (Hanson et al. 2010, Osborne 1999).

In recent years, several sightings and acoustic detections of Southern Residents have been obtained off the Washington and Oregon coasts in the winter and spring (Hanson et al. 2010, Hanson et al. 2013, NWFSC unpubl. data). Satellite-linked tag deployments have also provided more data on the SRKW movements in the winter indicating that K and L pods use the coastal waters along Washington, Oregon, and California during non-summer months. Detection rates of K and L pods on the passive acoustic recorders indicate Southern Residents occur with greater frequency off the Columbia River and Westport and are most common in March (Hanson et al. 2013). J pod has also only been detected on one of seven passive acoustic recorders positioned along the outer coast (Hanson et al. 2013). The limited range of the sightings/ acoustic detections of J pod in coastal waters, the lack of coincident occurrence during the K and L pod sightings, and the results from satellite tagging in 2012–2016 (NWFSC unpubl. data) indicate J pod’s limited occurrence along the outer coast and extensive occurrence in inland waters, particularly in the northern Georgia Strait.

Abundance, Productivity, and Trends. Southern Resident killer whales are a long-lived species, with late onset of sexual maturity (review in NMFS 2008). Females produce a low number of surviving calves over the course of their reproductive life span (Bain 1990, Olesiuk et al. 1990). Compared to Northern Resident killer whales (a resident killer whale population with a sympatric geographic distribution ranging from coastal waters of Washington State and British Columbia north to Southeast Alaska), Southern Resident females appear to have reduced fecundity (Ward et al. 2013, Vélez-Espino et al. 2014). The average inter-birth interval for reproductive Southern Resident females is 6.1 years, which is longer than the 4.88 years estimated for Northern Resident killer whales (Olesiuk et al. 2005). Recent evidence has indicated pregnancy hormones (progesterone and testosterone) can be detected in Southern Resident killer whale feces and have indicated several miscarriages, particularly in late pregnancy (Wasser et al. 2017). The authors suggest this reduced fecundity is largely due to nutritional limitation. Mothers and offspring maintain highly stable social bonds throughout their lives, which is the basis for the matrilineal social structure in the Southern Resident population (Baird 2000, Bigg et al. 1990, Ford 2000). Groups of related matrilines form pods. Three pods – J, K, and L – make up the Southern Resident community. Clans are composed of pods with similar vocal dialects and all three pods of the Southern Residents are part of J clan.

At present, the Southern Resident population has declined to historically low levels. Since censuses began in 1974, J and K pods have steadily increased their sizes. However, the population suffered an almost 20 percent decline from 1996-2001 (from 97 whales in 1996 to 81 whales in 2001), largely driven by lower survival rates in L pod. The overall population had increased slightly from 2002 to 2010 (from 83 whales to 86 whales). During the international science panel review of the effects of salmon fisheries (Hilborn et al. 2012), the Panel stated that during 1974 to 2011, the population experienced a realized growth rate of 0.71 percent, from 67 individuals to 87 individuals. Since then, the population has decreased to only 76 whales, a historical low in the last 30 years with a current realized growth rate (from 1974 to 2017) at half of the previous estimate described in the Panel report, 0.29 percent.

There is representation in all three pods, with 23 whales in J pod, 18 whales in K pod and 35 whales in L pod. There are currently 4 reproductively mature males in J pod, 8 in K pod, and 10 mature males in L pod between the ages of 10 and 42 years. Although the age and sex distribution are generally similar to that of Northern Residents that are a stable and increasing population (Olesiuk et al. 2005), there are several demographic factors of the Southern Resident population that are cause for concern, namely reduced fecundity, sub-adult survivorship in L pod, and the total number of individuals in the population (review in NMFS 2008). Based on an updated pedigree from new genetic data, most of the offspring in recent years were sired by two fathers, meaning that less than 30 individuals make up the effective reproducing portion of the population. Because a small number of males were identified as the fathers of many offspring, a smaller number may be sufficient to support population growth than was previously thought (Ford et al. 2011, NWFSC unpublished data). Some offspring were the result of matings within the same pod raising questions and concerns about inbreeding effects. Research into the relationship between genetic diversity, effective breeding population size, and health is currently underway to determine how this metric can inform us about extinction risk and inform recovery (NWFSC unpublished data). The historical abundance of Southern Resident killer whales is estimated from 140 to an unknown upper bound. The minimum estimate (~140) is the number of whales killed or removed for public display in the 1960s and 1970s added to the remaining population at the time the captures ended. Several lines of evidence (i.e., known kills and removals [Olesiuk et al. 1990], salmon declines (Krahn et al. 2002) and genetics (Krahn et al. 2002, Ford et al. 2011)) all indicate that the population used to be larger than it is now and likely experienced a recent reduction in size, but there is currently no reliable estimate of the upper bound of the historical population size.

Seasonal mortality rates among Southern and Northern Resident whales may be highest during the winter and early spring, based on the numbers of animals missing from pods returning to inland waters each spring. Olesiuk et al. (2005) identified high neonate mortality that occurred outside of the summer season. At least 12 newborn calves (nine in the southern community and three in the northern community) were seen outside the summer field season and disappeared by the next field season. Additionally, stranding rates are higher in winter and spring for all killer whale forms in Washington and Oregon (Norman et al. 2004). Data collected from three Southern Resident killer whale stranding in the last five years have contributed to our knowledge of the health of the population and the impact of the threats to which they are exposed. Transboundary partnerships have supported thorough necropsies of L112 (nicknamed “Sooke”) in 2012, J32 ("Rhapsody”) in 2014, and L95 (“Nigel”) in 2016, which included testing for contaminant load, disease and pathogens, organ condition, and diet composition. A final necropsy report for J34 (“double stuff”), who was found dead near Sechelt, British Columbia on December 20, 2016 is still pending.

The NWFSC continues to evaluate changes in fecundity and mortality rates, and has updated the work on population viability analyses conducted for the 2004 SRKW Status Review, as well as the science panel review of the effects of salmon fisheries (Krahn et al. 2004; Hilborn et al. 2012; Ward et al. 2013). Following from that work, the data now suggests a downward trend in population growth projected over the next 50 years. As the model projects out over a longer time frame (50 years) there is increased uncertainty around the estimates, however, if all of the parameters in the model remain the same the overall trend shows a decline in later years. This downward trend is caused in part by the changing age and sex structure of the population, but also related to the relatively low fecundity rate observed over the period from 2011 to 2016 (NMFS 2016f).

To explore potential demographic projections, Lacy et al. (2017) constructed a population viability assessment that considered sub-lethal effects and the cumulative impacts of threats (contaminants, acoustic disturbance, and prey abundance). They found that over the range of scenarios tested, the effects of prey abundance on fecundity and survival had the largest impact on the population growth rate. Furthermore, they suggested in order for the population to reach the recovery target of 2.3 percent growth rate, the acoustic disturbance would need to be reduced in half and the Chinook abundance would need to be increased by 15 percent (Lacy et al. 2017).

Because of this population’s small abundance, it is also susceptible to demographic stochasticity – randomness in the pattern of births and deaths among individuals in a population. Several other sources of stochasticity can affect small populations and contribute to variance in a population’s growth and extinction risk. Other sources include environmental stochasticity, or fluctuations in the environment that drive fluctuations in birth and death rates, and demographic heterogeneity, or variation in birth or death rates of individuals because of differences in their individual fitness (including sexual determinations). In combination, these and other sources of random variation combine to amplify the probability of extinction, known as the extinction vortex (Gilpin and Soulé 1986, Melbourne and Hastings 2008). The larger the population size, the greater the buffer against stochastic events and genetic risks. A delisting criterion for the SRKW DPS is an average growth rate of 2.3 percent for 28 years (NMFS 2008e). In light of the current average growth rate of 0.29 percent (from 1974 to present), this recovery criterion reinforces the need to allow the population to grow quickly.

Population growth is also important because of the influence of demographic and individual heterogeneity on a population's long-term viability. Population-wide distribution of lifetime reproductive success can be highly variable, such that some individuals produce more offspring than others to subsequent generations, and male variance in reproductive success can be greater than that of females (i.e., Clutton-Brock 1988, Hochachka 2006). For long-lived vertebrates such as killer whales, some females in the population might contribute less than the number of offspring required to maintain a constant population size (n = 2), while others might produce more offspring. The smaller the population, the more weight an individual's reproductive success has on the population's growth or decline (i.e., Coulson et al. 2006). For example, although there are currently 26 reproductive aged females (ages 11-42) in the SRKW population, only 14 have successfully reproduced in the last 10 years (CWR unpubl. data). This further illustrates the risk of demographic stochasticity for a small population like Southern Residents – the smaller a population, the greater the chance that random variation will result in too few successful individuals to maintain the population.

<u>Limiting Factors and Threats.</u> Several factors identified in the final recovery plan for Southern Residents may be limiting recovery. These are: (1) quantity and quality of prey, (2) nutritional limitation and body condition, (3) toxic chemicals that accumulate in top predators, (4) disturbance from sound and vessels, and (5) risk of oil spills. It is likely that multiple threats are acting together to impact the whales. Modeling exercises have attempted to identify which threats are most significant to survival and recovery (Lacy et al. 2017) and available data suggests that all of the threats are potential limiting factors (NMFS 2008).

(1) Quantity and Quality of Prey

Southern Resident killer whales consume a variety of fish species (22 species) and one species of squid (Ford et al. 1998; Ford 2000; Ford and Ellis 2006; Hanson et al. 2010; Ford et al. 2016), but salmon are identified as their primary prey. Southern Residents are the subject of ongoing research, including direct observation, scale and tissue sampling of prey remains, and fecal sampling. The diet data indicate that the whales are consuming mostly larger (i.e., older) Chinook salmon. Chinook salmon is their primary prey despite the much lower abundance in some areas and during certain time periods in comparison to other salmonids, for mechanisms that remain unknown but factors of potential importance include the species' large size, high fat and energy content, and year-round occurrence in the whales' geographic range. Chinook salmon have the highest value of total energy content compared to other salmonids because of their larger body size and higher energy density (kcal/kg) (O'Neill et al. 2014). For example, in order for a killer whale to obtain the total energy value of one Chinook salmon, they would need to consume approximately 2.7 coho, 3.1 chum, 3.1 sockeye, or 6.4 pink salmon (O'Neill et al. 2014). Recent research suggests that killer whales are capable of detecting, localizing and recognizing Chinook salmon through their ability to distinguish Chinook echo structure as different from other salmon (Au et al. 2010).

Scale and tissue sampling from May to September in inland waters of Washington and British Columbia indicate that their diet consists of a high percentage of Chinook salmon (monthly proportions as high as >90 percent) (Hanson et al. 2010; Ford et al. 2016). Genetic analysis of the Hanson et al. (2010) samples indicate that when Southern Residents are in inland waters from

May to September, they consume Chinook stocks that originate from regions including the Fraser River (including Upper Fraser, Mid Fraser, Lower Fraser, North Thompson, South Thompson and Lower Thompson), Puget Sound (North and South Puget Sound), the Central British Columbia Coast and West and East Vancouver Island.

Scientists use DNA quantification methods to estimate the proportion of different prey species in the diet from fecal samples (Deagle et al. 2005). Recently, Ford et al. (2016) confirmed the importance of Chinook salmon to the Southern Residents in the summer months using DNA sequencing from whale feces. Salmon and steelhead made up to 98 percent of the inferred diet, of which almost 80 percent were Chinook salmon. Coho salmon and steelhead are also found in the diet in spring and fall months when Chinook salmon are less abundant. Specifically, coho salmon contribute to over 40 percent of the diet in late summer, which is evidence of prey shifting at the end of summer towards coho salmon (Ford et al. 1998; Ford and Ellis 2006; Hanson et al. 2010; Ford et al. 2016). Less than three percent each of chum salmon, sockeye salmon, and steelhead were observed in fecal DNA samples collected in the summer months (May through September). Prey remains and fecal samples collected in inland waters during October through December indicate Chinook and chum salmon are primary contributors of the whale's diet (NWFSC unpubl. data).

Observations of whales overlapping with salmon runs (Wiles 2004; Zamon et al. 2007; Krahn et al. 2009) and collection of prey and fecal samples have also occurred in coastal waters in the winter months. Preliminary analysis of prey remains and fecal samples sampled during the winter and spring in coastal waters indicated the majority of prey samples were Chinook salmon, with a smaller number of steelhead, chum salmon, and halibut (NWFSC unpubl. data). The occurrence of K and L pods off the Columbia River in March suggests the importance of Columbia River spring runs of Chinook salmon in their diet (Hanson et al. 2013). Chinook genetic stock identification from samples collected in winter and spring in coastal waters included 12 U.S. west coast stocks, and over half the Chinook salmon consumed originated in the Columbia River (NWFSC unpubl. data). Columbia River, Central Valley, Puget Sound, and Fraser River Chinook salmon comprise over 90 percent of the whales' coastal Chinook salmon diet (NWFSC unpubl. data).

Over the past decade, some Chinook salmon stocks within the range of the whales have had relatively high abundance (e.g. WA/OR coastal stocks, some Columbia River stocks), whereas other stocks originating in the more northern and southern ends of the whales' range (e.g. most Fraser stocks, Northern and Central B.C. stocks, Georgia Strait, Puget Sound, and Central Valley) have declined. Changing ocean conditions driven by climate change may influence ocean survival of Chinook and other Pacific salmon, further affecting the prey available to Southern Residents.

Currently, hatchery production is a significant component of the salmon prey base returning to watersheds within the range of SRKW (Barnett-Johnson et al. 2007; NMFS 2008e). Although hatchery production has contributed some offset of the historical declines in the abundance of natural-origin salmon within the range of the whales, hatcheries also pose risks to natural-origin salmon populations (Nickelson et al. 1986; Ford 2002; Levin and Williams 2002; Naish et al. 2007). Healthy natural-origin salmon populations are important to the long-term maintenance of prey populations available to Southern Residents because it is uncertain whether a hatchery dominated mix of stocks is sustainable indefinitely and because hatchery fish can differ, relative to natural-origin Chinook salmon, for example, in size and hence caloric value and in availability/migration location and timing. However, the release of hatchery fish has not been identified as a threat to the survival or persistence of Southern Residents. It is possible that hatchery produced fish may benefit this endangered population of whales by enhancing prey availability as scarcity of prey is a primary threat to SRKW survival and hatchery fish often contribute to the salmon stocks consumed (Hanson et al. 2010).

(2) Nutritional Limitation and Body Condition

When prey is scarce, Southern Residents likely spend more time foraging than when prey is plentiful. Increased energy expenditure and prey limitation can cause poor body condition and nutritional stress. Nutritional stress is the condition of being unable to acquire adequate energy and nutrients from prey resources and as a chronic condition, can lead to reduced body size of individuals and to lower reproductive and survival rates of a population (Trites and Donnelly 2003). During periods of nutritional stress and poor body condition, cetaceans lose adipose tissue behind the cranium, displaying a condition known as “peanut-head” in extreme cases (Pettis et al. 2004, Bradford et al. 2012, Joblon et al. 2014). Between 1994 and 2008, 13 Southern Resident killer whales were observed from boats to have a pronounced “peanut-head”; and all but two subsequently died (Durban et al. 2009; Center for Whale Research, unpublished data). None of the whales that died were recovered, and therefore definitive cause of death could not be identified. Both females and males across a range of ages were found in poor body condition.

Since 2008, NOAA has used aerial photogrammetry to assess the body condition and health of SRKW, initially in collaboration with the Center for Whale Research and, more recently, with the Vancouver Aquarium and SR3. Aerial photogrammetry studies have provided finer resolution for detecting poor condition, even before it manifests in “peanut heads” that are observable from boats. Annual aerial surveys of the population from 2013-2017 (with exception of 2014) have detected declines in condition before the death of seven Southern Residents (L52 and J8 as reported in Fearnbach et al. 2018; J14, J2, J28, J54, and J52 as reported in Durban et al. 2017), including five of the six most recent mortalities (Trites and Rosen 2018). These data have provided evidence of a general decline in SRKW body condition since 2008, and documented members of J pod being in poorer body condition in May compared to September (at least in 2016 and 2017) (Trites and Rosen 2018).

Although body condition in whales can be influenced by a number of factors, including prey availability, disease, physiological or life history status, and may vary by season and across years, prey limitation is the most likely cause of observed changes in body condition in wild mammalian populations. It is possible that poor nutrition could contribute to mortality through a variety of mechanisms. To demonstrate how this is possible, we reference studies that have demonstrated the effects of energetic stress (caused by incremental increases in energy expenditures or incremental reductions in available energy) on adult females and juveniles, which have been studied extensively (e.g., adult females: Gamel et al. 2005, Schaefer et al. 1996, Daan et al. 1996, juveniles: Noren et al. 2009a, Trites and Donnelly 2003). Small, incremental increases in energy demands should have the same effect on an animal’s energy budget as small, incremental reductions in available energy, such as one would expect from reductions in prey. Ford and Ellis (2006) report that resident killer whales engage in prey sharing about 76 percent of the time. Prey sharing presumably would distribute more evenly the effects of prey limitation across individuals of the population than would otherwise be the case (i.e., if the most successful foragers did not share with other individuals). Therefore, although cause of death for most individuals that disappear from the population is unknown, poor nutrition could occur in multiple individuals as opposed to only unsuccessful foragers, contributing to additional mortality in this population.

(3) Toxic Chemicals

Various adverse health effects in humans, laboratory animals, and wildlife have been associated with exposures to persistent pollutants. These pollutants have the ability to cause endocrine disruption, reproductive disruption or failure, immunotoxicity, neurotoxicity, neurobehavioral disruption, and cancer (Reijnders 1986, de Swart et al. 1996, Subramanian et al. 1987, de Boer et al. 2000; Reddy et al. 2001, Schwacke et al. 2002; Darnerud 2003; Legler and Brouwer 2003; Viberg et al. 2003; Ylitalo et al. 2005; Fonnum et al. 2006; Viberg et al. 2006; Darnerud 2008; Legler 2008; Bonefeld-Jørgensen et al. 2011). Southern Residents are exposed to a mixture of pollutants, some of which may interact synergistically and enhance toxicity, influencing their health. High levels of these pollutants have been measured in blubber biopsy samples from Southern Residents (Ross et al. 2000; Krahn et al. 2007; Krahn et al. 2009), and more recently, these pollutants were measured in fecal samples collected from Southern Residents providing another potential opportunity to evaluate exposure to these pollutants (Lundin et al. 2016).

Killer whales are exposed to persistent pollutants primarily through their diet. For example, Chinook salmon contain higher levels of some persistent pollutants than other salmon species, but only limited information is available for pollutant levels in Chinook salmon (Krahn et al. 2007; O'Neill and West 2009; Veldhoen et al. 2010; Mongillo et al. 2016). These harmful pollutants, through consumption of prey species that contain these pollutants, are stored in the killer whale's blubber and can later be released; when the pollutants are released, they are redistributed to other tissues when the whales metabolize the blubber in response to food shortages or reduced acquisition of food energy that could occur for a variety of other reasons. The release of pollutants can also occur during gestation or lactation. Once the pollutants mobilize in to circulation, they have the potential to cause a toxic response. Therefore, nutritional stress from reduced Chinook salmon populations may act synergistically with high pollutant levels in Southern Residents and result in adverse health effects.

(4) Disturbance from Vessels and Sound

Vessels have the potential to affect killer whales through the physical presence and activity of the vessel, increased underwater sound levels generated by boat engines, or a combination of these factors. Vessel strikes are rare, but do occur and can result in injury or mortality (Gaydos and Raverty 2007). In addition to vessels, underwater sound can be generated by a variety of other human activities, such as dredging, drilling, construction, seismic testing, and sonar (Richardson et al. 1995; Gordon and Moscrop 1996; National Research Council 2003). Impacts from these sources can range from serious injury and mortality to changes in behavior. In other cetaceans, hormonal changes indicative of stress has been recorded in response to intense sound exposure (Romano et al. 2003). Chronic stress is known to induce harmful physiological conditions including lowered immune function, in terrestrial mammals and likely does so in cetaceans (Gordon and Moscrop 1996).

Killer whales rely on their highly developed acoustic sensory system for navigating, locating prey, and communicating with other individuals. While in inland waters of Washington and British Columbia, Southern Resident killer whales are the principal target species for the commercial whale watch industry (Hoyt 2001; O'Connor et al. 2009) and encounter a variety of other vessels in their urban environment (e.g., recreational, fishing, ferries, military, shipping). Several main threats from vessels include direct vessel strikes, the masking of echolocation and communication signals by anthropogenic sound, and behavioral changes (NMFS 2008). There is a growing body of evidence documenting effects from vessels on small cetaceans and other marine mammals (NMFS 2010c; NMFS 2016; NMFS in press). Research has shown that the whales spend more time traveling and performing surface active behaviors and less time foraging in the presence of all vessel types, including kayaks, and that noise from motoring vessels up to 400 meters away has the potential to affect the echolocation abilities of foraging whales (Holt 2008; Lusseau et al. 2009; Noren et al. 2009; Williams et al. 2010b). Individual energy balance may be impacted when vessels are present because of the combined increase in energetic costs resulting from changes in whale activity with the decrease in prey consumption resulting from reduced foraging opportunities (Williams et al. 2006; Lusseau et al. 2009; Noren et al. 2009a; Noren et al. 2012).

At the time of the whales' listing under the ESA, NMFS reviewed existing protections for the whales and developed recovery actions, including vessel regulations, to address the threat of vessels to killer whales. NMFS concluded it was necessary and advisable to adopt regulations to protect killer whales from disturbance and sound associated with vessels, to support recovery of SRKWs. Federal vessel regulations were established in 2011 to prohibit vessels from approaching killer whales within 200 yards and from parking in the path of the whales within 400 yards. These regulations apply to all vessels in inland waters of Washington State with exemptions to maintain safe navigation and for government vessels in the course of official duties, ships in the shipping lanes, research vessels under permit, and vessels lawfully engaged in commercial or treaty Indian fishing that are actively setting, retrieving, or closely tending fishing gear (76 FR 20870, April, 14, 2011).

In the final rule, NMFS committed to reviewing the vessel regulations to evaluate effectiveness, and also to study the impact of the regulations on the viability of the local whale watch industry. In March 2013, NMFS held a killer whale protection workshop to review the current vessel regulations, guidelines, and associated analyses; review monitoring, boater education, and enforcement efforts; review available industry and economic information and identify data gaps; and provide a forum for stakeholder input to explore next steps for addressing vessel effects on killer whales.

In December 2017, NOAA Fisheries completed a technical memorandum evaluating the effectiveness of regulations adopted in 2011 to help protect endangered SRKWs from the impacts of vessel traffic and noise (Ferrara et al. 2017). In the assessment, Ferrara et al. (2017)

used five measures: education and outreach efforts, enforcement, vessel compliance, biological effectiveness, and economic impacts. For each measure, the trends and observations in the five years leading up to the regulations (2006-2010) were compared to the trends and observations in the five years following the regulations (2011-2015). The memo finds that the regulations have benefited the whales by reducing impacts without causing economic harm to the commercial whale-watching industry or local communities. The authors also find room for improvement in terms of increasing awareness and enforcement of the regulations, which would help improve compliance and further reduce biological impacts to the whales.

(5) Oil Spills

In the Northwest, SRKWs are the most vulnerable marine mammal population to the risks imposed by an oil spill due to their small population size, strong site fidelity to areas with high oil spill risk, large group size, late reproductive maturity, low reproductive rate, and specialized diet, among other attributes (Jarvela-Rosenberger et al. 2017). Oil spills have occurred in the range of Southern Residents in the past, and there is potential for spills in the future. Oil can be discharged into the marine environment in any number of ways, including shipping accidents, refineries and associated production facilities, and pipelines.

Despite many improvements in spill prevention since the late 1980s, much of the region inhabited by Southern Residents remains at risk from serious spills because of the heavy volume of shipping traffic and proximity to petroleum refining centers in inland waters. Numerous oil tankers transit through the inland waters range of Southern Residents throughout the year. The magnitude of risk posed by oil discharges in the action area is difficult to precisely quantify. The total volume of oil spills declined from 2007 to 2013, but then increased from 2013 to 2017 (WDOE 2017). The percent of potential high-risk vessels that were boarded and inspected between 2009 to 2017 also declined (from 26 percent inspected in 2009 to 12.2 percent by 2017) (WDOE 2017).

Repeated ingestion of petroleum hydrocarbons by killer whales likely causes adverse effects; however, long-term consequences are poorly understood. In marine mammals, acute exposure to petroleum products can cause changes in behavior and reduced activity, inflammation of the mucous membranes, lung congestion and disease, pneumonia, liver disorders, neurological damage, adrenal toxicity, reduced reproductive rates, and changes in immune function (Geraci and St. Aubin 1990; Schwacke et al. 2013; Venn-Watson et al. 2015; de Guise et al. 2017; Kellar et al. 2017), potentially death and long-term effects on population viability (Matkin et al. 2008; Ziccardi et al. 2015). For example, 122 cetaceans stranded or were reported dead within five months following the Deepwater Horizon spill in the Gulf of Mexico (Ziccardi et al. 2015). An additional 785 cetaceans were found stranded from November 2010 to June 2013, which was declared an Unusual Mortality Event (Ziccardi et al. 2015). In addition, oil spills have the potential to adversely impact habitat and prey populations, and, therefore, may adversely affect Southern Residents by reducing food availability.

Status of Humpback Whales

Humpback whales were listed as endangered under the Endangered Species Conservation Act in June 1970 (35 FR 18319), and remained on the list of threatened and endangered species after the passage of the ESA in 1973 (35 FR 8491). A recovery plan for humpbacks was issued in November 1991 (NMFS 1991). On September 8, 2016, NMFS published a final rule to divide the globally listed endangered humpback whale into 14 DPSs and place four DPSs (Western North Pacific, Arabian Sea, Cape Verde/Northwest Africa, and Central America) as endangered and one (the Mexico DPS) as threatened (81 FR 62259). Only ESA-listed Central America and Mexico DPSs occur within the waters of the Pacific Northwest (the Hawaii DPS also appears in Washington Coastal Waters but is not ESA-listed).

Mexico DPS

The Mexico DPS of humpback whales is listed as threatened. A recovery strategy under the Species At Risk Act, often referred to as SARA, was published in 2013 (Fisheries and Oceans Canada 2013). The two goals of this recovery strategy are: In the short term, to maintain, at a minimum, the current abundance of humpback whales in British Columbia (using best estimate of 2,145 animals (95 percent CI = 1,970-2,331 as presented in Ford et al. 2009)); and, in the longer-term, to observe continued growth of the population and expansion into suitable habitats throughout British Columbia. To meet these goals, threat and population monitoring, research, management, protection and enforcement, stewardship, outreach and education activities were recommended.

<u>Spatial Structure and Diversity.</u> The Mexico DPS consists of whales that breed along the Pacific coast of mainland Mexico, and the Revillagigedos Islands and transit through the Baja California Peninsula coast. The Mexico DPS feeds across a broad geographic range from California to the Aleutian Islands, with concentrations in California-Oregon, northern Washington-southern British Columbia, northern and western Gulf of Alaska and Bering Sea feeding grounds.

<u>Abundance and Productivity.</u> The preliminary estimate of abundance of the Mexico DPS which informed the proposed rule was 6,000-7,000 from the SPLASH project, (Structure of Populations, Levels of Abundance and Status of Humpbacks) (Calambokidis et al.2008), or higher (Barlow et al. 2011). There were no estimates of precision associated with that estimate, so there was considerable uncertainty about the actual population size. However, the biological review team (BRT) was confident that the population was likely to be much greater than 2,000 in total size (above the BRT threshold for a population to be not at risk due to low abundance). Estimates of population growth trends do not exist for the Mexico DPS by itself. Given evidence of population growth throughout most of the primary feeding areas of the Mexico DPS (California/Oregon (Calambokidis et al. 2008), Gulf of Alaska from the Shumagins to Kodiak (Zerbini et al. 2006)), it was considered unlikely this DPS was declining, but the BRT noted that a reliable, quantitative estimate of the population growth rate for this DPS was not available. The Wade (2021) revised abundance estimate for the Mexico DPS is 2,913 (CV=0.066) animals, using the Multistrata model (Nmulti) (which uses both winter and summer data). The population trend is unknown.

Limiting Factors. Vessel collisions and entanglement in fishing gear pose the greatest threat to this DPS.

Central America DPS

Spatial Structure and Diversity. The Central America DPS is composed of whales that breed along the Pacific coast of Costa Rica, Panama, Guatemala, El Salvador, Honduras and Nicaragua. Whales from this breeding ground feed almost exclusively offshore of California and Oregon in the eastern Pacific, with only a few individuals identified at the northern Washington-southern British Columbia feeding grounds.

Abundance and Productivity. A preliminary estimate of abundance of the Central America population was ~500 from the SPLASH project (Calambokidis et al. 2008), or ~600 based on the reanalysis by Barlow et al. (2011). There were no estimates of precision associated with these estimates, so there was considerable uncertainty about the actual population size. Therefore, the actual population size could have been somewhat larger or smaller than 500-600, but the BRT considered it very unlikely to be as large as 2,000 or more. The size of this DPS was relatively low compared to most other North Pacific breeding populations (Calambokidis et al.2008) and within the range of population sizes considered by the BRT to be at risk based on low abundance. The trend of the Central America DPS was considered unknown. The Wade (2021) revised abundance estimate for the Central America DPS is 755 (Coefficient of Variation (CV)=0.242) animals, using the Multistrata model (Nmulti) (which uses both winter and summer data).

Limiting Factors. Vessel collisions and entanglement in fishing gear pose the greatest threat to this DPS.

Status of Sunflower Sea Star

The sunflower sea star (*Pycnopodia helianthoides*) occupies nearshore intertidal and subtidal marine waters shallower than 450 m (~1400 ft) deep from Adak Island, Alaska, to Bahia Asunción, Baja California Sur, Mexico. They are occasionally found in the deep parts of tide pools. The species is a habitat generalist, occurring over sand, mud, and rock bottoms both with and without appreciable vegetation. Critical habitat is currently indeterminable because information does not exist to clearly define primary biological features. Prey include a variety of epibenthic and infaunal invertebrates, and the species also digs in soft substrate to excavate clams. This star is a well-known urchin predator and plays a key ecological role in control of these kelp consumers. More information about sea star biology, ecology, and their life history cycle is found in the proposed listing (88 FR 2023).

From 2013 to 2017, the sunflower sea star experienced a range-wide epidemic of sea star wasting syndrome (SSWS) (Gravem et al. 2021; Hamilton et al. 2021; Lowry et al. 2022). While the cause of this disease remains unknown, prevalence of the outbreak has been linked to a variety of environmental factors, including temperature change, sustained elevated temperature, low dissolved oxygen, and decreased pH (Hewson et al. 2018; Aquino et al. 2021; Heady et al. 2022; Oulhen et al. 2022). As noted above, changes in physiochemical attributes of nearshore waters are expected to change in coming decades as a consequence of anthropogenic climate change, but the specific consequences of such changes on SSWS prevalence and severity are currently impossible to accurately predict.

2.2.2 Status of the Critical Habitats

This section examines the status of designated critical habitat affected by the proposed action by examining the condition and trends of essential physical and biological features throughout the designated areas. These features are essential to the conservation of the listed species because they support one or more of the species' life stages (e.g., sites with conditions that support spawning, rearing, migration and foraging).

Status of Salmon Critical Habitat

For salmon, NMFS ranked watersheds within designated critical habitat at the scale of the fifth-field hydrologic unit code (HUC5) in terms of the conservation value they provide to each listed species they support.8 The conservation rankings are high, medium, or low. To determine the conservation value of each watershed to species viability, NMFS's critical habitat analytical review teams (CHARTs) evaluated the quantity and quality of habitat features (for example, spawning gravels, wood and water condition, side channels), the relationship of the area compared to other areas within the species' range, and the significance to the species of the population occupying that area (NOAA Fisheries 2005). Thus, even a location that has poor quality of habitat could be ranked with a high conservation value if it were essential due to factors such as limited availability (e.g., one of a very few spawning areas), a unique contribution of the population it served (e.g., a population at the extreme end of geographic distribution), or if it serves another important role (e.g., obligate area for migration to upstream spawning areas). The physical or biological features of critical habitat for salmon and steelhead are identified in Table 28.

[8] The conservation value of a site depends upon "(1) the importance of the populations associated with a site to the ESU [or DPS] conservation, and (2) the contribution of that site to the conservation of the population through demonstrated or potential productivity of the area" (NOAA Fisheries 2005).

Table 28. Physical or Biological Features (PBFs) of critical habitats designated for ESA-listed salmon species considered in the opinion and corresponding species life history events. Yellow highlight denotes PBFs and Conservation Roles affected by the proposed action. Yellow highlight denotes area affected by the proposed action.

Physical or Biological Features Site Type	Physical or Biological Features Site Attribute	Species Life History Event
Freshwater spawning	• Substrate • Water quality • Water quantity	• Adult spawning • Embryo incubation • Alevin growth and development
Freshwater rearing	• Floodplain connectivity • Forage • Natural cover • Water quality • Water quantity	• Fry emergence from gravel • Fry/parr/smolt growth and development
Freshwater migration	• Free of artificial obstruction • Natural cover • Water quality • Water quantity	• Adult sexual maturation • Adult upstream migration and holding • Kelt (steelhead) seaward migration • Fry/parr/smolt growth, development, and seaward migration
Estuarine areas	• Forage • Free of artificial obstruction • Natural cover • Salinity • Water quality • Water quantity	• Adult sexual maturation and "reverse smoltification" • Adult upstream migration and holding • Kelt (steelhead) seaward migration • Fry/parr/smolt growth, development, and seaward migration
Nearshore marine areas	• Forage • Free of artificial obstruction • Natural cover • Water quantity • Water quality	• Adult growth and sexual maturation • Adult spawning migration • Nearshore juvenile rearing

CHART Salmon and Steelhead Critical Habitat Assessments

The CHART for each recovery domain assessed biological information pertaining to occupied by listed salmon and steelhead, determine whether those areas contained PBFs essential for the conservation of those species and whether unoccupied areas existed within the historical range of the listed salmon and steelhead that are also essential for conservation. The CHARTs assigned a 0 to 3 point score for the PBFs in each HUC_5 watershed for:

Factor 1. Quantity,
Factor 2. Quality – Current Condition,
Factor 3. Quality – Potential Condition,
Factor 4. Support of Rarity Importance,
Factor 5. Support of Abundant Populations, and
Factor 6. Support of Spawning/Rearing.

Thus, the quality of habitat in a given watershed was characterized by the scores for Factor 2 (quality – current condition), which considers the existing condition of the quality of PBFs in the HUC_5 watershed; and Factor 3 (quality – potential condition), which considers the likelihood of achieving PBF potential in the HUC_5 watershed, either naturally or through active conservation/restoration, given known limiting factors, likely biophysical responses, and feasibility.

Puget Sound Rockfish Critical Habitat

NMFS designated critical habitat for PS/GB yelloweye and PS/GB bocaccio rockfish on November 13, 2014 (79 FR 68042). Critical habitat is not designated in areas outside of United States jurisdiction; therefore, although waters in Canada are part of the DPSs' ranges for both species, critical habitat was not designated in that area. The U.S. portion of the Puget Sound/Georgia Basin that is occupied by PS/GB yelloweye rockfish and PS/GB bocaccio can be divided into five areas, or Basins, based on the distribution of each species, geographic conditions, and habitat features. These five interconnected Basins are: (1) The San Juan/Strait of Juan de Fuca Basin, (2) Main Basin, (3) Whidbey Basin, (4) South Puget Sound, and (5) Hood Canal. We have determined that approximately 644.7 square miles (1,669.8 sq km) of nearshore habitat for juvenile PS/GB bocaccio and 438.5 square miles (1,135.7 sq km) of deepwater habitat for yelloweye rockfish and PS/GB bocaccio meet the definition of critical habitat (Table 29).

Critical habitat for PS/GB bocaccio includes 590.4 square miles of nearshore habitat and 414.1 square miles of deep-water habitat. Based on the natural history of PS/GB bocaccio and their habitat needs, NMFS identified two physical or biological features, essential for their conservation: 1) Deepwater sites (>30 meters) that support growth, survival, reproduction, and feeding opportunities; and 2) Nearshore juvenile rearing sites with sand, rock and/or cobbles to support forage and refuge. Habitat threats include degradation of rocky habitat, loss of eelgrass and kelp, introduction of non-native species that modify habitat, and degradation of water quality.

Nearshore critical habitat for PS/GB bocaccio at juvenile life stages, is defined as areas that are contiguous with the shoreline from the line of extreme high water out to a depth no greater than 98 feet (30 m) relative to mean lower low water. The PBFs of nearshore critical habitat include settlement habitats with sand, rock, and/or cobble substrates that also support kelp. Important site attributes include: (1) Quantity, quality, and availability of prey species to support individual growth, survival, reproduction, and feeding opportunities; and (2) Water quality and sufficient levels of dissolved oxygen to support growth, survival, reproduction, and feeding opportunities.

Deep water critical habitat includes marine waters and substrates of the U.S. in Puget Sound east of Green Point in the Strait of Juan de Fuca, and serves both adult PS/GB bocaccio, and both juvenile and adult yelloweye rockfish. Deepwater critical habitat is defined as areas at depths greater than 98 feet (30 m) that supports feeding opportunities and predator avoidance.

The federal register notice for the designation of rockfish critical habitat in Puget Sound notes that many forms of human activities have the potential to affect the essential features of listed rockfish species, and specifically calls out, among others, (1) Nearshore development and in-water construction (e.g., beach armoring, pier construction, jetty or harbor construction, pile driving construction, residential and commercial construction); (2) dredging and disposal of dredged material; (3) pollution and runoff (79 FR 68041;11/13/14). Water quality throughout Puget Sound is degraded by anthropogenic sources within the Sound (e.g. pollutants from vessels) as well as upstream sources (municipal, industrial, and nonpoint sources). Nearshore habitat degradation exists throughout the Puget Sound from fill and dredge to create both fastland and navigational areas for commerce, from shore hardening to protect both residential and commercial waterfront properties, and from overwater structures that enable commercial and recreational boating.

NMFS' 2016 status update identifies recommended future actions including protection and restoration of nearshore habitat through removal of shoreline armoring, and protecting and increasing kelp coverage.

Table 29. Physical or Biological Features of Rockfish Critical Habitat. Yellow highlight denotes area affected by the proposed action.

DPS Basin	Nearshore square mile (for juvenile bocaccio only)	Deepwater square miles (for adult/juvenile yelloweye and adult bocaccio)	Physical or Biological Features		Activities
San Juan/Strait of Juan de Fuca	349.4	203.6	Deepwater sites (<30 meters) that support growth, survival, reproduction and feeding opportunities	Nearshore juvenile rearing sites with sand, rock and/or cobbles to support forage and refuge	1,2,3,6,9,10,11
Whidbey Basin	52.2	32.2			1,2,3,6,9,10,11
Main Basin	147.4	129.2			1,2,3,6,7,9,10,11
South Puget Sound	75.3	27.1			1,2,3,6,7,9,10,11
Hood Canal	20.4	46.4			1,2,3,6,7,9,10,11

Management Considerations Codes: (1) Nearshore development and in-water construction (e.g., beach armoring, pier construction, jetty or harbor construction, pile driving construction, residential and commercial construction); (2) dredging and disposal of dredged material; (3) pollution and runoff; (4) underwater construction and operation of alternative energy hydrokinetic projects (tidal or wave energy projects) and cable laying; (5) kelp harvest; (6) fisheries; (7) non-indigenous species introduction and management; (8) artificial habitats; (9) research; (10) aquaculture; and (11) activities that lead to global climate change and ocean acidification. Commercial kelp harvest does not occur presently, but would probably be concentrated in the San Juan/Georgia Basin. Artificial habitats could be proposed to be placed in each of the Basins. Non-indigenous species introduction and management could occur in each Basin.

Green Sturgeon, Southern DPS, Critical Habitat

A team similar to the CHARTs, referred to as a Critical Habitat Review Team (CHRT), identified and analyzed the conservation value of particular areas occupied by southern green sturgeon, and unoccupied areas they felt are necessary to ensure the conservation of the species (USDC 2009). The CHRT did not identify those particular areas using HUC nomenclature, but did provide geographic place names for those areas, including the names of freshwater rivers, the bypasses, the Sacramento-San Joaquin Delta, coastal bays and estuaries, and coastal marine areas (within 110 m depth) extending from the California/Mexico border north to Monterey Bay, California, and from the Alaska/Canada border northwest to the Bering Strait; and certain coastal bays and estuaries in California, Oregon, and Washington.

For freshwater rivers north of and including the Eel River, the areas upstream of the head of the tide were not considered part of the geographical area occupied by the southern DPS. However, the critical habitat designation recognizes not only the importance of natal habitats, but of habitats throughout their range. Critical habitat has been designated in coastal U.S. marine waters within 60 fathoms depth from Monterey Bay, California (including Monterey Bay), north to Cape Flattery, Washington, including the Strait of Juan de Fuca, Washington, to its United States boundary; the Sacramento River, lower Feather River, and lower Yuba River in California; the Sacramento-San Joaquin Delta and Suisun, San Pablo, and San Francisco bays in California; the lower Columbia River estuary; and certain coastal bays and estuaries in California (Humboldt Bay), Oregon (Coos Bay, Winchester Bay, Yaquina Bay, and Nehalem Bay), and Washington (Willapa Bay and Grays Harbor) and freshwater (USDC 2009). Table 30 delineates physical or biological features for southern DPS green sturgeon.

Table 30. Physical or biological features of critical habitat designated for southern green sturgeon and corresponding species life history events. Yellow highlight denotes area affected by the proposed action.

Physical or Biological Features Site Type	Physical or Biological Features Site Attribute	Species Life History Event
Freshwater riverine system	• Food resources • Migratory corridor • Sediment quality • Substrate type or size • Water depth • Water flow • Water quality	• Adult spawning • Embryo incubation, growth and development • Larval emergence, growth and development • Juvenile metamorphosis, growth and development
Estuarine areas	• Food resources • Migratory corridor • Sediment quality • Water flow • Water depth • Water quality	• Juvenile growth, development, seaward migration • Subadult growth, development, seasonal holding, and movement between estuarine and marine areas • Adult growth, development, seasonal holding, movements between estuarine and marine areas, upstream spawning movement, and seaward post-spawning movement
Coastal marine areas	• Food resources • Migratory corridor • Water quality	• Subadult growth and development, movement between estuarine and marine areas, and migration between marine areas • Adult sexual maturation, growth and development, movements between estuarine and marine areas, migration between marine areas, and spawning migration

The CHRT identified several activities that threaten the PBFs in coastal bays and estuaries and necessitate the need for special management considerations or protection. The application of pesticides is likely to adversely affect prey resources and water quality within the bays and estuaries, as well as the growth and reproductive health of Southern DPS green sturgeon through bioaccumulation. Other activities of concern include those that disturb bottom substrates, adversely affect prey resources, or degrade water quality through re-suspension of contaminated sediments. Of particular concern are activities that affect prey resources. Prey resources are affected by: commercial shipping and activities generating point source pollution and non-point source pollution that discharge contaminants and result in bioaccumulation of contaminants in green sturgeon; disposal of dredged materials that bury prey resources; and bottom trawl fisheries that disturb the bottom (but result in beneficial or adverse effects on prey resources for green sturgeon). In addition, petroleum spills from commercial shipping and proposed hydrokinetic energy projects are likely to affect water quality or hinder the migration of green sturgeon along the coast (USDC 2009).

Puget Sound Recovery Domain

Critical habitat has been designated in Puget Sound for PS Chinook salmon, PS steelhead, HC summer-run chum salmon, Lake Ozette sockeye salmon, southern green sturgeon, and for eulachon. Major tributary river basins in the Puget Sound basin include the Nooksack, Samish, Skagit, Sauk, Stillaguamish, Snohomish, Lake Washington, Cedar, Sammamish, Green, Duwamish, Puyallup, White, Carbon, Nisqually, Deschutes, Skokomish, Duckabush, Dosewallips, Big Quilcene, Elwha, and Dungeness rivers and Soos Creek.

Landslides can occur naturally in steep, forested lands, but inappropriate land use practices likely have accelerated their frequency and the amount of sediment delivered to streams. Fine sediment from unpaved roads has also contributed to stream sedimentation. Unpaved roads are widespread on forested lands in the Puget Sound basin, and to a lesser extent, in rural residential areas. Historical logging removed most of the riparian trees near stream channels. Subsequent agricultural and urban conversion permanently altered riparian vegetation in the river valleys, leaving either no trees, or a thin band of trees. The riparian zones along many agricultural areas are now dominated by alder, invasive canary grass and blackberries, and provide substantially reduced stream shade and large wood recruitment (Shared Strategy for Puget Sound 2007).

Diking, agriculture, revetments, railroads and roads in lower stream reaches have caused significant loss of secondary channels in major valley floodplains in this region. Confined main channels create high-energy peak flows that remove smaller substrate particles and large wood. The loss of side-channels, oxbow lakes, and backwater habitats has resulted in a significant loss of juvenile salmonid rearing and refuge habitat. When the water level of Lake Washington was lowered nine feet in the 1910s, thousands of acres of wetlands along the shoreline of Lake Washington, Lake Sammamish and the Sammamish River corridor were drained and converted to agricultural and urban uses. Wetlands play an important role in hydrologic processes, as they store water which ameliorates high and low flows. The interchange of surface and groundwater in complex stream and wetland systems helps to moderate stream temperatures. Forest wetlands are estimated to have diminished by one-third in Washington State (FEMAT 1993; Spence et al. 1996; Shared Strategy for Puget Sound 2007).

Loss of riparian habitat, elevated water temperatures, elevated levels of nutrients, increased nitrogen and phosphorus, and higher levels of turbidity, presumably from urban and highway runoff, wastewater treatment, failing septic systems, and agriculture or livestock impacts, have been documented in many Puget Sound tributaries (Shared Strategy for Puget Sound 2007).

Peak stream flows have increased over time due to paving (roads and parking areas), reduced percolation through surface soils on residential and agricultural lands, simplified and extended drainage networks, loss of wetlands, and rain-on-snow events in higher elevation clear cuts (Shared Strategy for Puget Sound 2007). In urbanized Puget Sound, there is a strong association between land use and land cover attributes and rates of coho spawner mortality likely due to runoff containing contaminants emitted from motor vehicles (Feist et al. 1996).

Dams constructed for hydropower generation, irrigation, or flood control have substantially affected PS Chinook salmon populations in a number of river systems. The construction and operation of dams have blocked access to spawning and rearing habitat (e.g., Elwha River dams block anadromous fish access to 70 miles of potential habitat) changed flow patterns, resulted in elevated temperatures and stranding of juvenile migrants, and degraded downstream spawning and rearing habitat by reducing recruitment of spawning gravel and large wood to downstream areas (Shared Strategy for Puget Sound 2007). These actions tend to promote downstream channel incision and simplification (Kondolf 1997), limiting fish habitat. Water withdrawals reduce available fish habitat and alter sediment transport. Hydropower projects often change flow rates, stranding and killing fish, and reducing aquatic invertebrate (food source) productivity (Hunter 1992).

Juvenile mortality occurs in unscreened or inadequately screened diversions. Water diversion ditches resemble side channels in which juvenile salmonids normally find refuge. When diversion headgates are shut, access back to the main channel is cut off and the channel goes dry. Mortality can also occur with inadequately screened diversions from impingement on the screen, or mutilation in pumps where gaps or oversized screen openings allow juveniles to get into the system (WDFW 2009). Blockages by dams, water diversions, and shifts in flow regime due to hydroelectric development and flood control projects are major habitat problems in many Puget Sound tributary basins (Shared Strategy for Puget Sound 2007).

The nearshore marine habitat has been extensively altered and armored by industrial and residential development near the mouths of many of Puget Sound’s tributaries. A railroad runs along large portions of the eastern shoreline of Puget Sound, eliminating natural cover along the shore and natural recruitment of beach sand (Shared Strategy for Puget Sound 2007).

Degradation of the near-shore environment has occurred in the southeastern areas of Hood Canal in recent years, resulting in late summer marine oxygen depletion and significant fish kills. Circulation of marine waters is naturally limited, and partially driven by freshwater runoff, which is often low in the late summer. However, human development has increased nutrient loads from failing septic systems along the shoreline, and from use of nitrate and phosphate fertilizers on lawns and farms. Shoreline residential development is widespread and dense in many places. The combination of highways and dense residential development has degraded certain physical and chemical characteristics of the near-shore environment (Hood Canal Coordinating Council 2005; Shared Strategy for Puget Sound 2007).

The Ozette Lake tributary basin is 77 mi^2 and includes several large tributaries and numerous smaller tributaries. Currently, land ownership in the watershed is 73 percent private land, 15 percent Olympic National Park, 11 percent Washington State, and 1 percent Tribal. Natural disturbance in the watershed was dominated by wind and hydrogeomorphic events, while contemporary disturbance additionally includes logging, road construction and maintenance, residential and agricultural development, stream channelization and direct and indirect stream wood clearance. These activities alter stream flow patterns and elevate of sediment loads and sedimentation. Wood removal has resulted in less hydraulic roughness, reduced instream water depths, and reduced backwater effects on Lake Ozette, which has thus altered the entire hydraulic control on Lake Ozette levels and changed the in-river stage-discharge relationship. More recently, deposition of sediment originating from Coal Creek at the lake outlet has further altered lake and river levels (Haggerty et al. 2009).

Private timber companies own approximately 93 percent of the four largest tributary watersheds to Lake Ozette. Logging accelerated over the period of record, with 8.7 percent of the Ozette Lake basin clear-cut by 1953, increasing to 83.6 percent of the basin area clear-cut by 2003 (Haggerty et al. 2009). Effects associated with logging depended on stream size, gradient, and time elapsed. In high-energy coast streams, landslides and debris torrents often modify steep slope tributaries and the mainstem of creeks. Bank erosion also alters stream channels on alluvial floodplains. These effects are additive in the system and reduced the quality of spawning and rearing habitat for juvenile salmonids (Hartman et al. 1996). Lower gradient streams typically have an accumulation of sediment. Second-growth sections are characterized by increased shade provided by deciduous forest canopy within 12 to 35 years after logging. Young deciduous forest provides lower biomass of trout and fewer predator taxa than old-growth sites (Murphy and Hall 1981). Based on the quantity and quality of the physical and biological features, the CHART assessed the conservation value of the Ozette Lake HUC_5 watershed (#1710010102) for sockeye salmon to be “high” (NOAA Fisheries 2005).

Eulachon critical habitat is designated in two discrete locations in the Puget Sound domain: the lower 4 miles of the Elwha River, and the lower 2 miles of the Quinault River. In both locations the critical habitat serves migration and spawning values. (76 FR 65324; 10/20/11). The lateral extent of critical habitat as the width of the stream channel defined by the ordinary high water line, as defined by the USACE in 33 CFR 329.11. Each specific area extends from the mouth of the specific river or creek (or its associated estuary when applicable) upstream to a fixed location. The activities that may affect PBFs of critical habitat in the Quinault are pollution from point and nonpoint sources, and in water construction, including channel modifications and diking. These are also noted as concerns for the Elwha, and while the designation documents also identify dams as a point affecting PBFs for eulachon critical habitat, subsequent to the designation the Glines and Elwha dams were removed, re-establishing habitat processes and potential access to larger areas for spawning.

In summary, critical habitat throughout the Puget Sound basin has been degraded by numerous management activities, including hydropower development, loss of mature riparian forests, increased sediment inputs, removal of large wood, intense urbanization, agriculture, alteration of floodplain and stream morphology (*i.e*., channel modifications and diking), riparian vegetation disturbance, wetland draining and conversion, dredging, armoring of shorelines, marina and port development, road and railroad construction and maintenance, logging, and mining. Changes in habitat quantity, availability, and diversity, and flow, temperature, sediment load and channel instability are common limiting factors in areas of critical habitat.

The PS recovery domain CHART (NOAA Fisheries 2005) determined that only a few watersheds with PBFs for Chinook salmon in the Whidbey Basin (Skagit River/Gorge Lake, Cascade River, Upper Sauk River, and the Tye and Beckler rivers) are in good-to-excellent condition with no potential for improvement. Most HUC_5 watersheds are in fair-to-poor or fair-to-good condition. However, most of these watersheds have some or a high potential for improvement (Table 31).

Table 31. Puget Sound Recovery Domain: Current and potential quality of HUC_5 watersheds identified as supporting historically independent populations of ESA-listed Chinook salmon (CK) and chum salmon (CM) (NOAA Fisheries 2005).[9] Watersheds are ranked primarily by "current quality" and secondly by their "potential for restoration." Yellow highlight denotes areas affected by the proposed action.

Current PBF Condition	Potential PBF Condition
3 = good to excellent	3 = highly functioning, at historical potential
2 = fair to good	2 = high potential for improvement
1 = fair to poor	1 = some potential for improvement
0 = poor	0 = little or no potential for improvement

Watershed Name(s) and HUC_5 Code(s)	Listed Species	Current Quality	Restoration Potential
Strait of Georgia and Whidbey Basin #1711000xxx			
Skagit River/Gorge Lake (504), Cascade (506) & Upper Sauk (601) rivers, Tye & Beckler rivers (901)	CK	3	3
Skykomish River Forks (902)	CK	3	1
Skagit River/Diobsud (505), Illabot (507), & Middle Skagit/Finney Creek (701) creeks; & Sultan River (904)	CK	2	3
Skykomish River/Wallace River (903) & Skykomish River/Woods Creek (905)	CK	2	2
Upper (602) & Lower (603) Suiattle rivers, Lower Sauk (604), & South Fork Stillaguamish (802) rivers	CK	2	1
Samish River (202), Upper North (401), Middle (402), South (403), Lower North (404), Nooksack River; Nooksack River (405), Lower Skagit/Nookachamps Creek (702) & North Fork (801) & Lower (803) Stillaguamish River	CK	1	2
Bellingham (201) & Birch (204) bays & Baker River (508)	CK	1	1
Whidbey Basin and Central/South Basin #1711001xxx			
Lower Snoqualmie River (004), Snohomish (102), Upper White (401) & Carbon (403) rivers	CK	2	2
Middle Fork Snoqualmie (003) & Cedar rivers (201), Lake Sammamish (202), Middle Green River (302) & Lowland Nisqually (503)	CK	2	1
Pilchuck (101), Upper Green (301), Lower White (402), & Upper Puyallup River (404) rivers, & Mashel/Ohop(502)	CK	1	2
Lake Washington (203), Sammamish (204) & Lower Green (303) rivers	CK	1	1
Puyallup River (405)	CK	0	2
Hood Canal #1711001xxx			
Dosewallips River (805)	CK/CM	2	1/2
Kitsap – Kennedy/Goldsborough (900)	CK	2	1
Hamma Hamma River (803)	CK/CM	1/2	1/2
Lower West Hood Canal Frontal (802)	CK/CM	0/2	0/1
Skokomish River (701)	CK/CM	1/0	2/1
Duckabush River (804)	CK/CM	1	2
Upper West Hood Canal Frontal (807)	CM	1	2

[9] On January 14, 2013, NMFS published a proposed rule for the designation of critical habitat for LCR coho salmon and PS steelhead (USDC 2013b). A draft biological report, which includes a CHART assessment for PS salmon, was also completed (NMFS 2012). Habitat quality assessments for PS steelhead are out for review; therefore, they are not included on this table.

Current PBF Condition	Potential PBF Condition
3 = good to excellent	3 = highly functioning, at historical potential
2 = fair to good	2 = high potential for improvement
1 = fair to poor	1 = some potential for improvement
0 = poor	0 = little or no potential for improvement

Watershed Name(s) and HUC_5 Code(s)	Listed Species	Current Quality	Restoration Potential
Big Quilcene River (806)	CK/CM	1	1/2
Deschutes Prairie-1 (601) & Prairie-2 (602)	CK	1	1
West Kitsap (808)	CK/CM	1	1
Kitsap – Prairie-3 (902)	CK	1	1
Port Ludlow/Chimacum Creek (908)	CM	1	1
Kitsap – Puget (901)	CK	0	1
Kitsap – Puget Sound/East Passage (904)	CK	0	0
Strait of Juan de Fuca Olympic #1711002xxx			
Dungeness River (003)	CK/CM	2/1	1/2
Discovery Bay (001) & Sequim Bay (002)	CM	1	2
Elwha River (007)	CK	1	2
Port Angeles Harbor (004)	CK	1	1

Southern Resident Killer Whale Critical Habitat

Critical habitat for the SRKW DPS was designated on November 29, 2006 (71 FR 69054) and the designation was revised on August 2, 2021 (86 FR 41668). The Critical habitat includes approximately 2,560 square miles of inland waters of Washington in three specific areas: 1) the Summer Core Area in Haro Strait and waters around the San Juan Islands; 2) Puget Sound; and 3) the Strait of Juan de Fuca, and also include 15,910 square miles (mi2) (41,207 square kilometers (km2)) of marine waters between the 20-feet (ft) (6.1-meter (m)) depth contour and the 656.2-ft (200-m) depth contour from the U.S. international border with Canada south to Point Sur, California. We have excluded one area, the Quinault Range Site. Based on the natural history of SRKWs and their habitat needs, NMFS identified the following physical or biological features essential to conservation: (1) Water quality to support growth and development; (2) Prey species of sufficient quantity, quality and availability to support individual growth, reproduction and development, as well as overall population growth; and (3) Passage conditions to allow for migration, resting, and foraging.

In 2006, few data were available on SRKWs distribution and habitat use in coastal waters of the Pacific Ocean. Since the 2006 designation, additional effort has been made to better understand the geographic range and movements of SRKWs. For example, opportunistic visual sightings, satellite tracking, and passive acoustic research conducted since 2006 have provided an updated estimate of the whales' coastal range that extends from the Monterey Bay area in California, north to Chatham Strait in southeast Alaska (NMFS 2019).

(1) Water Quality
Water quality supports SRKW's ability to forage, grow, and reproduce free from disease and impairment. Water quality is essential to the whales' conservation, given the whales' present contamination levels, small population numbers, increased extinction risk caused by any

additional mortalities, and geographic range (and range of their primary prey) that includes highly populated and industrialized areas. Water quality is especially important in high-use areas where foraging behaviors occur and contaminants can enter the food chain. The absence of contaminants or other agents of a type and/or amount that would inhibit reproduction, impair immune function, result in mortalities, or otherwise impede the growth and recovery of the SRKW population is a habitat feature essential for the species' recovery. Water quality in Puget Sound, in general, is degraded as described in the Puget Sound Partnership 2018-2022 Action Agenda and Comprehensive (Puget Sound Partnership 2018). For example, toxicants in Puget Sound persist and build up in marine organisms including SRKWs and their prey resources, despite bans in the 1970s of some harmful substances and cleanup efforts. Water quality varies in coastal waters from Washington to California. For example, as described in NMFS (2019), high levels of DDTs have been found in SRKWs, especially in K and L pods, which spend more time in California in the winter where DDTs still persist in the marine ecosystem (Sericano et al. 2014).

Exposure to oil spills also poses additional direct threats as well as longer term population level impacts; therefore, the absence of these chemicals is of the utmost importance to SRKW conservation and survival. Oil spills can also have long-lasting impacts on other habitat features. Oil spill risk exists throughout the SRKW's coastal and inland range. From 2002- 2016, the highest-volume crude oil spill occurred in 2008 off the California coast, releasing 463,848 gallons (Stephens 2017). In 2015 and 2016, crude oil spilled into the marine environment off the California coast totaled 141,680 gallons and 44,755, respectively; no crude oil spills were reported off the coasts of Oregon or Washington in these years (Stephens 2015, Stephens 2017). Non-crude oil spills into the marine environment also occurred off California, Oregon, and Washington in 2015 and 2016 (Stephens 2015, Stephens 2017).The Environmental Protection Agency and U.S. Coast Guard oversee the Oil Pollution Prevention regulations promulgated under the authority of the Federal Water Pollution Control Act. There is a Northwest Area Contingency Plan, developed by the Northwest Area Committee, which serves as the primary guidance document for oil spill response in Washington and Oregon. In 2017, the Washington State Department of Ecology published a new Spill Prevention, Preparedness, and Response Program Annual Report describing the Spills Program as well as the performance measures from 2007 – 2017 (WDOE 2017).

(2) Prey Quantity, Quality, and Availability

Most wild salmon stocks throughout the whales' geographic range are at fractions of their historic levels. Beginning in the early 1990s, 28 ESUs and DPSs of salmon and steelhead in Washington, Oregon, Idaho, and California were listed as threatened or endangered under the ESA. Historically, overfishing, habitat losses, and hatchery practices were major causes of decline. Poor ocean conditions over the past two decades have reduced populations already weakened by the degradation and loss of freshwater and estuary habitat, fishing, hydropower system management, and hatchery practices. While wild salmon stocks have declined in many areas, hatchery production has been generally strong.

Contaminants and pollution also affect the quality of SRKW prey in Puget Sound and in coastal waters of Washington, Oregon, and California. Contaminants enter marine waters and sediment from numerous sources, but are typically concentrated near areas of high human population and industrialization. Once in the environment these substances proceed up the food chain, accumulating in long-lived top predators like SRKWs. Chemical contamination of prey is a potential threat to SRKW critical habitat, despite the enactment of modern pollution controls in recent decades, which were successful in reducing, but not eliminating, the presence of many contaminants in the environment. The size of Chinook salmon is also an important aspect of prey quality (i.e., SRKWs primarily consume large Chinook) so changes in Chinook size may affect the quality of this component critical habitat. In addition, vessels and sound may reduce the effective zone of echolocation and reduce availability of fish for the whales in their critical habitat (Holt 2008).

(3) Passage
Southern Residents are highly mobile and use a variety of areas for foraging and other activities, as well as for traveling between these areas. Human activities can interfere with movements of the whales and impact their passage. In particular, vessels may present obstacles to whale passage, causing the whales to swim further and change direction more often, which can increase energy expenditure for whales and impacts foraging behavior (review in NMFS (2010b), Ferrara et al. (2017).

Status of Sunflower Sea Star Critical Habitat

Critical habitat is not yet proposed for this species.

2.3 Action Area

"Action area" means all areas to be affected directly or indirectly by the federal action and not merely the immediate area involved in the action (50 CFR 402.02). The action area consists of all the areas where the environmental effects of actions under this program may occur. There is overlap between the areas impacted by the proposed action and the range of ESA-listed salmon, steelhead, green sturgeon, eulachon, rockfish, Southern Resident killer whales, and humpback whales, and designated critical habitats.

Research activities would occur within Sequim Bay and the adjacent portion of the Strait of Juan de Fuca between Dungeness Spit and Protection Island, including Battelle/DOE owned Sequim parcels and the Tidal Marsh Area (Figure 5 and Figure 6).

Within the three components of the action area, specific populations of the three salmonid species are more likely to be present based on age, species type, life history behavior, and proximity of natal streams. We provide more detail about the species likely to be present in Section 2.4.2, below.

2.3.1 Strait of Juan de Fuca Research Area

The proposed Strait of Juan de Fuca research area is a semi-triangular area as shown in Figure 5, below. This area is waterward of MLLW from the mouth of Sequim Bay at the south corner, to Dungeness Bay at the northwest corner, and to Protection Island at the east corner, comprising a total area of approximately 42,600 acres. Water depth within this area is mostly 30 to 160 feet deep, reaching to >230 feet deep on the northern edge and the region south and west of

Protection Island. Currents are relatively slow, with daily maximums typically less than 1 knot (0.5 m/s). The substrate is primarily sand and shells with clay and mud components north of Travis Spit (NOAA 2013).

Figure 5. Action Area

There are FWS managed national wildlife refuges at both Dungeness Spit and Protection Island. The PNNL research would not occur within the boundaries of either of these refuges. There is also a larger Washington Department of Natural Resources (WDNR) managed Protection Island Aquatic Reserve surrounding Protection Island. Some research activities could occur within the aquatic reserve. Any activities within the reserve would be consistent with the management goals of the reserve and would be conducted in coordination with the WDNR refuge managers. In this portion of the action area Puget Sound Chinook salmon, Puget Sound steelhead, and HCSR chum are all likely to be present at any time of year.

2.3.2 Sequim Bay Research Area

Sequim Bay is a 5,000-acre saltwater body connected to the Strait of Juan de Fuca by a relatively narrow channel (650 feet wide at mean lower low water [MLLW])) between Travis Spit and the PNNL-Sequim Campus pier and floating dock. The bay has a maximum depth of approximately 100 feet at MLLW. Sediments in Sequim Bay can be characterized as mostly mixed-fine sediment or mud with some gravel/cobble in areas with swifter current such as the channel near the PNNL-Sequim Campus pier and floating dock. Eelgrass beds are patchy and are primarily located in fringe habitat around the shoreline.

The area proposed for PNNL research includes all of Sequim Bay from the connection to the Strait of Juan de Fuca to the approximate 6 feet (MLLW) to the south, waterward of the MLLW except for Battelle or DOE-owned land and tidelands. Research activities will also use Battelle or DOE owned land adjacent to the shoreline and tidelands (e.g., marsh, wetlands) for research purposes.

In this portion of the action area, juvenile Puget Sound Chinook salmon and HCSR chum are likely to be present in greater numbers than steelhead based on their nearshore dependency as smolts.

2.3.3 Sequim Bay Research Area – Tidal Marsh Area

The Tidal Marsh Area covers 52 acres within the Sequim Bay Research Area consists of areas below and above MHW along Bugge Spit (Figure 6). Vegetation in the area is consistent with that found in persistent emergent wetlands (Cowardin 1979). Vegetation consists of glasswort (*Sarcocornia pacifica*) mixed with saltgrass (*Distichlis spicata*), and as elevation increases, transitions to tufted hairgrass (*Deschampsia cespitosa*). Other species found in the area include: western yarrow (*Achillea millefolium*), annual vernalgrass (*Anthoxanthum aristatum*), common orach (*Atriplex patula*), Pacific hemlock-parsley (*Conioselinum pacificum*), salt marsh dodder (*Cuscuta salina*), American dunegrass (*Elymus mollis*), quack grass (*Elymus repens*), Puget Sound gumweed (*Grindelia integrifolia*), meadow barley (*Hordeum brachyantherum*), marsh jaumea (*Jaumea carnosa*), sea plantain (*Plantago maritima*), dwarf alkaligrass (*Puccinellia pumila*), saltmarsh sand-spurry (*Sperigularia marina*), and seaside arrowgrass (*Triglochin maritimum*). In this portion of the action area, juvenile Puget Sound Chinook salmon and HCSR chum are likely to be present in greater numbers than steelhead based on their nearshore dependency as smolts.

Figure 6. PNNL-Sequim Tidelands and Marsh included in the Sequim Bay Research Area

2.4 Environmental Baseline

The "environmental baseline" refers to the condition of the listed species or its designated critical habitat in the action area, without the consequences to the listed species or designated critical habitat caused by the proposed action. The environmental baseline includes the past and present impacts of all federal, state, or private actions and other human activities in the action area, the anticipated impacts of all proposed federal projects in the action area that have already undergone formal or early Section 7 consultations, and the impact of state or private actions which are contemporaneous with the consultation in process. The consequences to listed species or designated critical habitat from ongoing agency activities or existing agency facilities that are not within the agency's discretion to modify are part of the environmental baseline (50 CFR 402.02).

2.4.1 Current Environmental Conditions in the Action Area

Sequim Bay

The Sequim Bay watershed is located in Clallam County on the Olympic Peninsula in northwest Washington State. The watershed drains an area of approximately 35,813 acres, from its highest point at Mt. Zion (4,273 feet) in Olympic National Forest, north to the Strait of Juan de Fuca (JSKT 2013). Sequim Bay watershed is bounded on the east by Discovery Bay watershed and on the west by Dungeness watershed. Jimmycomelately Creek is Sequim Bay's primary subbasin. Other significant subbasins draining to Sequim Bay include Johnson, Dean, and Chicken Coop creeks. Bell Creek drains into Washington Harbor. Topography is steep in the upper, forested portions of the watershed with more gentle and flatter slopes toward Sequim Bay. In addition to the subwatershed drainages listed above, water used for domestic and farmland irrigation enters

Sequim Bay from the Dungeness River through irrigation tailwaters in Bell and Johnson Creeks and one ditch north of John Wayne Marina.

The Sequim Bay watershed is 72 percent forestland (encompassing 25,866 acres) and the rural residential category includes areas developed at a density of one residential unit per 1.5 to 5 acres (JSKT 2013). The area classed as agricultural land includes about 40 small farms and nine commercial farms. The agricultural area is used principally for hay and pasture, but there is an increasing amount of revenue-producing cropland. Small farms range in size from 8 to 20 acres with 5 to 10 cows or horses. Commercial operations average 72 acres in size with 30 to 40 head of livestock. The village of Blyn on the shoreline at the head of Sequim Bay is the home of Jamestown S'Klallam Tribe’s reservation.

The tidal exchange between the bay and the Strait of Juan de Fuca results in moderate tidal currents in this channel (up to 1.5 m/s), with up to a 2.7 m tidal exchange at the channel connection with the strait. Sediments in Sequim Bay are mostly mixed-fine sediment or mud with some gravel/cobble in areas of swifter current such as the channel near the PNNL-Sequim Campus pier and floating dock. Seagrass meadows consisting of eelgrass are patchy and are primarily located in fringe habitat around the shoreline. Sequim Bay is not currently listed as a 303(d) waterbody, but it has been designated as such in the past and surrounding areas currently have this designation. A 303(d) waterbody is impaired and may have low dissolved oxygen, point source contamination of polycyclic aromatic hydrocarbons, and fecal coliform (Elwha-Dungeness Planning Unit 2005), all of which limit commercial and recreational shellfish harvest activities. The bay also has a small boat marina (John Wayne Marina) and is bordered by residential properties, Sequim Bay State Park, and the PNNL-Sequim Campus.

Gibson, Bugge, and Travis Spits border the opening of Sequim Bay (PNPTC 2006b). The Middle Ground is a sandy shoal that is submerged except during lower tides. As mentioned above, there are two dominant streams that delta in the bay: Jimmycomelately Creek and Dean Creek. Jimmycomelately Creek is in south Sequim Bay and is the largest stream in the Sequim Bay watershed, flowing nine miles from headwaters to the bay (Clallam County 2005). Dean Creek, also in south Sequim Bay, is approximately four-mile-long (Clallam County 2005). These creek channels were reconfigured in 2005 during restoration efforts to reintroduce connectivity and channel complexity (PNPTC 2006b) and provide a substantial tidal flat (PNPTC 2006b). Habitat provided by the connectivity between Jimmycomelately and Dean Creeks (i.e., tidal marsh, lagoon, and tidal flats) is considered functional (PNPTC 2006b). These habitats are essential for species’ reproduction and rearing, particularly for several species of salmonids (PNPTC 2006a).

Sequim Bay is an estuarine habitat and a nearshore coastal marine area that may provide food resources, appropriate water quality (e.g., viability for all life stages), a migratory corridor (e.g., for safe passage between riverine, estuarine, or marine habitats), or appropriate depth and sediment quality (e.g., for shelter, foraging, migration; NMFS 2018c) for various aquatic species and marine mammals. There are several protected aquatic species (via the ESA or Marine Mammal Protection Act) that are either known to occur or potentially occur in and adjacent to Sequim Bay near the PNNL-Sequim Campus.

Strait of Juan de Fuca

The Strait of Juan de Fuca is located in western Washington, along the border between Canada and the United States. The Strait is a glacially carved fjord lying between Washington State and Vancouver Island, British Columbia. The western entrance to the Strait of Juan de Fuca is about 650 feet deep. Near Victoria, the shelf is about 200 feet deep and extends southward to separate the Strait into eastern and western sections. The eastern Strait separates about 84 miles east of the mouth into a northern portion and a southern portion. The northern portion goes through the San Juan Archipelago (via Rosario Strait, Haro Strait and San Juan Channel) into the Strait of Georgia. The southern portion, in which the action area lies, enters Puget Sound through Admiralty Inlet. The Strait of Juan de Fuca is a major transportation lane for Canadian and U.S. commercial and recreational ships and boats. There are oil refineries in Padilla Bay (off of Rosario Strait) and the Strait of Georgia.

The waters of the Strait of Juan de Fuca are partially mixed and weakly stratified. The primary freshwater source (approximately 75 percent) is the Fraser River in British Columbia (Herlinveaux and Tullly, 1961). The Fraser river flow has a strong seasonal cycle, with a maximum flow rate in early June at the peak of the high-altitude snowmelt. The remaining fresh water enters the Strait through Puget Sound (Washington rivers), along the Olympic Peninsula, and along Vancouver Island. Rivers on Vancouver Island are a freshwater source an order of magnitude smaller than the Fraser River, with a peak in the winter during heavy rains (Masson and Cummins, 1999).

Vigorous mixing occurs at entrances/exits to the Strait–in Rosario Strait, Boundary Pass (linking the Straits of Georgia and Juan de Fuca) and Admiralty Inlet (connecting the Strait of Juan de Fuca with Puget Sound). This vigorous mixing, caused primarily by high currents flowing over sills, serves to mix salty and fresh water, decreasing overall salinity gradients of the Strait of Juan de Fuca waters.

2.4.2 Species Presence and Critical Habitat in the Action Area

While it is preferred for research to be conducted during the in-water work window for Tidal Reference Area 10, to avoid the majority of salmon, that cannot always be done due to funding or the purposeful timing of the research projects. The analysis for this opinion was done assuming different life stages of species <u>will be present</u>, sometimes in greater numbers than at other times.

Puget Sound Chinook and Critical Habitat

The Puget Sound Chinook salmon ESU includes all naturally spawned populations of Chinook salmon from rivers and streams flowing into Puget Sound including the Straits of Juan De Fuca from the Elwha River, eastward (70 FR 37160). There are no Puget Sound Chinook salmon populations that spawn in streams flowing into Sequim Bay. However, the closest Puget Sound Chinook salmon population is in the Dungeness River watershed located west of Sequim Bay, within the Strait of Juan de Fuca, discharging into the action area. The nearshore environment of Sequim Bay and the Strait of Juan de Fuca may be used for rearing (70 FR 37160). The whole of Sequim Bay and areas around Gibson Spit, Protection Island and Dungeness Spit have been designated critical habitat (70 FR 52629). The Sequim Bay nearshore environment (from extreme high tide out to a depth of 30 meters) is considered a physical or biological feature for the DPS, as it generally encompasses photic zone habitats supporting plant cover (e.g., eelgrass and kelp) important for rearing, migrating, and maturing salmon and their prey. Deeper waters are occupied by subadult and maturing fish. Thus, juvenile Chinook could occupy the nearshore, while subadult and maturing fish could occupy deeper water. Juveniles prey upon insects, amphipods, and other crustaceans, while adults primarily prey upon fish. *The populations of this species are most likely to be affected by the proposed action are from Elwha River and Dungeness River*. The PBFs of CH in the action area are for estuarine and nearshore marine areas.

Hood Canal Summer Run Chum Salmon and Critical Habitat

The Hood Canal summer-run chum salmon ESU includes all naturally spawned populations of summer-run chum salmon in Hood Canal and its tributaries as well as populations in Olympic Peninsula rivers between Hood Canal and Dungeness Bay (70 FR 37160; 6/28/2005. The Hood Canal summer-run chum salmon population nearest to the project area spawns in Jimmycomelately Creek at the south end of Sequim Bay, which serves as spawning and rearing habitat and the Dungeness River (70 FR 52629; 9/2/2005). The whole of Sequim Bay and areas around Gibson Spit, Protection Island and Dungeness Spit have been designated critical habitat (70 FR 52629). The Sequim Bay nearshore environment (from extreme high tide out to a depth of 30 meters) is considered a physical or biological feature for the DPS, as it generally encompasses photic zone habitats supporting plant cover (e.g., eelgrass and kelp) important for rearing, migrating, and maturing salmon and their prey. Deeper waters are occupied by subadult and maturing fish. Thus, juvenile chum salmon could occupy the nearshore, while subadult and maturing fish could occupy deeper water. While in the marine environment, chum salmon prey upon copepods, fish, squid, and tunicates. *The sub populations most likely to be affected are from Jimmycomelately Creek, Salmon Creek, Snow Creek, Chimacum Creek.* The PBFs in the action area are for estuarine and nearshore marine areas.

Puget Sound Steelhead

The Puget Sound steelhead DPS includes all naturally spawned anadromous populations from streams in the river basins of the Strait of Juan de Fuca (72 FR 26722; 9/25/2008), within the Sequim Bay watershed. Most spawning takes place in Jimmycomelately and Bell Creeks and possibly Johnson Creek tributaries to Sequim Bay (NOAA 2020). Other known or potential spawning systems that feed into the Strait of Juan de Fuca Research Area include the Dungeness River, Cassalery Creek and Gierin Creek, tributaries to Sequim Bay. The nearshore migration patterns of Puget Sound steelhead is not well understood, but it is generally thought that smolts move quickly offshore. Unlike most other Pacific salmonids (e.g., Puget Sound Chinook and Hood Canal summer-run chum salmon), steelhead appear to make only ephemeral use of nearshore marine waters. The species' lengthy freshwater rearing period results in large smolts that are prepared to move rapidly through estuaries and nearshore waters to forage on larger prey in offshore marine areas. Although data specific to Puget Sound steelhead are limited, recent studies of steelhead migratory behavior strongly suggest that juveniles spend little time in estuarine and nearshore areas and do not favor migration along shorelines (in contrast, Puget

Sound Chinook and Hood Canal summer-run chum salmon are known to make extensive use of nearshore areas in Puget Sound). Therefore, unlike for Puget Sound Chinook and Hood Canal summer-run chum salmon, there are not specific nearshore areas within the geographical area occupied by Puget Sound steelhead on which are found physical or biological features essential to their conservation (78 FR 2726). Steelhead feed upon insects, mollusks, crustaceans, fish eggs, and other small fishes. *Populations of this species most likely to be affected are the Dungeness Winter-Run Strait of Juan de Fuca Tributaries Winter-Run and the Sequim/Discovery Bay Tributaries Winter-Run.* PS steelhead do not have CH in the action area.

North American Green Sturgeon, Southern DPS, and Critical Habitat

Designated critical habitat for the southern distinct population in marine waters is from Monterey Bay to the U.S.-Canada border, just north of Sequim Bay (NMFS 2018). Other specific designated critical habitat in coastal bays and estuaries in Washington includes Willapa and Grays Harbor, and the Lower Columbia River Estuary (from the mouth to river km 74; NMFS 2020d). While Sequim Bay is not designated critical habitat, the waters to the north of the bay have been designated. Green sturgeon are long-lived (c. 54 years) and late to mature (c. 15 years; NMFS 2018). Juveniles mature in fresh and estuarine waters for several years (1–4 years) before migrating to coastal marine habitats (NMFS 2019d). They spend a large portion of their lives in coastal marine waters as subadults and adults (NMFS 2020e). Spawning occurs in freshwater every 2–5 years from April through June (NMFS 2020e). Green sturgeon are opportunistic feeders and forage for microbenthic invertebrates as juveniles benthic and shellfish as adults (NMFS 2018; 74 FR 52299; 10/9/2009). Green sturgeon are not likely to occur in the Sequim Bay Research Area but may occur in the Strait of Juan de Fuca Research Area because of the substrate type, cover and food resources, and other available habitat in the vicinity.

Pacific Eulachon, Southern DPS

In the portion of the species' range that lies south of the United States-Canada border, most eulachon production originates in the Columbia River basin, with the major and most consistent spawning runs returning to the main stem of the Columbia River and the Cowlitz River. Critical habitat or Eulachon has been designated in the Elwha River to the west of the project area. Shortly after hatching, larval eulachon may remain in low salinity, surface waters of estuaries for several weeks or longer before entering the ocean. Once juvenile eulachon enter the ocean, they move from shallow nearshore areas to deeper areas over the continental shelf. There is currently little information available about eulachon movements in nearshore marine areas (76 FR 65324; 10/20/2011). However, adults and juveniles commonly forage at moderate depths (20–150 m) in nearshore marine waters. Nearshore foraging sites are an essential habitat feature for the conservation of eulachon, and abundant forage species and suitable water quality are specific components of this habitat (NMFS 2011a). Based on depth of use of nearshore areas, eulachon could potentially occur in the project areas, but would be rare and would spend very little of their lifetime there.

Puget Sound Bocaccio and Critical Habitat

Bocaccio are a large Pacific Coast rockfish. Adult bocaccio are most commonly found between 164 to 820 feet m depth, but may reside as deep as 1,558 feet. Juvenile bocaccio rockfish habitat includes settlements located in the nearshore with substrates such as sand, rock and/or cobble compositions that also support kelp are essential for conservation because these features enable forage opportunities and refuge from predators and enable behavioral and physiological changes needed for juveniles to occupy deeper adult habitats.

Bocaccio are late to mature, slow-growing, and a long-lived species, potentially living to 50+ years (NMFS 2019a; NMFS 2012). Adults generally move into deeper water as they increase in size and age but usually exhibit strong site fidelity to rocky bottoms and outcrops. Juveniles and subadults may be more common than adults in shallower water, and are associated with rocky reefs, kelp canopies, and artificial structures, such as piers and oil platforms (NMFS 2012). In Puget Sound, most bocaccio are found in the Central Sound (Palsson et al. 2009), south of Tacoma Narrows. Thus, it is likely that bocaccio would be relatively scarce in Sequim Bay and the Strait of Juan de Fuca. However, critical nearshore and deep-water habitat has been designated around Gibson Spit and within Dungeness and Sequim Bays (79 FR 68041; 11/13/2014), although it has been updated to include fish residing within the Puget Sound rather than fish originating from the Puget Sound (81 FR 43979; 1/23/2017). Although unlikely, bocaccio could occur in the Sequim Bay and Strait of Juan de Fuca Research Areas. Prey items include small fishes and invertebrates (PSI and UW 2019).

Puget Sound Yelloweye and Critical Habitat

Yelloweye rockfish are a large, long-lived Pacific Coast rockfish (15 to 20 inches, potentially reaching more than 100 years; NMFS 2012). Juveniles and subadults tend to be more common than adults in shallower water, and are associated with rocky reefs, kelp canopies, and artificial structures such as piers and oil platforms. Adults generally move into deeper water as they increase in size and age, but usually exhibit strong site fidelity to rocky bottoms and outcrops. Yelloweye rockfish occur in waters 80 to 1,558 feet deep but are most commonly found between 300 and 600 feet. Yelloweye rockfish range from northern Baja California to the Aleutian Islands, Alaska, but are most common from central California northward to the Gulf of Alaska (NMFS 2019g). It is likely that yelloweye rockfish would be relatively scarce in Sequim Bay (Palsson et al. 2009). However, critical nearshore and deep-water habitat has been designated in the Strait of Juan de Fuca and Sequim Bay research areas (79 FR 68041; 2/13/2105), although it has been updated to include fish residing within the Puget Sound rather than fish originating from the Puget Sound (82 FR 7711; 1/23/2107). Although unlikely, yelloweye rockfish could occur in Sequim Bay and the Strait of Juan de Fuca Research Areas. They feed upon invertebrates and small fishes (PSI and UW 2019).

Southern Resident Killer Whale DPS and Critical Habitat

The southern resident DPS consists of three pods (J, K, and L) that reside for part of the year in the inland waterways of Washington and British Columbia (Strait of Georgia, Strait of Juan de Fuca, and Puget Sound), principally during the late spring, summer, and fall. Pods visit coastal sites off Washington and Vancouver Island but travel as far south as central California and as far north as the Queen Charlotte Islands. Offshore movements and distribution are largely unknown for the southern resident DPS (71 FR 69054; 11/29/2006).

Critical habitat includes waters in the Strait of Juan de Fuca, Puget Sound, and Haro Strait, and waters around the San Juan Islands, relative to a contiguous shoreline delimited by the line at a depth of 6.1 m relative to extreme high tide (71 FR 69054;11/29/2006; 84 FR 49214; 10/17/2019). While killer whales are often located in the pelagic areas of the open ocean, it is not uncommon for the species to forage in shallower coastal and inland marine waters (NMFS 2008). As such, waters off of Gibson Spit and within the Strait of Juan de Fuca Research Area are part of the designated critical habitat. Although Sequim Bay was excluded from this critical habitat designation (71 FR 69054; 11/29/2006), it is located near areas with critical habitat designations and there was a sighting of a killer whale pod (which may have been West Coast transient killer whales) within the bay (Sequim Gazette 2015). The presence of the killer whales in the Sequim Bay portion of the action area should be considered rare and more likely in the action area within the Strait of Juan de Fuca.

Humpback Whale, California/Oregon/Washington Stock

We are relying on the Calambokidis and Barlow (2020) abundance estimate for the CA/OR/WA humpback whale stock: 4,973 (CV=0.048), with a Nmin of 4,776 animals. In addition, this abundance estimate has been included in the draft 2021 SAR for the CA/OR/WA stock (J. Carretta, SWFSC, personal communication, February 2021). Humpbacks migrate south to wintering destinations off Mexico and Central America (NMFS 2011b; WDFW 2013). Humpbacks filter feed on tiny crustaceans (mostly krill), plankton, and small fish and can consume up to 3000 pounds of food per day and use echolocation in communication. During the summer months, humpbacks spend most of their time feeding and building up fat stores for the winter (NMFS 2020f). Most humpback whales occur off Washington from July to September (WDFW 2013). In 2012, a humpback was present in Hood Canal from late January through much of February (WDFW 2013) and could potentially occur in the Strait of Juan de Fuca Research Area, just outside of Sequim Bay. NMFS assumes that there is a high probability that those humpback whales originate from one of the two listed DPSs. and apply either the 42 percent (Central America DPS) and 58 percent (Mexico DPS) proportional values described above for reports off CA/OR. However, they would be very unlikely to occur in Sequim Bay (NMFS 2011b).

Sunflower Sea Star

The sunflower sea star (*Pycnopodia helianthoides*) is a sea star that used to be commonly found in marine waters from Baja California (Mexico) to the Aleutian Islands, Alaska (United States), from nearshore to about 450m deep, although the greatest abundance occurred in waters shallower than 1,500 feet deep (Fisher 1928; Lambert 2000; Hemery et al. 2016). However, populations of sunflower sea star saw severe declines between 2013 and 2017 with the onset of the sea star wasting syndrome (SSWS), with 99-100 percent declines in California and Oregon, and 92-99 percent decline in Washington (Hamilton et al. 2021; Harvell et al. 2019). This decline has led the International Union for Conservation of Nature to list the species as Critically

Endangered (Gravem et al. 2020). Prior to the SSWS outbreak, sunflower sea stars were common sights in the shallow waters of Sequim Bay.

They fully disappeared from the project area for several years but have been occasionally observed in Sequim Bay channel in recent years. While sunflower sea stars occasionally get caught as bottom-trawl bycatch, no such activity occurs in the project area and the SSWS is the only known threat to the species. Sunflower sea stars have been associated with a diversity of substrates: mud, sand, shell, gravel, rocky seafloor, and kelp forests (Fisher et al., 1928; Lambert 2000); and with cool water temperature (9-11.5°C; Hemery et al. 2016). While considered a generalist and opportunistic predator, the sunflower sea star is a keystone species across its distribution area, preying on many invertebrate predator species and with very few species feeding on the sunflower sea star (Herrlinger 1983; Mauzey et al. 1968). Sunflower sea stars are broadcast spawners, producing planktonic larvae that will spend up to ten weeks in the water column before settling and metamorphosing (Greer 1962). Although the species exhibits indeterminate growth, lifespan and growth rate are unknown (Heady et al. 2022). Was the population to rebound in the Salish Sea, the currently rare sunflower sea star could once again become a common species in the project area.

A range of different behavioral and physiological experiments have been conducted on sensory abilities of starfish and the general conclusion has been that they possess several senses, including chemoreception (gustation and olfaction), mechanoreception (touch, rheotaxis and geotaxis), and photoreception. Other senses (e.g., hearing, electroreception, and magnetoreception) might also be present, but these have never been evaluated experimentally (Garm 2017).

2.4.3 Climate Change

As described more fully in the status of species and critical habitat (Section 2.2) the environmental baseline includes the ongoing effects of climate change. Mauger et al (2015) predicted circulation in Puget Sound to be affected by declining summer precipitation, increasing sea surface temperatures, shifting streamflow timing, increasing heavy precipitation, and declining snowpack. While these changes are expected to affect mixing between surface and deep waters within Puget Sound, it is unknown how these changes will affect upwelling.

Changes in precipitation and streamflow may be shifting salinity levels in Puget Sound by altering the balance between freshwater inflows and water entering from the North Pacific Ocean. In many areas of Puget Sound, variations in salinity are also the main control on mixing between surface and deep waters. Reduced mixing, due to increased freshwater input at the surface, can reduce phytoplankton growth, impede the supply of nutrients to surface waters, and limit the delivery of dissolved oxygen to deeper waters. Patterns of natural climate variability (e.g., El Niño/La Niña) can also influence Puget Sound circulation via changes in local surface winds, air temperatures, and precipitation.

All three ESA-listed Puget Sound salmonids were classified as highly vulnerable to climate change in a recent climate vulnerability assessment (Crozier et al. 2019). In estuarine environments, the two greatest concerns associated with climate change are rates of sea-level rise and temperature warming (Wainwright and Weitkamp 2013, Limburg et al. 2016). While the effects of climate change-induced ocean acidification on invertebrate species are well known, the direct exposure effects on salmon remains less certain (Crozier et al. 2019).

Physiological effects of acidification may also impair olfaction, which could hinder homing ability (Munday et al. 2009), along with other developmental effects (Ou et al. 2015). Although a recent review of ocean acidification studies on fish has called into question many of the behavioral effects of ocean acidification (Clark et al. 2020). Using the criteria of Morrison et al. (2015) for scoring, PS Chinook salmon, HCSR chum salmon, and PS steelhead had low-to moderate sensitivity to ocean acidification (Crozier et al. 2019).

The same document states that "sea level rise is projected to expand the area of some tidal wetlands in Puget Sound but reduce the area of others, as water depths increase and new areas become submerged. For example, the area covered by salt marsh is projected to increase, while tidal freshwater marsh area is projected to decrease. Rising seas will also accelerate the eroding effect of waves and surge, causing unprotected beaches and bluffs to recede more rapidly. The rate of sea level rise in Puget Sound depends both on how much global sea level rises and on regionally-specific factors such as ocean currents, wind patterns, and the distribution of global and regional glacier melt. These factors can result in higher or lower amounts of regional sea level rise (or even short-term periods of decline) relative to global trends, depending on the rate and direction of change in regional factors affecting sea level" (Mauger et al. 2015).

2.4.4 Prior Consultations in the Baseline

Finally, NMFS as described in Section 1.2 where we describe the prior consultations with PNNL for activities previously considered and now part of the baseline (On January 27, 2016 NMFS issued a letter of concurrence (WCR- 2015-3761) for a minor suite of research activities within Sequim Bay. Between 2015 and 2022 multiple addendums to WCRO-2015-3761 and separate, but related, activity consultations have been completed (Dungeness Spit Mapping WCRO-2018-8853, Clallam Bay Mapping WCRO-2018-10566, Aquatic Sound Source WXCRO-2018-11181, and Triton Initiative WCRO-2020-01218). The majority of actions by PNNL previously considered and that are in the baseline were for temporary research activities that had been concluded as NLAA consultations. A formal consultation on PNNL's campus development in Sequim Bay was also previously completed. That project constructed a pier, ramp, and float, with permanent localized habitat impacts, and several temporary adverse effects to water quality. The project included offsetting activities as well.

2.5 Effects of the Action

Under the ESA, "effects of the action" are all consequences to listed species or critical habitat that are caused by the proposed action, including the consequences of other activities that are caused by the proposed action. A consequence is caused by the proposed action if it would not occur but for the proposed action and it is reasonably certain to occur. Effects of the action may occur later in time and may include consequences occurring outside the immediate area involved in the action (see 50 CFR 402.17). In our analysis, which describes the effects of the proposed action, we considered 50 CFR 402.17(a) and (b).

The NMFS regularly assess effects of the action on time scales. In this programmatic we will assess the effects as shore term actions, intermittent actions, and long-term actions. Short term effects consist of acute exposure lasting minutes to hours. Intermittent effects are those occurring at irregular intervals and are not continuous or steady. Finally, long term effects are those occurring over a relatively long period of time. For this consultation, that means those lasting up to 2 years.

The nature of the programmatic consultation does not allow us, at this time, to know exactly how long any of the covered projects will remain in place or in motion, until they are proposed, at which time the verification process will determine their specific location, duration, and character. We will assess a one-time activity (for example, a 1-hour acoustic study), and longer-term repetition of the one-time activity with breaks (1-hour acoustic study, repeated daily for 2 weeks), and longer-term without breaks (stationary turbine in place for a year).

Each implementation will have a start/installation and end/removal date. No project under this programmatic is permanent, therefore enduring effects are not expected. Should a study need to last longer than 2 years, it will require re-verification. For a given project to remain within this programmatic, it may not be re-verified more than once (i.e. the original verification plus one more verification).

2.5.1 General Presentation of Effects Pathways

Projects covered under the PNNL RAP action, despite the use of required GCMs, PDCs, and OPCs (which area all intended to reduce or minimize impacts), will result in impacts to ESA species and critical habitat through construction effects or presence of structures or equipment in water. Among the 13 different categories of work anticipated to occur under this program, eight different "effect pathways" are expected: (a) shading; (b) migration impacts; (c) water quality (turbidity and pollution); (d) loss of critical habitat (spatially and functionally); (e) sound impacts; (f) reduction of prey/forage (benthic prey, forage fish, prey fishes); (g) entrainment, and (h) capture and release (Table 32). Each Activity has multiple effects pathways over different lengths of time.

These effects may occur at short-term, intermittent, or long-term duration (long-term being considered here as up to 2 years). Construction, installation, and removal associated with any physical element will produce some short-term effects (e.g. noise, turbidity, general disturbance), and some projects will be installed very briefly, making the presence of those elements also short-term effects. We present the effects here by pathway, and address the range of duration per each pathway.

Table 32. Effects Pathways

No.	Activity	(a) Shading	(b) Migration	(c) Water Quality	(d) Loss of Aquatic Habitat	(e) Sound	(f) Benthic Impacts	(g) Entrainment	(h) Capture and Release
1A	Buoys	x	X		x		x		
1B	Grated Floats	x	X		x		x		
1C	Solid Floats	x	X		x		x		
2	Dock Installations	x							
3A	Seabed Installations		X		x		x		
3B	Subsurface Probes, Markers, Targets				x		x		
4A	ASV/AUV (water)		X			x	x	x	
4B	UAS (Aerial)		X						
5A	Benthic Sediment Sampling			x	x	x	x	x	x
5B	Benthic Characterization *Non-Intrusive						x		
5C	Benthic Characterization *Intrusive			x			x		
6	Water Column Sampling							x	x
7	Dye and Particulate Releases			x					
8	Seagrass, Macroalgae, and Intertidal			x	x		x		
9A	Eye Safe Lights		X						
9B	Non-Eye Safe Lights		X		x				
10A	Acoustic: Outside Hearing Range								
10B	Acoustic: In Hearing Range		X		x	x			
11A	EMF Devices		X		x		x		
11B	EMF Cables		X		x		x		
12A	Marine Energy Devices w/ BMPS		X		x	x	X	x	x
12B	Marine Energy Devices w/o BMPS		X		x	x	x	x	x
13	Tidal Turbine		X		x	x	x	x	x

a. Shading

Shade is cast by four project types (Buoys, Grated Floats, Solid Floats, and Dock Installations) while they are present in the environment. Shading can have both positive and negative impacts on fish health, depending on the type of water body, the amount of shade, and the specific fish species involved. On the negative side, in some locations it can (1) negatively affect SAV and (2) alters predator/prey dynamics. On the positive side, shading can provide temperature regulation, a safe place for cover and refuge of some species. In the case of this programmatic, (3) habitat offsets are required, indicating that shade will not produce loss of habitat or habitat function.

Incorporating grating consistent with design criteria of this program ensure that shading is reduced by allowing some light to penetrate below the Overwater Structures (OWSs).

a.1 Shading effects on SAV
OWSs, even with grating, adversely affect SAV, if present, and inhibit the establishment of SAV where absent, by creating enduringly shaded areas (Kelty and Bliven 2003). Decreased ambient light typically results in lower overall productivity, which is ultimately reflected in lower shoot density and biomass (Shafer 1999; 2002). In contrast to other studies in the Pacific Northwest, Shafer (2002) specifically considers small residential OWS and states, "much of the research conducted in Puget Sound has been focused on the impacts related to the construction and operation of large ferry terminals. Although some of the results of these studies may also be applicable to small, single-family docks, there are issues of size, scale, and frequency of use that may require separate sets of standards or guidelines. Notwithstanding, any overwater structure, however small, is likely to alter the marine environment."

In addition to reduced SAV biomass and shoot density, shading also has been shown to be correlated with reduced density of the epibenthic forage under OWS's (Haas et al. 2002, Cordell et al. 2017). While the reduction in light and SAV were likely a cause for the reduction in epibenthos, changes in grain size due to boat action and current alteration also may have contributed (Haas et al. 2002).

a.2 Shading effects on predator/prey dynamics
Some overwater structures, especially those with sufficient light penetration, can attract small prey fish seeking shelter or food sources. This can concentrate prey in certain areas, potentially making them more vulnerable to predation by larger fish. Conversely, OWSs casting shade can serve as hotspots for larger predatory fish, as they offer ambush points and potentially higher prey concentrations. This can lead to increased predation pressure in those areas.

a.3 Conservation offsets of shading
Offsets are required, for some projects based on the timing and duration criteria above, to compensate for the effects on shading and predator/prey dynamics caused by OWSs.

b. Migration

Eight activity types (or, more precisely, 14 subcategories of action) potentially reduce safe migration values. Fish migration can be impeded by various natural and human-made barriers, which can have significant impacts on fish populations and ecosystems. Some common impediments to fish migration are (1) obstructions in migration areas, and (2) activities which alters migration (lights, sound, EMFs).

b.1 Obstructions in migration areas.
Overwater structures can create physical barriers that impede or block the natural migration pathways of fish, particularly anadromous fish like salmon and steelhead, that migrate between freshwater and marine environments. Overwater structures also can contribute to the fragmentation of aquatic habitats, making it more difficult for migratory fish to access spawning grounds, nursery areas, or feeding grounds along their migration routes.

b.2 Activities which alters migration: lights, sound, EMFs
Artificial lighting, sound, EMFs, and can disorient and disturb migratory fish, causing them to alter their migration patterns or become delayed or lost during their journeys (Tabor et al. 2017).

Lights
Light generation from artificial sources will be temporary and intermittent, with the exception of shrouded biofouling lights which will be continuous. Shrouded lights are not likely to create impacts above intermittent light sources. Several different types lights will be used during research projects: flood lights and strobe lights may be required to support photography or monitoring purposes (secondary effect of the project intention, and lasers (red, green, etc.) will be used as a projects primary study avenue. Depending on the frequency and wavelength, some lasers are eye safe, some are not.

Sound
For marine mammals, harassment due to sound can be either Level A, which is defined as a permanent threshold shift or hearing injury, or it can be Level B, which includes changes in behavior such as migration, breathing, nursing, breeding, feeding, or sheltering. For fish, there is some evidence that fish school less coherently in noisy environments and avoid areas where man-made noise levels are high (Slabbekoorn e al. 2010). The presence of sound could keep fish away from preferred spawning sites and change their migration routes (van der Knaap et al. 2022).

ElectroMagnetic Fields
Temporary electromagnetic fields (EMFs) would be generated during operation and could temporarily affect the associated benthic habitat or water column and may discourage habitat use nearby (Bevelhimer et al 2013).

c. Water Quality

Water quality is likely to be affected during in-water work, including installation, or removal of structures or equipment. Additionally, four types of activity are likely to affect water quality. Water quality effects include (1) increased turbidity, (2) decreased dissolved oxygen, and (3) the release of dyes and particulates. When installation, removal, or the action itself occurs consistent with the in-water work window established by WDFW, this helps ensure that fish presence (particularly salmonids), at project site is low as compared to other times of the year. This helps minimize the number of fish exposed to effects on water quality. This programmatic allows work to occur outside of the preferred work window, in turn exposing more ESA-listed individuals to reduced water quality than when work occurs exclusively inside the work window.

c.1 Turbidity

Sampling will be done by grab samplers, box-core, or trowels, to name a few. Turbid conditions are likely to occur during activities involving water bottom work. Such activities include: (a) benthic sediment sampling; (b) intrusive benthic characterization surveys; and, (c) Seagrass, macroalgae, and intertidal studies.

In estuaries, state water quality regulations (WAC173-201A-400) establish an estuary mixing zone of 200 feet plus the depth of water over the discharge port(s) and oceanic mixing zone of 300 feet plus the depth of water over the discharge port(s) as measured during mean lower low water. It is expected that the activities mentioned above (or similar) will temporarily increase water turbidity within this mixing zone, though most likely a much smaller area.

c.1 (a) benthic sediment sampling & (b) intrusive benthic characterization surveys

Sampling will be done by grab samplers, box-core, or trowels, to name a few. Sediment sampling operations, as a means of soil testing, may themselves cause erosion, sedimentation, or other temporary site disturbances.

c.1.(c) Seagrass, macroalgae, and intertidal studies

As seen in OPC #3, most PNNL research activities will be required to carefully avoid impacts to sensitive habitats such as eelgrass beds, SAV, and intertidal areas. However, some research focused specifically on understanding these areas may be performed as well as "Seabed Installations" and “Benthic Characterization Surveys” for the explicit purpose of SAV research. Research projects are designed to not significantly alter the habitats that are being researched, and given the limit of no more than a total of 108 sqft of disturbance per area (Sequim Bay and Strait of Juan de Fuca), including SAV collection, in any given area in any given year (216 sqft total) and the dispersed manner of collection (10 percent of the eelgrass in any given collection area) that would reduce the impact at any given point within a collection area and thus speed natural recovery through vegetative growth.

The PNNL’s practice of low and dispersed harvest is based on expected slow natural regeneration due to generally low flowering shoot densities and seed viability below 10 percent in the Pacific Northwest (Thom et al. 2008). In an unpublished study conducted over 2 years, PNNL monitored eelgrass recovery in 1 square meter plots where different percentages of plants (0–50%) had been removed and found no difference in any of the plots, regardless of harvest level, even after one year. Seagrass communities in the two research areas were considered stable in 2015 (DNR 2017) and are expected to remain stable due to the dispersed collection restrictions significantly reducing the effect of research activities to SAV. Sediment and vegetation sampling would be required to be small scale. SAV collection would be conducted with hand tools or with small research vessels in deep-water habitat areas. Installed instruments would be required to be small scale and be removed once they are no longer needed.

Unrestrained, larger equipment is expected to disperse particles up to 20 feet, while smaller equipment will typically expel particles up to 10 feet. This is well within regulatory limits - in estuaries, state water quality regulations (WAC173-201A-400) establish an estuary mixing zone of 200 feet plus the depth of water over the discharge port(s) and oceanic mixing zone of 300 feet plus the depth of water over the discharge port(s) as measured during mean lower low water. It is expected that during the days that the activities mentioned above (or similar) occur in the water, elevated suspended sediment levels could occur within this mixing zone, though most likely a much smaller area.

Suspended sediment typically "settles out" with larger, heavier particles falling back to the seabed quickly and in close proximity to the area of disturbance, and smaller particles settling more slowly and dispersing more broadly due to tide, currents, and wave action, however in coastal and estuarine environments no systematic relationship exists between settling velocity and particle size (Ahn 2012). Suspended sediment or turbidity as a water quality disruption, is a temporary effect with each occurrence.

c.2 Reduced Dissolved Oxygen (DO)

Suspension of anoxic sediment compounds (turbidity/suspended sediment, described above) during in water work can result in reduced DO in the water column within the mixing zone area as the sediments oxidize. Based on a review of six studies on the effects of suspended sediment on DO levels, LaSalle (1988) concluded that, when relatively low levels of suspended material are generated and counterbalancing factors such as flushing exist, anticipated DO depletion around in water work activities will be minimal. High levels of turbidity could have contemporaneous reduction in dissolved oxygen within the same affected area.

While Sequim Bay already has areas of low dissolved oxygen, reduced DO from suspended sediments from project impacts is not expected to exceed the established mixing zone of 200 feet plus the depth of water over the discharge port(s) and oceanic mixing zone of 300 feet plus the depth of water over the discharge port(s) as measured during mean lower low water. Under the proposed action, spacing of projects minimizes the amount of fine sediments entering nearshore marine and estuary areas. As established above, the duration of turbid conditions is expected to brief and the extent of turbid conditions spatially constrained with each occurrence.

c.3 Dyes and Particulate Releases

Fluorescent dyes such as Rhodamine WT are commonly used for hydrological and circulation studies, and they are non-toxic to humans and sea life at the concentrations intended for use (that will not exceed 20 ppb). All usage will be required to follow manufacturers guidelines or label requirements, and releases will use minimum concentrations necessary to accomplish desired research objectives.

d. Loss of Aquatic Habitat

This pathway refers to both direct loss as habitat is (1) occupied by structures and (2) impacted by sampling, but also indirectly as habitat is lost due to outside interference which case the species to (3) avoid the area. Nine activity types (or, 14 subcategories of activity) make some amount of habitat unavailable, for varying amounts of time.

d.1 Loss to (Displacement by) Structures or Equipment

Aquatic and tidally influenced habitats in the proposed project area have been designated critical habitat for many life stages of salmon, green sturgeon, rockfish, SRKWs. Categories of habitat in the action area include estuarine emergent wetlands, water column, and estuarine and marine water bottoms (mud, gravel and cobble).

The physical footprint of overwater structures, including anchors and other support structures, can directly displace and destroy existing aquatic benthic habitats like eelgrass beds, oyster reefs, and rocky substrates that provide habitat for various species. Additionally, the construction and presence of overwater structures can alter hydrodynamics and sediment transport patterns, leading to increased sedimentation in some areas and erosion in others. This can smother or degrade sensitive habitats like seagrass meadows and shellfish beds.

d.2 Loss to Surveys/Sampling

Sediment sampling activities, if not properly planned and executed, can potentially lead to the loss or degradation of habitats for various aquatic species. The process of collecting sediment samples, especially with techniques like grab sampling or coring, can directly disturb or damage sensitive benthic habitats like seagrass meadows, coral reefs, and shellfish beds. The physical impact of the sampling equipment can uproot or crush these habitats. Sediment sampling can resuspend large amounts of sediment into the water column, increasing turbidity and sedimentation rates. This can bury nearby habitats, such as oyster reefs or fish spawning areas when it settles out, and while in suspension, reduce light penetration which is critical for SAV. While the impact of a single sediment sampling event may be localized, repeated or long-term sampling activities in the same area can have additive impacts on habitats, leading to their gradual degradation or loss. Here, based on design criteria, performance criteria, and offsetting requirements, we expect the area impact and the duration of impact to not create large or systemic loss of habitat.

d.3 Loss due to Avoidance (caused by lights/sound/EMF)

The loss of aquatic habitat can occur due to species avoidance behavior in response to various human activities and environmental changes. When certain areas become unfavorable or disturbed, some species may avoid or abandon those habitats, leading to their degradation or loss. Human activities such as construction, vessel traffic, or recreational activities can generate noise and disturbance that may cause species to avoid certain areas. For example, marine mammals may avoid areas with high levels of underwater sound, leading to the abandonment of breeding or feeding habitats.

Changes in the physical structure or characteristics of a habitat, such as changes in water flow, temperature, or vegetation cover, can make it less favorable for certain species. If they avoid these altered habitats, it can lead to the effective loss of habitats for those species. The presence of predators or increased predation risk in certain areas can cause prey species to avoid those habitats, even if they were previously critical for their survival and reproduction.
In some cases, species may avoid areas with high levels of human presence or activities, such as recreational areas or areas with intensive development, leading to the effective loss of their habitats in those locations.

e. Sound

Five activity types (six subcategories) are likely to produce sound that will be detected by marine mammals or fish in their habitat.

Underwater noise from human activities is a significant concern for marine mammals and fish in and around the Salish Sea. PNNL performs numerous in-water research activities that include sound emissions. Sounds may be classified as either impulsive sounds or non-impulsive sounds.

Impulsive sounds are typically transient, brief (less than 1 second), broadband, and consist of high peak sound pressure with rapid rise time and rapid decay; impulsive sounds include impact piledriving, explosives, and air guns. PNNL research activities are not expected to include impulsive sound sources, but it might occur occasionally over the life of the programmatic.

Non-impulsive sounds can be broadband, narrowband or tonal, brief or prolonged, continuous or intermittent, but typically do not have a high peak sound pressure with rapid rise/decay time. Non-impulsive sound sources include vibratory pile drivers, sonar, communication modems, echosounders, and others.

Hertz and decibels are fundamental units used in sound measurement, each serving a distinct purpose in understanding sound characteristics:

Hertz (Hz):

- Hertz measures frequency, indicating how many times a sound wave oscillates per second.
- It determines the pitch of a sound; higher frequencies are perceived as higher pitches.
- The human hearing range typically spans from 20 Hz to 20 kHz, with variations among individuals.
- Hertz is an absolute unit that remains consistent regardless of external factors.

Decibels (dB):

- Decibels measure the intensity or amplitude of sound waves, representing the volume or loudness of a sound.
- It is a logarithmic unit that quantifies the strength of a signal; each 10 dB increase corresponds to a tenfold increase in intensity.
- Decibels are influenced by factors like air pressure and the medium through which sound travels.
- For reference, the human hearing range in decibels typically extends from 0 dB to around 120-130 dB, with sounds above 90 dB having the potential to cause hearing damage.

To simplify, hertz quantifies the frequency or pitch of a sound wave, while decibels gauge the intensity or volume of the sound. Understanding both units is essential for comprehensively assessing and characterizing different aspects of sound perception and measurement.

While the basic physics of sound in water are similar to those in air, the density of the medium is greater and as a result sound travels about 4.8 times faster than in air (1500 m s^{-1} v. 343 m s^{-1}). As a result, a 100 Hz sound has a wavelength of 3.43 m in air, but it is 15 m in water.

In PNNL RAP, sound is introduced via (1) boats and machinery and (2) through acoustic studies.

e.1 Sound from Boats and Machinery
Motorized vessels and machinery will be used on many projects and are expected to increase the amount of sound in an area surrounding each project site and their transit paths. Some of these sounds will be temporary (autonomous vehicle transiting from one location to another) and others will be last longer (a turbine in operation).

e.2 Sound from Acoustic Studies
NMFS has provided guidance for assessing the effects of sound on marine mammals (NOAA 2018a). This guidance defines three groups of cetaceans based on hearing range and sensitivity and two groups of pinnipeds. Harassment due to sound can be either Level A, which is defined as a permanent threshold shift or hearing injury, or it can be Level B, which includes changes in behavior such as migration, breathing, nursing, breeding, feeding, or sheltering.

Level A harassment threshold levels are based on a time-weighted cumulative exposure; thus, the animal is assumed to be exposed to the threshold level for the entire time period. For instance, if an echosounder is operated for six continuous hours, the animal would need to be within the calculated isopleth distance for the entire 6 hours to sustain the permanent injury. In most cases the animal would be free to leave the area and would not be exposed long enough to sustain the permanent injury.

Level B harassment is measured as the root mean square (RMS) of the sound level (dB_{rms}) and does include a time component. Behavioral effects are thought to be greater when the sound is continuous (i.e., vibratory piledriving) compared to intermittent (sonar, communications, soundings), and the Level B threshold level is lower for continuous sounds.

Acoustic injuries to fish are for a result of impulsive sounds, especially pile driving. Most fish can detect sounds between approximately 50 Hz up to 1 to 1.5 kHz, although some hearing specialists can hear sounds up to 3 or 4 kHz (Popper and Hastings 2009). Salmonids can detect sounds between about 10 Hz and 600 Hz with an optimum at about 150 Hz (Teachout 2012). Effect thresholds for injury are slightly higher for adult or larger fish than for smaller or juvenile fish 2- gram threshold). 150 dB_{rms} is an accepted, conservative estimate of the threshold for behavioral effects in fish (Caltrans 2015; Teachout 2012).

As a companion to its 2018 technical guidance (NOAA 2018a) NMFS provides a set of spreadsheet tools and a user manual (NOAA 2018b) for use in calculating sound level isopleths from different types of sound sources. The NMFS spreadsheets were used to calculate the marine mammal Level A and Level B isopleths and standard equations were used to estimate injury and behavioral isopleths for fish for a variety of sound sources.

Table 33 summarizes the isopleth distance for various types of sound sources that are likely to be used for PNNL research purposes in the next five years. Included are underwater acoustic communication modems, low-frequency sub-bottom profilers, Navy high source level sound projectors, underwater positioning systems, fisheries echosounders, and small-scale turbines. For marine mammals, the table only shows the high-frequency cetacean hearing group as it has the largest isopleth for the sound sources investigated; the isopleths for other marine mammal hearing groups are at least one and usually at least two orders of magnitude smaller than for the high-frequency cetaceans (the injury threshold for high-frequency cetaceans is at least 25 dB cumulative sound exposure level (SELcum) lower than for the other groups of marine mammals). The behavioral isopleth is the same for all marine mammal groups.

Table 33. Sound thresholds. Yellow indicates groups of concern.

Functional Hearing Group	Relevant Species	Functional Hearing Range	Level A (Injury Threshold) (dB SELcum)	Level B (continuous/ intermittent) (dBrms)	Injury threshold (dB SELcum)	Behavioral threshold (dBrms)	Hearing Range (dB)
Low-frequency cetaceans	Humpback and Gray whales	7 Hz - 35 kHz	199	120 /160			
Mid-frequency cetaceans	SRKW	150 Hz - 160 kHz	198	120 /160			
High-frequency cetaceans	Harbor porpoise	275 Hz - 160 kHz	173	120 /160			
Phocid pinnipeds	Harbor seal	50 Hz - 86 kHz	201	120 /160			
Otariid pinnipeds	California sea lion	60 Hz - 39 kHz	219	120 /160			
Fish		10 Hz - 4 kHz			187(<2g) 183(>2g)	150	
Humans		20Hz – 20 kHz					0 – 130

Additionally, PNNL RAP includes the use of playback of animal sounds (e.g. dolphin clicks or snapping shrimp) in the acoustic studies bundle. Marine acoustic studies using animal sounds involve analyzing the vocalizations and sounds produced by various marine animals for research purposes. These studies can provide valuable insights into the behavior, ecology, and conservation of these species or species attracted to the sound. Acoustic studies help researchers identify species, monitor population sizes, understand communication and social behavior, and assess the impacts of anthropogenic sound on these species. Acoustic studies can help identify fish spawning grounds, monitor fish populations, and understand their behavior and ecology and interactions with Energy projects. These animal sound studies are conducted to get a better understanding of the species interactions with energy research, development, and policies related to energy sources, technologies, and environmental impacts.

f. Benthic Impacts

Eight activity types (15 subcategories), along with installation and removal of structures and equipment, can disturb or modify benthic conditions which reduce or change the composition of biological communities that would provide prey or cover, or change the exposed sediment composition which can alter its suitability for various species (e.g. rockfish favor high rugosity more than silty or sandy substrates).

The benthic environment provides a habitat for a wide variety of organisms, including bacteria, algae, invertebrates (such as crustaceans, mollusks, and worms), and some fish species. These organisms play crucial roles in the marine ecosystem, contributing to nutrient cycling, food webs, and overall biodiversity. The benthic environment serves as a food source for many marine organisms, including bottom-feeding fish, crustaceans, and other invertebrates. These organisms feed on the benthic organisms or the organic matter present on the seafloor. In some marine environments, such as shallow coastal areas, the benthic region can contribute significantly to primary production through the growth of benthic algae and seagrasses, which form the base of the food web. PNNL RAP will affect the benthic community by (1) shading, structures, and sediment manipulation, and (2) through EMF studies.

f.1 Impacts from Shading, Structures, and Equipment

As mentioned in the *Shading Pathway* section above, OWSs produce shade that affect the habitats below them. See the *Shading* section for more detail. Similarly, as mentioned in the *Water Quality Pathway* section above, activities that cause turbidity are those that disrupt the bottom sediments, altering benthic conditions. See the *Water Quality* section above.

f.2 Impacts from ElectroMagnetic Fields

Cable or devices will generate EMF. All species that occur in the project areas may be affected by EMF from research equipment that emits such, with those that move slowly (e.g., sea star) being more susceptible. EMF are comprised of electric fields (E-fields) and magnetic fields (B-fields). Both E- and B-fields are associated with natural phenomena such as conductivity of seawater, the Earth’s geomagnetic field and rotation, and the motion of tides/currents that create localized fields. Electric fields are expressed in volts per meter (V/m), and magnetic fields are represented as Tesla (T) units. Natural electric fields in marine environments are typically in the range of μV/m (micro-Volts) and natural magnetic fields are typically between 25-60 μT (micro-Tesla). EMF emissions may also be generated from anthropogenic sources such as electric motors, loudspeakers, high power electronics, and tidal, wave, or offshore wind energy deployments. Electric motors and loudspeakers have built in 0.4–1 T magnets and the electromagnets that interface with them are capable of producing magnetic fields of at least that magnitude. Magnetic field strength decreases rapidly with distance; for instance, the field surrounding a 1.25 T Neodymium magnet decreases to nano-Tesla levels within 1 m, thus the water volume that would be affected by the upper limit of 1.25 T would be very small. Virtually all electric fields are constrained within wrapped insulation which keeps it from contaminating natural environments, however magnetic fields are difficult to similarly constrain as they travel through insulation.

g. Entrainment

Five activity types (six subcategories) may entrain or impinge listed species. Entrainment is when an animal is drawn into the equipment despite screening, and impingement is when the animal is pressed against the equipment or screen without ability to escape, typically because the velocity of the water is greater than the animal's swimming strength.

Marine entrainment refers to the process by which organisms or materials suspended in the water column are drawn into and transported by water currents, typically associated with the intake structures of coastal facilities such as power plants, desalination plants, or industrial facilities that use seawater for cooling or other purposes. In this case entrainment can occur through (1) intakes (boat cooling systems or water sampling), (2) sediment sampling, (3) marine energy devices, and (4) turbines.

g.1 Intakes

Entrainment occurs when fish and other small aquatic organisms are drawn into the intake flow and pulled through the intake system. Entrainment can cause physical damage, injury, or death to these organisms, especially for early life stages like eggs and larvae, which are extremely vulnerable. As water is drawn towards the intake structure, fish and other organisms can become trapped or impinged against the intake screens or grates. This can lead to physical injury, stress, or suffocation, especially for larger fish that cannot easily escape the intake flow. The construction and operation of water intakes can disrupt or alter aquatic habitats, affecting spawning areas, nursery grounds, or migration routes for fish and other species.

The high-velocity water flows around water intakes can subject fish and other organisms to turbulence and shear stress, which can cause physical damage, disorientation, or increased energy expenditure. Additionally, the artificial structures associated with water intakes can attract predatory fish, increasing the risk of predation for smaller fish and other organisms that may become concentrated or disoriented near the intake areas.

To mitigate these risks, water intakes are often required to implement various protective measures, such as screens, behavioral deterrents (e.g., lights, sounds), and appropriate intake velocities and design features to minimize the entrainment and impingement of aquatic organisms. Ongoing monitoring and adaptive management strategies are also important to ensure the protection of fish populations and aquatic ecosystems near water intake structures.

g.2 Sampling/Surveys

Entrainment is the process where objects are enclosed and transported within some form of vessel or where solid particles are drawn-in and transported by the flow of a fluid. In this context, entrainment refers to the uptake of aquatic organisms by sediment sampling equipment, as well as the transport of organisms by the downward motion of sediments during any in-water disposal. The likelihood of entrainment increases with a fish's proximity to the sample site, and the frequency of interactions.

Fish that are above the target are likely to detect the moving object and attempt to evade the perceived threat. Based on the available research, fish are likely to initially dive and then initiate horizontal evasion, or to simply move laterally if already on or near the bottom. The determining factor in avoiding entrainment will be whether the fish can swim fast enough to move out of the way once the fish detects the threat. The risk of entrainment would increase with proximity to the center of the target and/or to the seafloor. Individuals that become entrained, or are unable to escape before contact with the substrate are likely to be buried under the sediments. The probability of fish entrainment is largely dependent upon the likelihood of fish occurring within the project area, depth, fish densities, the entrainment zone (water column), location, type of equipment operations, time of year, and species life stage.

g.3 Marine Energy Devices

Marine energy devices, including wave energy converters (WECs) are described in Section 1.3.1. The OES-Environmental 2020 State of the Science Report comprehensively discusses the current knowledge of marine renewable energy environmental effects (Copping and Hemery 2020). Installation and operation of such devices may affect protected species and critical habitats during installation, as well as during operation due to collision with or entrainment within moving parts of the device as described in Copping and Hemery (2020). Marine energy devices are thought to be more benign than tidal turbines with respect to collision risk because there are fewer submerged moving parts that have collision potential [Sparling et al. 2020]). Devices can extend into the water column from the surface or seabed where they may be installed. Deployment of devices and associated infrastructure may result in temporary disruption of foraging or other habitat use but is expected to be minor as species may use nearby unaffected habitat (Copping and Hemery 2020). Operation and rate of movement of moving parts are dependent on wind, wave, temperature or tidal currents and are therefore expected to be intermittent and variable, respectively. Sound and EMF generated from operation are covered separately, above.

g.4 Turbines

Tidal turbines comprise horizontal and vertical axis turbines that extend into the water column from installation on the seabed or on the surface. The sounds turbine produce is below levels typically emitted by fishing and recreational vessels (Sparling et al. 2020). Tidal turbines are thought to have greater collision risk than WECs (Furness et al. 2012) because there are more submerged moving parts that have collision potential (blades and rotors, as well as dynamic technologies, such as tidal kites or oscillating blades) [Sparling et al. 2020]).

Installation and operation of tidal turbines may affect protected species and critical habitats during installation, as well as during operation due to collision with moving parts (e.g., blades, rotors) of the device. Collision risk between a device and marine animal has been a significant barrier in the permitting process for such devices (Horne et al. 2022).

Tidal turbines do not operate under all flow conditions. There is a cut-in flow speed, under which a turbine will not be operated due to poor performance and economic return. For example, for an 86 cm diameter turbine, a conservative cut-in speed is 0.5 m/s flow. To demonstrate the effect of turbine cut-in, a two-month simulation of a turbine operating in Sequim Bay was performed, resulting in the rotation rate time-series shown in Figure 7. This can also be viewed as a cumulative distribution function, Figure 8, depicting the fraction of time the turbine would operate at less than a given rotation rate. Under these realistic conditions, the turbine would not be spinning 42 percent of the time, decreasing the likelihood of collision compared to full-time operation, and the rotation rate would be lower than 30 rpm over 2/3 of the time. Thus, operation and rate of blade movement are dependent on current speed and are therefore expected to be intermittent and variable, respectively.

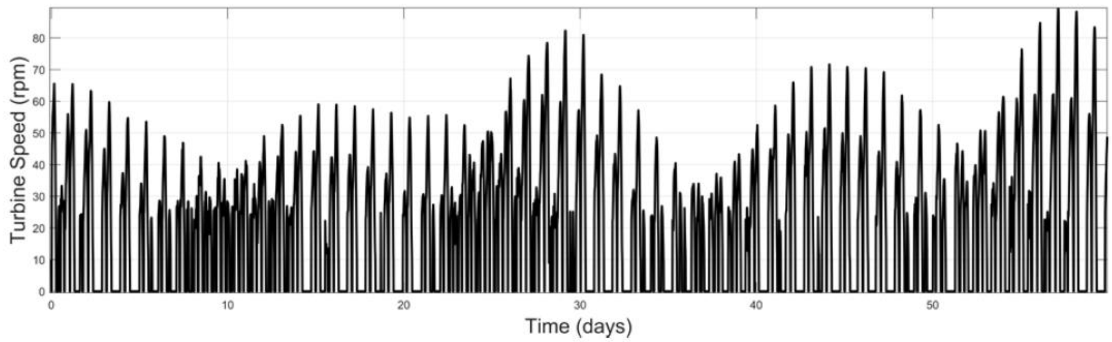

Figure 7. Two-Month Simulation of Rotation Rate of an 86-cm Diameter Vertical-Axis (DOE PBA)

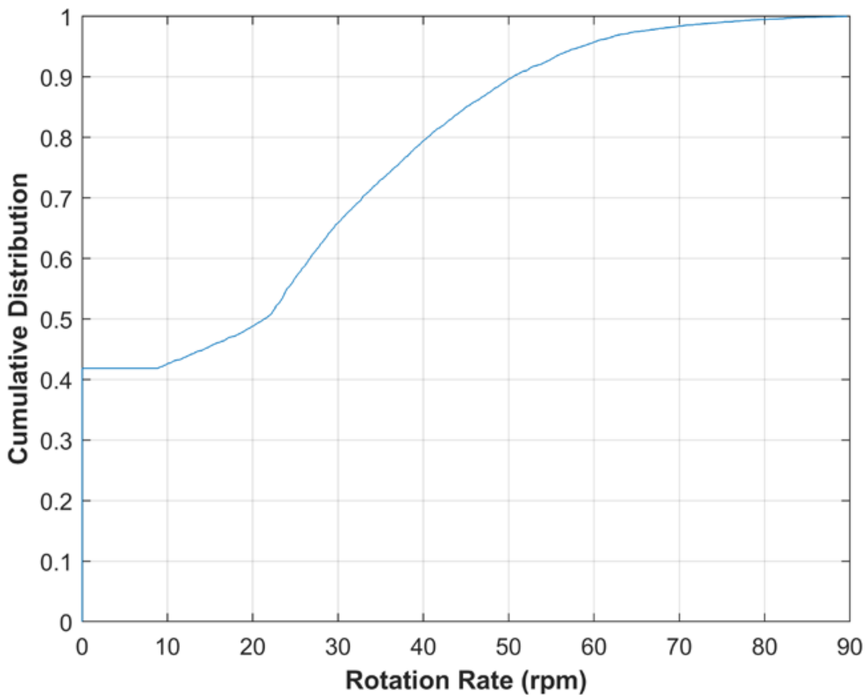

Figure 8. Example Cumulative Distribution Function of Turbine Rotation Rate (DOE PBA)

An even more recent review of the literature on the interaction and collision risks of marine animals with marine energy systems was conducted by da Silva et al. (2022). There are no reports in the literature of collisions of marine mammals, diving seabirds and other animals with marine renewable energy (MRE) devices, only interactions of fish with turbines without harmful effects (da Silva et al. 2022). This does not mean that they did not occur; they may not have been detected due to the limited number of implemented projects and the significant challenges of monitoring (da Silva et al. 2022).

Collision risk may vary with location, water depth, and tidal velocity (Waggitt et al. 2017, Sparling et al. 2020). Collision risk is also dependent on the characteristics of the devices which are variable (e.g., design, tip speed ratio), animal behavior (unknown in response to site-specific environmental hydrodynamics in the action area), and animal densities in the action area at the depth of the relevant moving parts of devices (e.g., unknown in the action area). Spatial and temporal patchiness in marine animal distribution, influenced by the tidal cycle and fine-scale hydrodynamics (at the scale of meters to a few hundred meters), could also influence encounter rates and collision risk (Cox et al. 2013, Sparling et al. 2020) and is largely unknown for the action area. Collision risk estimated on the basis of wide-scale information may not reflect actual risk at any one specific site (Sparling et al. 2020). Estimating collision risk for the action area using models, and specifically for the small currently proposed tidal turbine deployment area, for which site-specific information is lacking, may not be commensurate with the level of effort needed to generate such, and the reality of resulting estimates would be highly uncertain.

h. Capture and Release

Four activity types (5 subcategories) may require that individuals of listed fish be handled to release them from accidental entrapment (capture) during the performance of those activities. Benthic Sediment Sampling, Water Column Sampling, Marine Energy Devices (both with and without BMPS) and Tidal Turbines.

Effects from in-water work are generally avoided and minimized through use of in-water work isolation strategies that often involve capture and release of trapped fish and other aquatic invertebrates, and by constraining work to as short a period as possible during work windows when the fewest individuals of a species are present or any fish present are limited to those least vulnerable to exposure to adverse effects of program activities.

Capturing and handling fish causes them stress, though they typically recover fairly rapidly from the process and therefore the overall effects of the procedure are generally short-lived (NMFS 2002). The primary contributing factors to stress and death from handling are differences in water temperatures (between the natural location and the holding location), dissolved oxygen conditions, the amount of time that fish are held out of the water, and physical trauma. Stress on salmonids increases rapidly from handling if the water temperature exceeds 18^{o} C (64^{o} F) or dissolved oxygen is below saturation.

Program GCM #4 proposed for fish capture and release provides that where practicable, allow listed fish species to migrate out of the work area; if the fish will not leave of its own ability, fish capture should be supervised by a qualified fisheries biologist, with experience in work area isolation and competent to ensure the safe handling of all fish, and report any capture/release events to NMFS). The GCM is based on standard NMFS guidance to reduce the adverse effects of these activities (NMFS 2022). Key conservation measures in the guidance such as limiting work during times of high-water temperatures significantly reduces mortality that can occur during work area isolation.

In this programmatic fish capture and release might occur during (1) sampling and surveys, and (2) incidental capture in devices.

h.1 Incidental Capturing during Sampling and Surveys

During sediment sampling, fish capture and release are crucial considerations to minimize the impact on aquatic life. Sediment sampling involves collecting sediment deposits from rivers or water bodies for analysis. When conducting sediment sampling, it is essential to be mindful of fish populations in the area to avoid harming them during the sampling process. Fish capture and release practices ensure that any fish inadvertently caught during sediment sampling are promptly released back into the water unharmed.

h.2 Incidental Capture in Devices

The operation of marine energy devices, such as tidal turbines or wave energy converters, can potentially lead to the capture and release of fish in their systems. Details on these pathways can be found in section *Benthic Impacts* and *Entrainment*.

2.5.2 Effects on Critical Habitat

As described above in the section providing a general presentation of effect pathways, each of the 13 activity types, the respective subcategories, and activities to install or remove any structures, devices, or equipment, result in several types of effects, in a variety of combinations, which will occur on a temporary basis, with no effect lasting longer than 2 years without verification by NMFS. The spatial and temporal effects are limited by performance and design criteria. We present each of the eight effects pathways for their influence on physical and biological features of designated critical habitat for the PS Chinook Salmon, Hood Canal Summer Run chum, Puget Sound/Georgia Basin, Yelloweye Rockfish, Puget Sound/Georgia Basin Bocaccio, green sturgeon, and SRKW.

Critical habitat for PS Chinook salmon, HCSR chum salmon, green sturgeon (southern DPS), PS/GB Bocaccio, PS/GB Yelloweye rockfish, and SRKWs all occur within the action area for this programmatic consultation. NMFS reviews effects on critical habitat affected by a proposed action by examining how the PBFs of critical habitat will be altered, and the duration of such changes, and the influence of these changes on the potential for the habitat to serve the conservation values for which it was designated.

In estuarine, nearshore, and marine areas, the features of designated habitat common to each of the five fish species of concern are (a) water quality and (b) forage or prey/food resources, and (c) nearshore habitat with suitable conditions for growth and maturation, including sub-aquatic vegetation. For Chinook, chum, and sturgeon (d) safe migration areas are an additional feature of critical habitat.

For the SRKW, NMFS identified the following physical or biological features essential to conservation: (a) Water quality to support growth and development; (b) Prey species of sufficient quantity, quality and availability to support individual growth, reproduction and development, as well as overall population growth; and (c) Passage conditions to allow for migration, resting, and foraging.

The PBFs in common to all of the species and which will be affected by the proposed action are (1) Water Quality, (2) Prey, and (3) Passage/Safe Migration. Because no other features of critical habitat for any species are affected and we omit analyzing them.

Table 34. Common Critical Habitat PBFs and Effect Pathways

Effect Pathway	(1) Water Quality	(2) Prey	(3) Passage/Safe Migration
(a) Shade		x	x
(b) Migration		x	x
(c) Water Quality	x	x	x
(d) Loss of Critical Habitat	x	x	x
(e) Sound	x	x	x
(f) Benthic Effects	x	x	x
(g) Entrainment	x	x	x
(h) Capture and Release			x

a. Shading

Shade effects are described more fully in the effects pathway section of this document. While shade is minimized by the compliance with design and performance criteria, some habitat will still be affected by shade. In this section we evaluate specific features of designated critical habitat for the impact of shade.

(1) Water Quality (all designated critical habitat (CH)) – not affected

(2) Prey (all designated CH) – Loss of forage quality and quantity due to overwater structures and seabed installations. However, in some cases, in-water structures can introduce additional physical structure, complexity, and rugosity to the underwater environment that rockfish prefer. Many aquatic plants and algae rely on sunlight for photosynthesis, which is the process of converting light energy into chemical energy. When sunlight is blocked by overwater structures, it can limit the growth and productivity of these organisms, which form the base of the marine food web. These losses are limited in duration and footprint, and the program's requirement to offset of habitat impacts ensure that these adverse effects do not aggregate in space or time in a manner that detriment the conservation role of the critical habitats.

(3) Passage/Safe Migration (CH for PS Chinook salmon, HCSR chum, juvenile bocaccio)– Shading can interfere with the natural cycles of light and darkness that many marine organisms rely on for activities such as feeding, mating, and migration. This disruption can have cascading effects on the entire ecosystem. The shading caused by overwater structures can alter the physical characteristics of the marine habitat. For example, it can prevent the growth of SAV, which provides food, shelter, and nursery areas for various fish and invertebrate species.

Shading Conclusion
Shading will occur in the migratory corridor from OWSs. Most of the project approved through PNNL RAP are of a very short-term nature and will have little, to no, effect on migration and prey. Structures that occupy the water for longer periods (outside of work window and over 6 days) are expected to be fully offset through beneficial activities (mitigation bank credit purchase by DOE/PNNL).

b. Migration

As described in the effects pathways section above, migration areas are likely to be diminished by several activity types, either by physical structures, or due to light sound or EMF that inhibit species presence or behavior in areas designated for their migration role. We evaluate here features in migratory areas that could be affected.

(1) Water Quality (all designated CH) – not affected

(2) Prey (all designated CH) – Overwater structures can provide shelter and perching opportunities for predators, such as birds or larger fish. This can lead to increased predation pressure on prey species, especially in areas where they may have previously, or typically, found refuge. Short-term reduction in forage due to equipment activities (rovers/crawlers, etc.) and scattering of prey species due to environmental irritation/stimulants. Benthic prey communities typically re-establish within weeks to months after benthic disturbance, though in some circumstances re-establishment to pre-disruption species abundance and composition may take as much as 3 years. Recruitment is a function of adjacent colonies, season, temperature, water movement, and the degree of disturbance. Here multiple disruptions are anticipated, but timing, location, and size of disturbance is limited by design and performance criteria.

(3) Passage/Safe Migration (PS Chinook Salmon, HCSR chum, green sturgeon, SRKW) – Lengthening of migration pathways in nearshore areas due to the new in and over water structures. These structures can create physical barriers that disrupt or block the natural migration routes of fish, marine mammals, and other aquatic organisms. Species that migrate along coastlines or between different water bodies may encounter obstacles posed by overwater structures, forcing them to detour or turn back, potentially disrupting their migration cycles. Disruption of migratory behavior in areas affected by the following three conditions or activities is also likely.

> *Light*
> Laser beams or diffuse laser illumination in water could potentially disorient migrating fish by interfering with their visual cues, sensory perception, or navigation abilities. This could trigger avoidance behavior and cause them to stray from their typical migration routes. Fishing bycatch studies have reported that some fish are attracted to lights (differing wavelengths and intensities), others are repulsed by light, and still others have no response (Marchesan et al 2005).
>
> Operation of light sources as described is not expected to affect large portions of critical habitat as the operation would be restricted to a small portion of the project areas, given size restrictions of devices within design and performance criteria. Temporary use of light sources during operation could temporarily affect the water column and may discourage use of habitat in the area by some species briefly. However, the small relative area and temporary operations are not expected to result in more than minor effects to use of critical habitat as nearby unaffected habitat could be used for foraging or migration.

Sound

Acoustic generating devices have the potential to adversely affect ESA-listed species and marine mammals. The operation of the devices could cause some fish species to avoid the area around the sound device which could constitute a temporary loss of foraging habitat and could temporarily affect migration patterns and access to breeding sites. However, restrictions on operation and implemented mitigation actions such as PSOs are expected to reduce the impacts of acoustic devices on critical habitat.

ElectroMagnetic Fields

Operation of EMF fields as described is not expected to affect large portions of critical habitat as the operation would be restricted to a small portion of the project areas. Temporary EMF fields would be generated during operation and could temporarily affect the associated benthic habitat or water column and may discourage habitat use nearby. However, the small relative area and temporary operations are not expected to result in more than minor effects to use of critical habitat as nearby unaffected habitat could be used for foraging or migration.

There remains a lack of specific information regarding impact of EMFs associated with subsea cables and the overall risk of EMFs to biota. Klimley et al. 2017 found no impact to the movement of salmonid smolts and green sturgeon around a high voltage DC cable deployed in California. There are reports of sensitivity for some species, but at levels of EMF intensities above marine renewal energy devices (reviewed in Gill and Desender 2020). The size of the EMF fields is expected to be relatively small due to the upper operating limit of 1.25 T, which results in nearly undetectable levels at 1 m distance from any given device or structure. The small relative area and temporary operations are expected to have minimal effects to use of habitat in the project areas as nearby unaffected habitat could be used for foraging or migration. Longer duration deployments of EMF-producing devices (e.g., cables) would similarly affect a relatively small area, but over a longer period of time.

Migration Conclusion

The sum of the projects will cause designated critical habitat to experience temporary and long-term diminishment of safe migration for PS Chinook, HCSR chum salmon, and green sturgeon. Each category of activity with potential to disrupt migration is limited in terms of number, placement, and duration in order to minimize adverse effects. Where migration behavior is interrupted by structures, equipment, or devices, offsetting measures (such as grating or mitigation) are required to ensure that, over space and time, the effects do not aggregate in a manner that diminish the conservation role of the designated critical habitats. For example, this PBF is not expected to be diminished for SRKW because marine mammal monitoring programs will be in place for acoustic and light studies and will result in shutdowns, if necessary, if SRKW are present.

c. Water Quality

(1) Water Quality (all designated CH) – As described thoroughly in Section 2.5.1, temporary water quality reductions from increased turbidity, suspended sediment, and potential decreases in DO are expected. Increased turbidity and suspended sediment effects are expected to be intermittent during in-water work, extend no more than 200 feet (estuarine) or 300 feet (marine) from in-water work area, have little effect on DO, and return to baseline within hours after work ceases. Based on these factors, the temporary turbidity, suspended sediment, decreased DO related impairment of this PBF will not reduce the conservation value of the habitat. Values for species movement, growth, maturation, and fitness are all retained. The presence of the dyes or tracers in the water column would be short term, and they would be quickly diluted. Although the impact on the species consider in this opinion can be meaningful, the total amount of habitat affected by increases in suspended sediments at any given time is tiny when compared to the amount of habitat available for these species, thus impacts to critical habitats would be negligible. While each episode of water quality reduction is adverse, the spatial extent and brief duration of these effects are limited by design and performance criteria of the program, so that when considered together, the adverse effects are minimized in a manner that does not allow the conservation role of designated critical habitats to be reduced.

(2) Prey (all designated CH) – Potential short-term reduction in forage due to turbidity plumes (sampling) and impaired vision (dyes and particulates). As PS Chinook salmon are a PBF of SRKW critical habitat, their repeated/chronic exposure to stressors in successive cohorts results in a diminishment of the forage PBF of SRKW critical habitat. Both quantity and quality of prey will slightly decline as a result of impacts to water quality, as these effects are likely to cause latent health effects on fish that slightly reduce adult abundance, and also reduce the quality of adult fish that do return and serve as SRKW prey. Overwater and in-water structures reduce nearshore habitat quality, increase migration time, and increase predation on juvenile salmonids. Over time, this reduces the amount of salmon available as forage for SRKWs.

The PNNL RAP proposed action includes conservation offsets to compensate for the loss of nearshore habitat quality. As a result, the projects authorized under PNNL RAP will result in no-net loss of nearshore habitat quality. Given the total quantity of prey available to SRKWs throughout their range numbers in the millions, the reduction in prey related to short-term construction effects from the proposed action is extremely small. Therefore, NMFS anticipates that the short-term reduction of Chinook salmon from temporary effects would have little adverse effect on SRKWs and would not impair normal behavior in the action area.

(3) Passage/Safe Migration (PS Chinook salmon, HCSR chum) – Temporary disruption of free passage due to low visibility could occur during release of dyes, or in locations where high suspended sediment is present. Increased turbidity or decreased visibility in the water due to sediment loads, algal blooms, or other factors (dyes and particulates) can impair the ability of migratory species to navigate and orient themselves during their journeys. This can cause them to become disoriented or stray from their intended routes.

Many migratory species, such as salmon and certain fish, require high levels of dissolved oxygen in the water for respiration during their long journeys. Poor water quality with low oxygen levels can impede their migration, lead to physiological stress, or even cause mortalities.

Water Quality Conclusion
We consider the effects of the proposed action on water quality and determined it will create a temporary diminishment of the water quality PBF for all designated critical habitat in the action area. However, with BMPs and GCMs to minimize effects the water quality PBF will be degraded, but these effects are ephemeral, and return within hours (turbidity, low DO) to days (dyes) to baseline conditions. The reduction in this feature of critical habitat/s is not at a scale or intensity or frequency that would impair the designated critical habitat conservation role. We do believe that the effect of the action will not diminish the overall value of critical habitat for salmon, rockfish, sturgeon or SRKW.

d. Loss of Aquatic Habitat

As described more fully in the effect pathways s section, nine activity types (or, 14 subcategories of activity) make some amount of aquatic habitat unavailable, for varying amounts of time. The habitat elements displaced or inaccessible include the water column (water quality) prey species, and migration areas free of obstruction and excess predation.

(1) Water Quality (all designated CH) – The loss of critical habitat to structures can have significant impacts on marine water quality. Structures like floats and sea beds installations can lead to a loss of habitat due to the fill (i.e. the structure), affecting foraging habitats for fish and marine mammals and shading marine plants and algae. Additionally, these structures can modify water currents, flushing, sedimentation, and sediment transport, impacting the overall marine and estuarine environment. Construction activities associated with these projects also impact the marine environment temporarily but significantly, especially with large-scale or long-term projects. Structures in critical marine habitats can alter the environment and affect water quality, emphasizing the importance of considering the ecological implications of such developments. Some water will be removed, via water sampling, but not enough to amount to a measurable effect to fish.

(2) Prey (all designated CH) – Short-term reduction in forage due to sediment/benthic studies, eelgrass and macroalgae studies. The loss of critical habitat can have significant impacts on the food sources of protected species. When habitats are damaged or lost, it becomes challenging for species to find the necessary food sources, especially in cases where the lost habitat is essential for a species' survival or where it serves as a crucial feeding ground at specific times or stages in their life cycle (Benton et al, 2021).

(3) Passage/Safe Migration (all designated CH) –The loss of marine critical habitat can significantly impact the migration routes of protected species. Critical habitats, and the protections that come with them, are crucial for migratory species like fish and whales. However, the effectiveness of designated critical habitat areas in safeguarding highly migratory species with large geographic ranges can be limited, as these species often move outside the borders of protection during their annual cycles. Habitat loss can lead to a decline in species numbers,

particularly affecting large animals that range across vast areas, causing fragmentation of their home ranges and forcing them into unsuitable habitats or managed seascapes.

Loss of Aquatic Habitat Conclusion

When considered together as a series of losses of (or avoidance of) designated critical habitat, NMFS considers the temporal limitation (no more than 2 years without verification by the Service), the spatial constraints of the design criteria, and the limit on number and placement in the performance criteria sufficient to minimize this loss so that conservation values are not impaired. When the offsetting actions requirement of the program are then also factored (in an effort to establish "not net loss" structures that occupy critical habitat outside of the work window and over 60 days are required to purchase mitigation., NMFS has confidence that even over the duration of the program, the adverse effects of the activities will not impair conservation values of critical habitat.

e. Sound

As described in the general effects section five activity types (six subcategories) are likely to produce sound that will be detectable by marine mammals or fish in their habitat. We evaluate how sound affects the features of designated critical habitat/s. Restrictions on operation, and implemented mitigation actions such as PSOs are expected to reduce the impacts of acoustic devices. Additionally, the operation of most devices would be for limited periods of time during the day and season (hydrokinetic energy devices operated for longer periods but would be variable during each day).

1) Water Quality (all designated CH) – While the actual chemical condition of water is not altered by sound in the way that is typically considered by the Clean Water Act, introduced sound in water modifies the aquatic habitat in a manner that interferes with the ability of marine animals to communicate, find mates, locate prey, avoid predators, navigate, and defend territories. The impacts of noise pollution include temporary or permanent hearing loss, behavioral changes, physiological alterations, masking of important sounds, injuries, and even death among marine mammals. It can lead to stress responses in fish, impaired embryo development in invertebrates, increased mortality rates in various species, and disruptions in the ecosystem's health and productivity. Excessive and repetitive sound deters fish and mammals from using an area, thereby lowering the habitat quality. Therefore, while sound diminishes the quality of the aquatic habitat for multiple vital conservation values, the program's design and performance criteria constrain the duration and character of these effects in order to minimize the diminishment, and generally retain the level of conservation provided by the critical habitats.

(2) Prey (all designated CH) – We expect loss in forage species production due to acoustic irritation. Without mitigation the operation of acoustic generating devices has the potential to adversely affect ESA-listed species and marine mammals. The operation of the devices could cause some fish species to avoid the area around the sound device which could constitute a temporary loss of foraging habitat and could temporarily affect migration patterns and access to breeding sites. However, restrictions on operation and implemented mitigation actions such as PSOs are expected to reduce the impacts of acoustic devices. Additionally, the operation of most devices would be for limited periods of time during the day and season (hydrokinetic energy

devices operated for longer periods but would be variable during each day) this would be an overall minor impact on critical habitats.

(3) Passage/Safe Migration (PS Chinook, HCSR chum, SRKW) – We expect temporary disruption of free passage due to underwater sound from acoustic studies is likely. Effects of the proposed action also include the potential for exposure to the and sound generated by vessels and machinery associated with the proposed action. The increase in vessel presence and sound in SRKW critical habitat, in particular, contribute to total effects on passage conditions. However, vessels associated with the proposed action do not target whales and disturbance would likely be transitory, including small avoidance movements away from vessels. Considering the state and federal regulations in place, the number and spread of vessels is not expected to result in blocking movements of the whales in their travel corridors. Therefore, it is unlikely that any small transitory disturbance from vessels that might occur would have more than a very minor effect on passage in designated critical habitat. Lastly, given all projects that include acoustic studies will include a Marine Mammal Monitoring Plan that is sufficient to ensure the sound ceases before marine mammals enter the area where sound will exceed 120 dBrms, effects from these activities on passage in SRKW critical habitat is likely minor.

f. Benthic Impacts

The sources of and range of benthic impacts is described in the effects pathways section. This section presents the influence of those benthic changes on key features of designated critical habitat/s.

(1) Water Quality (all designated CH) – Temporary water quality degradation, including increased turbidity, due to structure placement or removal, and sampling. Many benthic organisms, such as clams, mussels, and certain worms, require sufficient dissolved oxygen in the water for respiration. Low oxygen levels, often caused by excess nutrients or organic matter decomposition, can lead to stress, reduced growth, and even mortality in these organisms. Increased turbidity and sedimentation: Elevated levels of suspended sediments and turbidity in the water can smother benthic organisms, clog their feeding structures, and reduce light penetration, which can negatively impact photosynthetic organisms like benthic algae and seagrasses. As described in the subsection on turbidity, the water quality effect of benthic disturbance is an ephemeral and localized effect with each occurrence. Water quality quickly regains its baseline condition.

(2) Prey (all designated CH) – As described above, short-term reduction in forage will occur as a consequence of project activities. The diet of Puget Sound rockfish consists of small prey items such as calanoid copepods, crab larvae, chaetognaths, hyperiid amphipods and siphonophores (Moulton 1977, Miller et al. 1978, in WDFW 2009). In South Sound, yelloweye rockfish feed on fishes, especially walleye pollock (*Theragra chalcogramma*), cottids, poachers, and Pacific cod (Gadus macrocephalus) (Washington et al. 1978, in WDFW 2009). The proposed action will cause short-term reduction in invertebrate and fish forage items due to sediment disturbance and construction activities however the performance criteria limit the number, and location of benthic-disturbing activities, and the design criteria limit the spatial extent and duration of these activities.

(3) Passage/Safe Migration (PS Chinook, HCSR chum, green sturgeon, SRKW) – Operation of EMF fields as described is not expected to affect large portions of critical habitat as the operation would be restricted to a small portion of the project areas. Temporary EMF fields would be generated during operation and could temporarily affect the associated benthic habitat or water column and may discourage habitat use nearby. However, the small relative area and temporary operations are not expected to result in more than minor effects to use of critical habitat as nearby unaffected habitat could be used for foraging or migration. The relatively small area affected renders any effects on overall critical habitat minor.

Benthic Impacts Conclusion
Impacts on benthic communities can have cascading effects on critical habitats for various marine species in several ways. Many benthic organisms, such as oysters, mussels, and corals, provide essential habitat structure and complexity for other species. When these benthic organisms are impacted by poor water quality, physical disturbances, or other stressors, it can lead to the degradation or loss of these critical habitat structures, affecting the species that rely on them for shelter, feeding, or breeding. Additionally, benthic communities form an important part of the marine food web, serving as prey for various fish, crustaceans, and other species. Impacts on benthic organisms can disrupt these food webs, potentially leading to cascading effects on higher trophic levels and affecting the overall productivity and function of the ecosystem. The benthic effects described above are temporary, typically lasting for the duration of project or momenta of impact. The resulting effects may last for several months, but habitat quality will eventually fully recover. Finally, the program's requirement for offsetting measures are intended to ensure that when taken together over the life of the program, adverse effects cannot aggregate in a manner that reduces the conservation role of the designated critical habitat/s.

g. Entrainment

(1) Water Quality (all designated CH) – not affected

(2) Prey (all designated CH) – Entrainment can negatively impact prey in critical habitats by removing them from the ecosystem. Impingement and entrainment, as seen in the case of Atlantic sturgeon, can affect critical habitat by removing prey species from their natural environment. This process can disrupt the food chain and lead to imbalances in the ecosystem, affecting the overall health and stability of critical habitats (Grange 2016). Entrainment can lead to significant losses of plankton and other small organisms that serve as essential prey for various species, ultimately affecting the biodiversity and ecological balance within critical habitats.

Operation of marine energy devices with higher approach velocities may entrain forage species of salmonids, and also entrain salmonids, which are prey of SRKW. However, because the footprint of such installations is expected to be minor with multiple nearby unaffected habitats available, we expect entrainment-based reduction will be virtually indistinguishable relative the action area's abundance of prey resources.

(3) Passage/Safe Migration (PS Chinook salmon, HCSR chum, bocaccio (juveniles) eulachon) – Entrainment (and impingement) can injure or kill listed species, which indicates that the migration areas of these species is reduced.

Entrainment Conclusion
Entrainment poses a threat to water quality in critical habitats by disrupting marine ecosystems and causing mortality among various aquatic organisms. Regulatory measures are essential to mitigate these impacts and protect vulnerable species and their habitats from the adverse effects of entrainment. The impacts will be diminished by using NMFS approved screens around parts open to both the environment and generator/turbine that will be of mesh size sufficient to omit protected species as well as prey species, by default, that could enter into the device. Critical habitats may be temporarily affected by deployment of tidal turbines and marine energy devices on the seabed, or installation on the surface with a pelagic profile. Collision of forage species may result from operation. However, the footprint of such installations is expected to be minor with regard to nearby unaffected habitats.

If entrainment were to occur at very high levels (injuring or killing many of the individual fish that rely on the action area), it could lead to population level effects (reduced productivity and reduced spatial structure) but the design criteria, performance criteria, and offsets which are elements of the proposed action are expected to keep the level of entrainment low, so that the reduced abundance of individuals cannot rise to population level effects (retains the conservation role of the critical habitat)

h. Capture and Release

(1) Water Quality – Not affected
(2) Prey – Not affected
(3) Passage/Safe Migration – See *Entrainment* and *Benthic Impacts* above.

2.5.3 Effects on Listed Species

As was detailed in above sections (general presentation of effects pathways at 2.5.1, and critical habitat effects at 2.5.2) the proposed activities would cause an array of adverse effects on habitat features, availability and function, along with more system-wide detriments associated with the action. Species will be exposed to these effects. Although the projects are designed to be short lived, the area will be repeatedly impacted with new projects for the foreseeable future. Thus, individuals from multiple cohorts of the multiple populations of PS Chinook salmon, PS steelhead, Hood Canal summer-run chum, southern DPS of green sturgeon, eulachon, PS/GB bocaccio rockfish, PS/GB Yelloweye rockfish, SRKW, and humpback whales would experience impacts from the activities.

Although sunflower sea stars are habitat generalists and present abundance is a fraction of historic level, this species will be present and exposed to some of the adverse effects of the proposed action. This species may occur over sandy, muddy, and rocky bottoms both with and without appreciable vegetation in nearshore intertidal and subtidal marine waters, up to a depth of 450 m (~1400 ft).

In addition to design and performance criteria that minimize effects and corollary exposure, the requirement to offset the impacts of some overwater and in-water structures through the conservation offsets is expected to compensate for the loss of nearshore habitat quality, further reducing the amount of exposure of species to some of the habitat-based effects, as well as minimizing entrainment, and capture and release. Minimization and compensatory elements notwithstanding, effects and exposure will occur.

Effects on listed species is a function of: (1) the numbers of individuals exposed to habitat changes or direct effects of an action; (2) the duration, intensity, and frequency of exposure to those effects; and (3) the life stage at exposure. This section presents first a general explanation of likely exposure of each listed species to effects and then provides a pathway by pathway analysis of exposure and response both to habitat effects, and some effects that occur directly on species (i.e. entrainment, capture, release).

Table 35. Effects pathways and species

Effect Pathway	PS Steelhead	PS Chinook	HCSR Chum	PS/GB Yelloweye Rockfish	PS/GB Bocaccio	Eulachon	Green Sturgeon	SRKW	Humpback Whale	Sunflower sea star
(a) Shade	x	x	x		x					x
(b) Migration	x	x	x		x	x	x			
(c) Water Quality	x	x	x	x	x	x	x			x
(d) Loss of Aquatic Habitat	x	x	x	x	x					x
(e) Sound	x	x	x	x	x	x	x	x	x	
(f) Benthic Effects					x		x			x
(g) Entrainment				x	x					x
(h) Capture and Release	x	x	x	x	x	x	x			x

Although not reflected in the table, effects on prey are influenced by all of the pathways described here. For the rest of this section, the term "all effects" includes exposure to reduced prey.

Period of Likely Exposure by Species

As described in Section 1.3 (Proposed Action), in-water work could occur inside or outside of the WDFW in-water work window (i.e. any time of year). The in-water work window coincides with the lowest fish abundance at that location. Those projects occurring during in-water water windows significantly reduces the number of individual salmonids exposed to the temporary construction effects. Because work windows do not strictly govern all activities, we evaluate the likelihood of exposure on factors related to species abundance, migration patterns, and life history behaviors.

Salmonids

As described in Section 2.3, three species of salmonids are likely to occur in some or all of the action area, and as mentioned directly above, because the proposed action includes activities that can occur outside of typical work windows, or that stay in place beyond work windows, *exposure of these species can occur at any time of year. These species may be present as adults or as juveniles.* While every population of the three salmonid species has some potential for exposure, the populations most likely to be exposed (identified in Sections 2.2.1 and 2.4.2) are likely to be present and exposed to effects as juveniles. PS Chinook from Elwha River and Dungeness River, HCSR chum from Jimmycomelately Creek, Salmon Creek, Snow Creek, Chimacum Creek, and PS steelhead from Dungeness Winter-Run Strait of Juan de Fuca Tributaries Winter-Run and the Sequim/Discovery Bay Tributaries Winter-Run all have the highest potential for exposure to all effects of the proposed action, based on proximity of natal streams. The likelihood of exposure is greatest among the PS Chinook fall salmon and HCSR chum populations, based on their smaller size as smolts entering marine waters.

Life history stage (i.e. adult versus juvenile) can influence the duration of exposure to some effects, the nature of response to some exposure, and the degree of response. Section 2.4.2 provides details about specific populations of these species that are expected to have exposure and response to the proposed action's physical, chemical, and biological effects, but for the remainder of this section we refer to the listed fishes by species rather than by population. Where lifestage influences response, we include such additional detail.

Adult salmonids. Adult PS Chinook salmon, HCSR chum salmon, and PS steelhead occupy deep water, like those found in the Strait of Juan de Fuca portion of the action area. We expect the direct habitat effects from overwater and in-water structures to create some exposure or response among adult PS Chinook salmon, chum, and PS steelhead. Some data suggests that up to 70 percent of PS Chinook salmon spend their adult period in Puget Sound without migrating to the ocean (Kagley et al. 2016), suggesting that most adult PS Chinook will experience far reaching effects such as vessel noise, some water quality diminishments and reduced prey. Exposure is likely among adult salmonids. Adult salmon are likely to experience effects from sound and light studies which generally occur in deeper waters. *Exposure to all described effects except benthic impacts, entrainment, and capture/release is likely among adult salmonids*, however at this life stage, response of adults to all likely effects is expected to be behavioral with few implications for health and fitness, unlike juvenile salmonids.

Juvenile Puget Sound Chinook salmon. Juvenile Chinook generally emigrate from freshwater natal areas to estuarine and nearshore habitats from January to April as fry, and from April through early July as larger sub-yearlings. Juveniles have been found in PS neritic waters between April and November (Rice et al. 2011). Additionally, a substantial percentage of Chinook salmon rear in Puget Sound without migrating to ocean areas (O'Neill and West 2009). *Exposure to all described effects, except for benthic impacts*, is likely among juvenile PS Chinook salmon, with the greatest likelihood of exposure among Elwha River and Dungeness River.

Juvenile PS steelhead. Juvenile steelhead primarily emigrate from natal streams in April and May, and appear to move directly out into the ocean to rear, spending little time in the nearshore zone (Goetz et al. 2015). However, steelhead smolts have been found in low abundances in the marine nearshore, outside of their natal estuary, between May and August (Brennan et al. 2004). *Exposure to all described effects except entrainment/capture/release is likely among juvenile PS steelhead.*

Juvenile Hood Canal Summer Run Chum. In late winter, juvenile chum can spend up to one month in estuarine shallow waters (all salinity zones) before moving to the ocean. After leaving estuaries, juveniles may exhibit extended residency within Puget Sound before migrating, and may even overwinter in the Sound (Salo 1991, Johnson et al. 1997). Wait et al (2018) show widespread use of nearshore habitat by summer run chum, even at sites that are distant from natal streams. Migration rates of chum salmon in nearshore areas are variable and depend upon fish size, foraging success, and environmental conditions (currents and prevailing winds). Small chum salmon fry (< 50-60 mm) appear to migrate primarily along the shoreline in shallow water less than 2 meters in depth. Use of shallow water habitats relates to predator avoidance and prey availability. When present in shallow water habitats, juvenile chum salmon less than 60 mm consume primarily epibenthic invertebrates, particularly harpacticoid copepods and gammarid amphipods. These epibenthic prey are primarily associated with protected, fine-grained substrates, and often eelgrass, and are especially abundant early in the year in some locations. This suggests that these habitat types are especially important to small, early migrating chum salmon, some of which are presumably summer chum salmon. *Exposure to all described effects is likely among Hood Canal Summer run chum (Fresh 2006).*

Rockfish

Adult Rockfish. We would expect the presence of adult PS/GB bocaccio and yelloweye. The action area does have suitable habitat for this lifestage, as the preferred habitat features (such as depth and rugosity) are found the deeper portions of the action area in the Strait. Additionally, given the ability of this species to move throughout the marine environment, we conclude that they could occur within the action area. *Exposure to all effects is likely among adult bocaccio rockfish, in the San Juan portion of the action area. For yelloweye rockfish, exposure to all effects except shade, migration and benthic impacts s likely in the San Juan portion of the action area.*

Larval and Juvenile Rockfish. Larval rockfish presence peaks twice in the spawning period, once in spring and once in late summer. It is likely that during the spawning period large numbers of larval rockfish, both PS/GB bocaccio and yelloweye, will be exposed to project effects, and thus exposed to sound and high turbidity and any associated contaminants or low dissolved oxygen. *Exposure to all effects is likely among juvenile rockfish, with entrainment posing the greatest risk.*

Eulachon

While populations have declined in some areas, eulachon are still found in reasonable numbers in the Puget Sound region during their spawning season, which typically runs from late winter through early spring. However, it's important to note that eulachon abundance can vary from year to year and location to location within the Puget Sound, depending on factors such as ocean conditions, river flows, and habitat quality. Overall, given their historical and current presence, as well as conservation efforts, the likelihood of encountering eulachon in the Puget Sound region, particularly during their spawning season, is considered relatively high compared to many other areas along the Pacific Coast. *Exposure to all effects except migration impacts is likely among eulachon.*

Green Sturgeon, Southern DPS

Green sturgeon are more likely to be found in the deeper waters and main basins of the Puget Sound than in the action area, particularly in spring and summer when feeding conditions are optimal. However, green sturgeon populations have declined significantly due to habitat loss, overfishing, and other factors. While not extremely common, over the duration of the PNNL RAP, there is a moderate-to-good likelihood of encountering the protected green sturgeon species in certain areas and times within the action area, as it falls within their historic Pacific Coast range. *Exposure to any effect of the proposed action is expected to rare among green sturgeon.*

Southern Resident Killer Whales.

Between the three pods that comprise this DPS, identified as J, K, and L, some members of the DPS are present in Puget Sound at any time of the year though data on observations since 1976 generally shown that all three pods are in Puget Sound June through September. As discussed in the Status section, the whales' seasonal movements are only somewhat predictable because there can be large inter-annual variability in arrival time and days present in inland waters from spring through fall. Late arrivals and fewer days present in inland waters have been observed in recent years. The likelihood of exposure to the effects are high (Olson et al. 2018). However, implementation of a marine mammal monitoring plan would greatly reduce the likelihood that SRKWs will actually experience negative effects from in-water construction. *Exposure to all effects except shade, entrainment, and capture/release is likely among SRKWs.*

Humpback Whales

The likelihood of encountering humpback whales in the Strait of Juan de Fuca is relatively high during certain times of the year. The Strait of Juan de Fuca is part of the migratory route for humpback whales traveling between their feeding grounds in the nutrient-rich waters off the coast of British Columbia and their breeding grounds near Hawaii and Mexico. The highest likelihood of encountering humpback whales in the Strait of Juan de Fuca is typically between May and September, when they are actively feeding in the area. *Exposure is likely among humpback whales to effects on free migration, water quality, loss of aquatic habitat, and sound.*

Sunflower Sea Stars

Because sunflower sea stars are habitat generalists, despite the significant reduction in abundance overall, it remains likely that over the course of the PNNL RAP, they will be present in the action area. Exposure of a small number of these individuals to all effects except migration impacts is likely.

a. Species Response to Shading

Up to 359 individual shade-casting projects may occur simultaneously, in any given year of the program, and at no time can that number exceed 125,785 total square feet of shade casting coverage (~3 acres), as seen in Figure 9.

Figure 9. For visual reference, the green triangle represents 3 acres of coverage in the action area, if all project were clumped in one area, of which they are not allowed to be due to PDCs.

a.1 – Response to shading effects on SAV
Salmonids: Bax et al. (1978) determined the abundance of chum fry was positively correlated with the size of shallow nearshore zones, and sublittoral eelgrass beds have been considered to be the principal habitat utilized by the smaller salmonids. Fresh et al. (2006) researched the effects of grating in residential floats on eelgrass, a substrate for herring spawning, and a Chinook salmon forage species. They reported a statistically significant decline in eelgrass shoot density underneath six of the 11 studied floats in northern Puget Sound. However, the physiological pathways that result in the reduction in shoot density and biomass from shading applies to all SAV. Thus, it is reasonable to assume that shading from OWS adversely affects all SAV, and juvenile salmonids in turn have less area with suitable cover, refugia, and forage. This may result in some individual salmonids - primarily chum and Chinook salmon (with the greatest likelihood of exposure among Elwha River and Dungeness River) having reduced growth, fitness, or survival.

Juvenile PS/GB bocaccio rockfish. When this life stage reach sizes of 1 to 3.5 in (3 to 9 cm) or 3 to 6 months old, they settle into shallow, intertidal, nearshore waters in rocky, cobble and sand substrates with or without kelp (Love et al. 1991; Love et al. 2002). This habitat feature offers a beneficial mix of warmer temperatures, food, and refuge from predators (Love et al. 1991). Areas with floating and submerged kelp species support the highest densities of juvenile PS/GB bocaccio rockfish. OWS, then, by reducing prey communities and impairing SAV growth, diminish both values for PS/GB bocaccio, impairing their survival, growth, and fitness.

Eulachon and Green Sturgeon (and adult rockfish)– typically will be located in deeper areas with less light penetration, and thus 'shade' is unlikely to affect their behaviors.

Marine Mammals will not be directly exposed to shade or areas where SAV is reduced by shade.

Sunflower sea stars, like other invertebrates, often live in or around areas with aquatic vegetation or algal growth. Overwater shading can degrade these habitats, making them less suitable for starfish and other species. Shading from overwater structures can also alter water temperatures, which can affect the metabolic rates, growth, and development of starfish, especially during sensitive early life stages of starfish.

a.2 - Response to shading effects on predator/prey dynamics.
Fishes – as established above, SAV provides cover for some species (where they may avoid predators), and spawning substrate for others (creating forage base). A reduction to the primary production of SAV beds is likely to incrementally reduce the food sources and cover for juvenile PS Chinook, HCSR chum salmon, PS steelhead, and juvenile PS/GB bocaccio. The reduction in food source includes epibenthos (Haas et al. 2002) as well as forage fish. This reduction occurs in areas where smoltified salmonids have entered salt water and require abundant prey for growth, maturation and fitness for their marine life history stage. Eelgrass is a substrate for herring spawning, and herring spawn is Chinook salmon forage species. The likely incremental reduction in epibenthic prey associated with OWS projects will reduce forage for listed fish, and lack of SAV as cover for listed fish (primarily juveniles but also eulachon because of their small size) may make them more vulnerable to predators. We note here that salmonids have slow

vision response to shade, and reactions to shade itself includes avoidance, which can result in delayed migration, reduced forage behavior, and increased predation risk.

Green sturgeon on the other hand, feed by stirring up sediments and then ingesting mobilized prey; dense sea grasses may inhibit their ability to forage (NMFS 2021c).

Marine Mammals – Neither whale species is directly affected by shade.

Sunflower Sea Stars - For the sunflower sea star, shading can lead to changes in water chemistry, such as reduced DO levels, which can stress starfish and other marine organisms. Overwater shading may decrease the abundance of prey species which sunflower sea stars rely on, such as bivalves, small crustaceans, and other invertebrates, potentially leading to food scarcity. However, given that sunflower sea stars are currently in low abundance, reductions in prey are not likely to create conditions of competition, even if prey is reduced. Sunflower sea stars are highly mobile and this makes localized prey reductions less meaningful as individuals from this species are able to seek out prey over relatively broad areas (Hodin et al. 2021).

a.3 Conservation offsets of shading
Because design and performance criteria minimize shade, and conservation offsets will provide habitat improvements, we believe that the reduced fitness or survival among individuals of the listed fishes, and of sunflower sea stars will not reach a reduction sufficient to alter the population dynamics of any of these species.

Shading Conclusion
Impacts from shading are more likely to affect the animals in shallower habitats (juvenile salmonids, bocaccio, and sunflower sea stars). Green sturgeon, eulachon, adult rockfish, SRKWs and humpback whales live in deeper habitats and are less impacted by shading.

b. Species Response to Migration Disruption

Shade can disrupt migration – as above, up to 359 individual shade-casting projects may occur simultaneously, in any given year of the program, and at no time can that number exceed 125,785 total square feet of shade casting coverage (~3 acres) (see **Figure 9**). Light, Sound, and ElectroMagnetic Fields also can disrupt migration and these are limited to 5, 10 and 1 disrupting devices at a time, respectively).

All species considered in this opinion are likely to have disruptions to safe migration or free migration.

b.1 – Response to obstructions in migration areas
Salmonids - Juvenile fall Chinook salmon and juvenile HCSR chum migrate along shallow nearshore habitats, and OWS's will disrupt their migration and increase their predation risk. Most juvenile Chinook and juvenile HCSR chum will encounter some OWSs during their out-migration. We cannot estimate the number of individuals that will experience migration delays and increased predation risk from the proposed OWSs, but we anticipate that PS Chinook affected will predominantly be from Elwha River and Dungeness River, and the HCSR chum

will be from Jimmycomelately Creek, Salmon Creek, Snow Creek, Chimacum Creek based on proximity of natal streams. Adult Chinook, adult and juvenile steelhead, and adult chum, do not explicitly rely on shallow nearshore habitats; OWS are not considered to be a significant obstruction to their movements.

Overwater structures cause delays in migration for PS Chinook salmon from disorientation, fish school dispersal (resulting in a loss of refugia), and altered migration routes (Simenstad 1999). Juvenile salmonids stop at the edge of the structures and avoid swimming into their shadow or underneath them (Heiser and Finn 1970; Able et al. 1998; Simenstad 1988; Southard et al. 2006; Toft et al. 2013; Ono 2010). Swimming around structures lengthens the migration distance and is correlated with increased mortality. Anderson et al. (2005) found migratory travel distance rather than travel time or migration velocity has the greatest influence on the survival of juvenile spring Chinook salmon migrating through the Snake River.

Juvenile salmon, in both the marine nearshore and in freshwater, migrate along the edge of shadows rather than through them (Nightingale and Simenstad 2001; Southard et al. 2006; Celedonia et al. 2008a; Celedonia et al. 2008b; Moore et al. 2013; Munsch et al. 2014). In freshwater, about three-quarters of migrating Columbia River fall Chinook salmon smolts avoided a covered channel and selected an uncovered channel when presented with a choice in an experimental flume setup (Kemp et al. 2005). In Lake Washington, actively migrating juvenile Chinook salmon swam around structures through deeper water rather than swimming underneath a structure (Celedonia et al. 2008b). Structure width, light conditions, water depth, and presence of macrophytes influenced the degree of avoidance. Juvenile Chinook salmon were less hesitant to pass beneath narrower structures (Celedonia et al. 2008b).

In the marine nearshore, there is substantial evidence that OWS impede the nearshore movements of juvenile salmonids and reduced feeding rates for those fish that do utilize OWS (Heiser and Finn 1970; Able et al. 1998; Simenstad 1999; Southard et al. 2006; Toft et al. 2007; Moore et al. 2013, Munsch et al. 2014, see ref). In the Puget Sound nearshore, 35-millimeter to 45-millimeter juvenile chum and pink salmon were reluctant to pass under docks (Heiser and Finn 1970). Southard et al. (2006) snorkeled underneath ferry terminals and found that juvenile salmon were not underneath the terminals at high tides when the water was closer to the structure, but only moved underneath the terminals at low tides when there was more light penetrating the edges. Moore et al. (2013) concluded in their study that the Hood Canal Bridge may attract PS steelhead smolts to its shade while also inhibiting passage by disrupting Hood Canal currents. They found this delayed migration, for a species whose juveniles typically migrate rapidly out to the open ocean, likely resulted in steelhead becoming more susceptible to predation by harbor seals and avian predators at the bridge. These findings show that over water structures can disrupt juvenile salmonid migration in the Puget Sound nearshore.

As mentioned above, an implication of juvenile salmon avoiding OWS is that some of them will swim around the structure (Nightingale and Simenstad 2001). This behavioral modification will cause them to temporarily utilize deeper habitat, thereby exposing them to increased piscivorous predation. Hesitating upon first encountering the structure, as discussed, also exposes salmonids to avian predators that may use the floating structures as perches. Typical piscivorous juvenile salmonid predators, such as flatfish, sculpin, and larger juvenile salmonids, being larger than their prey, generally avoid the shallowest nearshore waters that outmigrant juvenile salmonids prefer— especially in the earliest periods of their marine residency. When juvenile salmonids temporarily leave the relative safety of the shallow water, their risk to being preyed upon by other fish increases. The risk is illustrated in the marine environment where juvenile salmonid consumption by piscivorous predators increased fivefold when juvenile pink salmon were forced to leave the shallow nearshore (Willette 2001). Elevated pinniped predation rates have been documented at major anthropogenic structures that inhibit movement and cause unnaturally large aggregations of salmonid species (Jeffries and Scordino 1997, Keefer et al. 2012, Moore et al. 2013). The most widely known and intensely studied pinniped/salmonid conflict is California sea lion predation on winter steelhead at the Ballard Locks in Seattle, Washington (Jeffries and Scordino 1997). Although California sea lions first began appearing in the Ballard Locks area on a somewhat regular basis in 1980, their predation on steelhead was not viewed as a resource conflict until 1985, when a significant decline in the wild winter steelhead spawning escapement was noted (Gearin et al. 1996). Subsequent scientific studies documented that sea lions were removing significant numbers of adult steelhead that were returning to the Lake Washington system to spawn (Scordino and Pfeifer 1993).

Another study was conducted by Moore et al. 2013 at the Hood Canal Bridge, a floating structure that extends 3.6 meters underwater and forms a partial barrier for steelhead migrating from Hood Canal to the Pacific Ocean. The authors found more steelhead smolt mortality events occurred within the vicinity of the Hood Canal Bridge than at any other site that was monitored from 2006 through 2010. Smolts that passed by the Hood Canal Bridge receiver array behaved differently than those migrating past similarly spaced receiver arrays inside the Hood Canal, in Puget Sound, and in the Strait of Juan de Fuca. The observed changes in behavior was potentially a result of one or several interacting physical, ecological or environmental factors altered by the bridge structure. Mortalities are likely caused by predation by a marine mammal, inferred from movement patterns recorded on Hood Canal Bridge receivers that would be atypical of surviving steelhead smolts or tags consumed by avian predators (Moore et al. 2013). Longer migration times and paths are likely to result in a higher density of smolts near the bridge in relation to other sites along the migration route, possibly inducing an aggregative predator response to steelhead smolts (Moore et al. 2013).

Further, swimming around OWS lengthens the salmonid migration route, which has been shown to be correlated to increased mortality. Migratory travel distance rather than travel time or migration velocity has been shown to have the greatest influence on survival of juvenile spring Chinook salmon migrating through the Snake River (Anderson et al. 2005). In summary, NMFS anticipates that the increase in migratory path length from swimming around OWS as well as the increased exposure to piscivorous predators in deeper water likely will result in proportionally increased juvenile PS Chinook salmon and HCSR chum mortality. Except for the Hood Canal Bridge example where the pontoons span roughly 95 percent of the width of the Hood Canal at low tide, PS steelhead do not tend to be nearshore dependent and thus the presence of these structures is unlikely to affect their behavior.

Habitat modifications resulting from anthropogenic infrastructure, including over water structures, have been shown to inhibit movement of migrating salmon and cause unnaturally large aggregations. The aggregation of salmon has shown an increase in mortalities due to predation by marine mammals (Jeffries and Scordino 1997, Keefer et al. 2012, Moore et al. 2013).

Rockfish – Adult lifestages of yelloweye and bocaccio are in deeper areas that are less likely to be locations for deployment of most of the PNNL activities. However, juvenile bocaccio prefer shallower areas, and migrate as they age and grow to deeper locations. We consider this lifestage may have similar responses to structures and activities in the environment as Chinook juveniles.

Eulachon – Migration issues are not expected to affect eulachon.

Green Sturgeon -Migration to and from the action area is unlikely to be affected by the proposed action, however movement within the action area may be inhibited by structures on the seabed, including electric cables. We provide more on that in the subsection on EMF, below.

Whales – In particular, sounds created by the PNNL RAP activities may cause behavioral responses that include modified movement/avoidance of areas when and where sound is detected. We do not expect such behavioral response to result in injury among individuals of either SRKW or humpbacks.

Sunflower Sea Stars - Migration issues are not expected to affect rockfish, eulachon or the sunflower sea star.

b.2 – Response to activities which alters migration: lights, sound, EMFs

Light

During daylight hours, operation of an artificial light source would not substantially increase light beyond ambient levels and thus effects to aquatic species would be minimal. During nighttime hours, the use of artificial illumination will be intermittent and less often than during daytime operation and interaction with aquatic species is likely to vary. For example, artificial light has been shown to result in attraction behavior by some surface species (Marchesan et al. 2005), while it has also been shown to result in avoidance behavior in relatively deep water (Raymond and Widder 2007). Consequently, while the activation of the strobes may result in a temporary behavioral response for the short duration of the illumination during nighttime periods, this is unlikely to be biologically significant.

Operation of lasers for LiDAR or other applications has the potential to cause ocular injury to marine life. There is minimal research available with empirical data related to ocular laser injury for marine mammals, and none for fish. There is, however, an extensive background on laser safety as it pertains to ocular injury in humans. By combining knowledge of human and marine mammal eye anatomies, an extension of known human eye safety standards can be applied to marine mammals (Zorn et al. 2000).

The main areas of visible laser light absorption are in the retina and choroid of the eye. Research points to the mechanism of radiation damage in the human and marine mammal eye from laser exposure as being from thermal absorption by pigment granules in the retinal pigment epithelium. Marine mammals have fewer pigment granules in the retinal pigment epithelium than humans, likely reducing the risk of damage relative to the human eye (Zorn et al. 2000). Marine mammals also have tapetum lucidum which is a reflective tissue within the eye that can reduce risk of ocular damage by reflecting a portion of the light back toward the retina.

Maximum permissible exposure (MPE) estimates for human eye safety (ANSI Z136.1–2014 [LIA 2014]) along with specific parameters of the laser being operated provide a nominal ocular hazard distance (NOHD) which is the range at which laser beam becomes safe under an MPE value. Operating a laser in seawater adds a significant attenuation effect (i.e., 0.4 m-1–0.7 m-1 for green [532 nm] light) on propagation which will decrease the NOHD when compared to propagation in air. Combining attenuation in sea water and decreased ocular sensitivity of light compared to humans (Zorn et al. 2000) will further decrease the NOHD. In other words, when used at the same distance, lasers are less likely to be hazardous in seawater than in air.

Although marine mammal visual acuity is greater than humans (Levenson and Schusterman 1999), their ocular sensitivity to injury is less than humans and therefore a laser that is rated eye-safe for humans, like the red one presented in Table 12 above, will automatically be eye-safe to marine mammals (Zorn et al. 2000). Sensitivity ratios of humans and marine mammals show that marine mammals have decreased risk compared to humans. Zorn et al. (2000) estimated sensitivity ratios for various marine mammals by determining the irradiance values (energy per unit area) on the retinas of animals and humans using the values for focal length, pupil diameter, and retinal resolution. The irradiance value for an animal was divided by the irradiance value for a human to determine the sensitivity ratios. All calculated ratios were less than 0.2. Estimates of marine mammal exposure limits were computed by dividing the human limit by the sensitivity ratio. In all cases the marine mammal exposure limits were higher than humans (Zorn et al. 2000).

Table 36 provides the calculated NOHD distances for the green laser described in Table 12 for the least and most sensitive species (gray whale and fur seal respectively) discussed in Zorn et al. (2000); species likely to occur near the project sites have values between these upper and lower bounds. Table 36 shows the human exposure limits for both a 0.25 s (the amount of time it takes a human to blink) and 10 s (worst case scenario) exposures (LIA 2014). The corresponding marine mammal exposure limits are obtained by dividing the human exposure limit by the species sensitivity ratio. The attenuation coefficient was also incorporated into this based on an assumed value spectrum (0.4 m-1–0.7 m-1) (van Norden and Litts 1979; Jerlov 1976) for coastal marine waters around Washington.

Table 36. Marine mammal MPE and NOHD for 0.25-s and 10-s Exposures to the 532 nm Green Laser described in Table 12. Taken from the PNNL BA.

		0.25 s exposure			10 s exposure		
Species	Sensitivity Ratio[a]	Human MPE W/cm^2	Marine Mammal MPE W/cm^2	NOHD (m) for attenuation 0.4–0.7 m^{-1}	Human MPE W/ cm^2	Marine Mammal MPE W/cm^2	NOHD (m) for attenuation 0.4–0.7 m^{-1}
Gray whale	0.013	2.55E-03	1.96E-01	7.5–4.3	1.00E-03	7.69E-02	8.8–5.0
Fur seal	0.167	2.55E-03	1.53E-02	12.8–7.3	1.00E-03	5.99E-03	15.1–8.7

[a] Values from Zorn et al. 2000

The values in Table 36 are based on multiple exposures due to the pulse frequency (200 kHz was used for a conservative exposure estimate) and exposure time (ANSI standards of 0.25 s and 10 s). However, under actual operating conditions, as a LiDAR laser pulses it is also scanning (moving) horizontally and then vertically, which lessens the amount of potential exposure.

A likely scenario is a single exposure pulse, which would decrease the NOHD values. Depending on the attenuation coefficient of the water during operations, the NOHD values would be between 2.5 m–3.5 m; beyond this range marine mammals would be safe from laser radiation eye injury. Marine mammals with less sensitive eyes, such as Harbor seals and sea lions, would be safe at even shorter NOHD ranges.

Because of the relatively high attenuation coefficient in marine waters typical of Sequim Bay and the Strait of Juan De Fuca (0.4 to 0.7 m-1 for green light) even relatively strong laser sources are not visible to marine animals within relatively short distances. In general, light is scattered such that after about 11 attenuation lengths (inverse of attenuation coefficient) the light will appear diffuse rather than as a focused point, as described in terms of depolarization ratio at a relevant albedo of 0.95 by Cochenour et al (2010). This corresponds to distances of between about 16 to 28 m, at which point the irradiance would be about 10-8 W/cm2. Wartzok and Ketten (1999) suggest that pinniped sensitivity limits may be around 10-9 W/m2, which suggests a detection range of about 18 to 30 m. Cetaceans are thought to have similar visual abilities (Perrin et al. 2009).

Use of LiDAR devices carried by aircraft or UAS and pointed at the water for bathymetry or other purposes could also affect marine mammals that are on the surface when the device is overhead. Because attenuation in air is much less than in water, the NOHD can be hundreds of meters.

Effects of laser light sources on marine mammals would be partially mitigated using trained PSOs during non-eye-safe laser / LiDAR operations. All non-eye-safe laser / LiDAR operations would be halted if any marine mammals are observed within 50 m of an in-water project site or observed within an area prior to or during aerially scanning (Appendix B). Additionally, engineering controls will be used when possible. For instance, the UMSLI system described above has an automatic shut-off control, so if an animal is detected within 10 m of the light source, the green laser is shut off, assuring that ocular injury would not occur; this system is sensitive enough to detect an adult steelhead.

Artificial light sources (specifically those not known to be potentially harmful to organisms' eyes) may attract forage fish. Artificial light sources, such as the green laser, are known to be harmful to some organisms' eyes (e.g., pinnipeds) and may be harmful to others (e.g., birds [Harris 2021]). In above- and in water activities where lights may be used it is noted that some underwater devices employing green lasers (e.g., UMSLI) have automated shutdown capability upon detection of objects of a minimum size of 62 cm by 20 cm or greater within 10 m. In addition, devices with automated shutdown capability would also have that capability enabled during deployment. PNNL will implement the above practice to any configuration of one or more green laser light emitting instruments, including any associated with marine renewable energy (MRE) research deployments (e.g., tidal turbines).

Sound

The NMFS has provided guidance for assessing the effects of sound on marine mammals (NOAA 2018a). This guidance defines three groups of cetaceans based on hearing range and sensitivity and two groups of pinnipeds. Harassment from increased sound can be either Level A or Level B. Level A harassment threshold levels are based on a time-weighted cumulative exposure; thus, the animal is assumed to be exposed to the threshold level for the entire time period. For instance, if an echosounder is operated for six continuous hours, the animal would need to be within the calculated isopleth distance for the entire 6 hours to sustain the permanent injury. In most cases the animal would be free to leave the area and would not be exposed long enough to sustain the permanent injury. Level B harassment is measured as the root mean square (RMS) of the sound level and does include a time component. Behavioral effects are thought to be greater when the sound is continuous (i.e., vibratory piledriving) compared to intermittent (sonar, communications, soundings), and the Level B threshold level is lower for continuous sounds.

The responses of cetaceans to sound sources are often dependent on the perceived motion of the sound source as well as the nature of the sound itself. For a given source level, fin and right whales are more likely to tolerate a stationary source than they are one that is approaching them (Watkins, 1986). Humpback whales are more likely to respond at lower received levels to a stimulus with a sudden onset than to one that is continuously present (Malme et al., 1985). These startle responses are one reason many seismic surveys are required to "ramp up" the signal so fewer animals will experience the startle reaction and so that animals can vacate the area of loudest signals. There is no evidence, however, that this action reduces the disturbance associated with these activities.

The ramp-up of a playback signal or a seismic air-gun array takes place over a short timescale (a few tens of minutes maximum) compared to the changing received levels an animal experiences as it swims toward a stationary signal source. Bowheads react to playback levels of drill ship noise at levels they apparently tolerate quite well when they swim close to operating drill ships. Richardson et al. (1995) provide two explanations for these behavioral differences. First is the speed of ramp-up, and second, the whales seen near an operating drill ship may be the ones that are more tolerant of noise. The sensitive whales seen responding to the playback levels may have already avoided the actual drill ship at ranges that were undetected by observers near the ship.

Responses of animals also vary depending on where the animals are when they encounter a novel sound source. Pinnipeds generally show reduced reaction distances to ships when the animals are in the water compared to when they are hauled out. Swimming walrus move away from an approaching ship at ranges of tens of meters, whereas walrus hauled out leave the ice at ranges of hundreds of meters (Fay et al., 1988). Similar differences in avoidance ranges have been seen in California sea lions and harbor seals. Sight and smell might also be important cues for hauled-out animals (National Research Council 2003b).

Bowhead whales in shallow water are more responsive to the overflights of aircraft than are bowheads in deeper water (Richardson and Malme, 1993). Beluga whales are more sensitive to ship noise when they are confined to open-water leads in the ice in the spring (Burns and Seaman, 1985). Migrating gray whales diverted around a stationary sound source projecting playbacks of LFA sonar when the source was located in the migratory path but seemed to ignore the sound source when it was located seaward of the migratory path. When the source was in the path, received levels of 140 dB re 1 µPa were sufficient to cause some path deflection. However, when the source was located seaward of the migratory path, the whales ignored source levels of 200 dB re 1 µPa at 1 m and received levels greater than 140 dB re 1 µPa (Tyack and Clark, 1998).

The effects of in-water sound matter to fish, and increased in-water sound can have adverse consequences for individual fish. If the effect on individuals is sufficiently adverse, these effects can matter to the populations to which those individuals belong. Although sonar, piling and explosions typically attract most attention, it is reasonable to argue that the greater impact on fish will be from less intense sounds that are of longer duration and that can potentially affect whole ecosystems.

We expect studies in the aquatic environment are likely to be an order of magnitude harder than for similar studies in air, for example due to human observers having difficulty in seeing aquatic animals over large areas and localizing sounds underwater.

ElectroMagnetic Fields

Research has shown that cable and EMF devices that emit EMFs do not significantly impact green sturgeon migration. However, prior studies on other EMF-sensitive species indicate more nuanced interactions can occur near subsea power cables. Slow swim speeds are linked with exploratory behavior, disrupting the journey to their final destination (Wyman et al 2023). EMF will be discussed further in the *Benthic Impacts* effects pathway section.

Response to migration disruption conclusion

Overwater structures can obstruct the migration of juvenile Chinook and chum salmon, causing them to swim around the structures, increasing migration distance and exposure to predation. Artificial lights during nighttime may attract or repel some aquatic species, but the effects are generally not considered biologically significant. Lasers, such as those used in LiDAR, can potentially cause ocular injury to marine mammals, but the risk is reduced in water due to attenuation. Automated shutdown capabilities and trained observers help mitigate this risk. Underwater sound can elicit various behavioral responses in marine mammals and fish, depending on the source, duration, and context. Continuous sounds and sudden onsets tend to be more disruptive. EMFs from cables and devices have been shown to disrupt the migration of some EMF-sensitive species, causing exploratory behavior and slowing their journey.

Most over and in water projects in PNNL RAP will have size limits and will be in the water less than 2 years. The two factors alone lean towards less impact to species, but coupled with continuous cycling of projects (old project out, new one in) the impacts are significant. However, conservation offsets are required (for some projects) to compensate for impacts to migration, so that the number of individuals affected by the program is kept low over time, and will not rise to a level that impairs other population parameters

c. Species Response to Diminished Water Quality

Sampling surveys and in-water work will cause a temporary increase in the turbidity/suspended sediment levels, and potential declines in DO. Elevated turbidity and TSS levels during construction could extend up to 200 feet radially from project location during construction, and would return to background levels shortly after the end of the work (hours to days). In most cases, the increase is expected to last for a few days to a few months. In some cases, and the increase could last for months or longer. As explained earlier, project locations are likely to be distributed across the action area and the likelihood that the area impacted by any project's temporary work area effects will overlap is very low.

Up to 30 sediment sampling projects annually and installation of equipment or structures (see shade causing structures) can occur at any time, causing and increases in turbidity and suspended sediment levels. For this reason, individual salmonids, rockfish, green sturgeon, eulachon, PS/GB rockfish, and sun flower sea stars are all likely to be exposed at any time, and multiple exposures at individual and population scales are reasonably expected.

c.1 – Response to turbidity

The effects of suspended sediment on fish increase in severity with sediment concentration and exposure time and can progressively include behavioral avoidance and/or disorientation, physiological stress (e.g., coughing), gill abrasion, and death—at extremely high concentrations. Newcombe and Jensen (1996) analyzed numerous reports on documented fish responses to suspended sediment in streams and estuaries, and identified a scale of ill effects based on sediment concentration and duration of exposure, or dose. Exposure to concentrations of suspended sediments expected during the proposed in-water construction activities could elicit sublethal effects such as a short-term reduction in feeding rate or success, or minor physiological stress such as coughing or increased respiration.

Salmonids - Studies show that salmonids have an ability to detect and distinguish turbidity and other water quality gradients (Quinn 2005; Simenstad 1988), and that larger juvenile salmonids are more tolerant to suspended sediment than smaller juveniles (Servizi and Martens 1991; Newcombe and Jensen 1996). The effects of suspended sediment on fish increase in severity with sediment concentration and exposure time and can progressively include behavioral avoidance and/or disorientation, physiological stress (e.g., coughing), gill abrasion, and death (at extremely high concentrations). Newcombe and Jensen (1996) analyzed numerous reports on documented fish responses to suspended sediment in streams and estuaries, and identified a scale of ill effects based on sediment concentration and duration of exposure, or dose. Exposure to concentrations of suspended sediments could elicit sublethal effects such as a short-term reduction in feeding rate or success, or minor physiological stress such as coughing or increased respiration. Studies show that salmonids have an ability to detect and distinguish turbidity and other water quality gradients (Quinn 2005; Simenstad 1988), and that larger juvenile salmonids are more tolerant to suspended sediment than smaller juveniles (Servizi and Martens 1991; Newcombe and Jensen 1996).

Puget Sound Chinook salmon, and HCSR chum salmon are likely to be present during in-water activities and likely to be exposed to the temporary turbidity effects, most notably elevated levels of suspended sediment. We anticipate that PS Chinook affected will predominantly be from Elwha River and Dungeness River, and the HCSR chum will be from Jimmycomelately Creek, Salmon Creek, Snow Creek, Chimacum Creek based on proximity of natal streams.

Turbidity and TSS levels would return to background levels quickly and be localized to the in-water project areas (200-foot radius turbidity mixing zone). Decreased DO is expected to be contemporaneous with and in the same footprint of the suspended sediment. While salmon are likely to encounter these areas, they can detect and avoid areas of high turbidity, and exposure is expected to be brief. Thus, duration and intensity of exposure of salmon is also unlikely to cause injury or a harmful response.

The majority of the work that involves manipulation of sediment will be in the nearshore portions of the action area. Despite being present during the work, PS steelhead are not nearshore dependent and so are not expected to be in the shallow water in large numbers. Those present are expected to be only briefly in the area where elevated suspended sediment would occur (within a 300-foot radius to account for the point of compliance for aquatic life turbidity criteria) and to have strong capacity as larger juveniles to avoid areas of high turbidity. To the degree that there is a contemporary decrease in DO within the same footprint, because steelhead are expected to have only brief exposure to the affected area, we do not anticipate a significant response to reduced DO. We accordingly consider their exposure to the temporary effects will not be sufficient to cause any injury or harmful behavioral response to PS steelhead.

<u>Green Sturgeon</u> - Green sturgeon forage by ‘stirring’ bottom sediments and consuming exposed prey, therefore they appear well adapted to turbidity which should not produce adverse response

<u>Rockfish</u> - While there is little information regarding the habitat requirements of rockfish larvae, other marine fish larvae biologically similar to rockfish larvae are vulnerable to low dissolved oxygen levels and elevated suspended sediment levels that can alter feeding rates and cause abrasion to gills (Boehlert 1984; Boehlert and Morgan 1985; Morgan and Levings 1989). Because the work window will overlap with one peak in larval presence, which is a several month pelagic stage without significant capacity for avoidance behavior (larval rockfish can swim at a rate of roughly 2 cm per second (Kashef et al. 2014) but are likely passively

distributed with prevailing currents (Kendall and Picquelle 2003)), we can assume that project sites will have areas of high turbidity, and that larvae can be present in significant numbers (PS/GB bocaccio) that will be adversely affected.

Eulachon – This species appears to be well adapted to turbid conditions, with spawning runs often into streams with high sediment load, and eggs deposited in sediment that is passively carried downstream on currents. We do not expect turbidity to create adverse response in this species.

Whales – Turbidity will not be impactful enough to affect whales.

Sunflower Sea Stars - Increased sedimentation from coastal development, dredging, and other human activities can smother sea star habitats and clog their filtering mechanisms, making it difficult for them to feed and breathe.

c.2 – Response to reduced dissolved oxygen (DO)
Salmonids - At stated above, increases of TSS can also produce localized reductions in DO. Sub-lethal effects of DO levels below saturation can include metabolic, feeding, growth, behavioral, and productivity effects. Behavior responses can include avoidance and migration disruption (NOAA Fisheries 2005). These effects are likely to occur contemporaneously with a subset of the events described above. As such it is expected that low DO exposure will occur in multiple locations each year, and will adversely affect multiple listed fish species at multiple life stages. We anticipate that PS Chinook affected will predominantly be from Elwha River and Dungeness River, and the HCSR chum will be from Jimmycomelately Creek, Salmon Creek, Snow Creek, Chimacum Creek based on proximity of natal streams.

Green sturgeon do not appear to be easily swayed from their routine due to water quality or DO, as reviewed by Kelly et al. (2007). Green sturgeon directional movements did not appear related to temperature, salinity or dissolved oxygen gradients in the well-mixed estuary. These fish range widely across a variety of environmental conditions.

Rockfish and Eulachon - Sustained exposure to low dissolved oxygen levels can have lasting negative effects on any fish population, influencing their growth, behavior, and overall ecological health. However, DO will not affect adult PS/GB bocaccio, juvenile and adult PS/GB yelloweye rockfish, and eulachon due to their location.

Whales – Reduced DO levels will not be impactful enough to affect whales.

Sunflower Sea Stars - The Sunflower Sea Star populations have been significantly impacted by various factors, including changes in DO levels. Research indicates that there has been a long decline in their population sizes, with the decline steepening in recent years, emphasizing the importance of maintaining suitable DO levels for their survival and recovery efforts (Heady et al. 2022). Overall, maintaining optimal DO levels is crucial for the health and survival of Sunflower sea stars, as low oxygen levels can exacerbate their population decline and impact broader marine ecosystems.

c.3 – Response to dyes and particulate releases

Dye and particulate tests may not release more than 20 ppb of the subject material in any given test.

Fishes - Toxicity and ecotoxicity tests (on rats, daphniae and algae) have been performed on degradation byproducts of florescent dye tracers (Gombert et al. 2017). These tests do not show any acute toxicity but a low to moderate ecotoxicity. Most used fluorescent tracers and their artificial and natural degradation byproducts do not exhibit significant toxicity to humans and the aquatic environment, at the concentrations generally noted in this opinion. We expect only that the ESA-listed fishes may have impaired ability to detect prey and predators when the visibility in the water is obscured by dyes. The presence of the dyes or tracers in the water column would be short term, and they would be quickly diluted. Listed species could experience a temporary reduction in water visibility and thus a small disturbance to foraging habitat. This impact is expected to be minor.

Sunflower Sea Stars - Little is known about specific effects of water quality on sunflower sea stars, or how stress from exposure to water quality changes affects susceptibility to sea star wasting syndrome. Laboratory challenge tests have exposed larval stages of various marine invertebrates to hydrocarbons, heavy metals, pesticides, and other contaminants commonly found in stormwater runoff. Documented impacts range from developmental abnormalities to behavioral augmentation, and mortality is common at concentrations as low as several parts per million (e.g., Hudspith et al. 2017, de Almeida Rodrigues et. al 2022). For juvenile and adult marine invertebrates, including sea stars and other echinoderms, a variety of sublethal behavioral and physiological effects from these toxic contaminants have been documented, but mortality is also possible. Suspended sediment may also be a concern as stars that become covered by sediment may experience greater risk of wasting disease. Absent species-specific data for the sunflower sea star, ecologically and physiologically similar species can be used as proxies to state that poor water quality is likely to harm, injure, or kill sunflower sea stars, having the greatest effects during the larval life history stage.

Marine Mammals - While toxic chemical can bioaccumulate across food webs eventually ending with the megafauna (SRKWs and humpback whales) we do not expect the dyes and tracers allowed in the programmatic to have the same ill effects.

Response to water quality impacts conclusion

The main concerns with water quality on our ESA listed species is the increased turbidity and suspended sediment levels which can cause behavioral avoidance, physiological stress, gill abrasion, and potentially death in fish at extremely high concentrations. Salmonids, rockfish larvae, and sunflower sea stars are likely to be exposed and adversely affected. Additionally, reduced dissolved oxygen (DO) levels can lead to metabolic, feeding, growth, behavioral, and productivity effects in fish. Listed fish species at multiple life stages are expected to be adversely affected, except adult PS/GB bocaccio and juvenile/adult PS/GB yelloweye rockfish. Dyes and particulate releases, and their byproducts, exhibit low to moderate ecotoxicity, but are not expected to have significant toxicity at the concentrations used. However, they can temporarily reduce water visibility and cause minor disturbances to foraging habitat for listed species.

Green sturgeon appears less affected by water quality changes, while sunflower sea stars and larval stages of marine invertebrates are more vulnerable to contaminants and poor water quality.

d. Species Response to Loss of Aquatic Habitat

In this effect pathway subsection, we will present the several ways in which aquatic habitat may be inaccessible, and present species response to these collectively.

d.1 – Response to loss to structures
As mentioned above, in the *Migration Pathway* section, when aquatic habitat is literally occupied by a structure, species are forced to go around the obstruction. The elongation of the migratory route could lead to exhaustion and a new set of predator/prey dynamics (see *Shading* section).

d.2 – Response to loss to surveys/sampling (sediment/SAV/etc.)
To minimize the loss (degradation) of aquatic habitats due to sediment sampling, it is essential to carefully plan sampling activities, implement best practices, and adopt mitigation measures. These may include avoiding sensitive habitats, using minimally invasive sampling techniques, and implementing sediment control measures.

d.3 – Response to loss to avoidance (lights/sound/EMF)
The "loss" of aquatic habitats due to avoidance behavior can have severe consequences for the survival and persistence of affected species. It is essential to identify and mitigate the factors that contribute to avoidance behavior, such as reducing sound and disturbance and preserving or restoring suitable habitat conditions, to prevent the loss of habitats and ensure the long-term viability of species populations.

Species response to loss of aquatic habitat
While the actual loss of aquatic habitat through sampling structures that displace water or cover substrate removes critical habitat from the area, the loses accounted for in the programmatic will be small - though consistent for the area and the life of the programmatic. Many of the features "lost" are presented more fully as diminished function of features, which are addressed in other sections. And some areas will be avoided by species due to visual or auditory disturbance, or possibly EMFs. To understand why the loss of habitat (through occupation or removal) is important, it is important to understand that the features of habitat are needed to support recovery of the listed species, which is why some areas are designated as critical, with particular features called out as essential.

A 2005 peer reviewed study (Taylor et al. 2005) found that plants and animals with federally protected critical habitat are more than twice as likely to be moving toward recovery than species without it. For the species considered here, only HCSR chum juveniles and PS Chinook juveniles, and juvenile bocaccio are highly dependent on the nearshore marine and estuarine locations. All other listed species considered in this consultation have broad areas of habitat available and free access to those locations. And, even though SRKW have designated critical habitat that includes shallower locations, they are not notably dependent on these areas, as their preferred prey are larger lifestages of PS chinook (and chum) salmon located in deeper areas.

For the species consulted on in the opinion, the loss of critical habitat will in small footprints, with limited duration, and fractional to the available critical habitat. We consider the response of species to this series of temporary losses of habitat will be not reduce growth, fitness or survival of listed species, particularly when offsetting measures are considered.

e. Species Response to Sound

All species will be exposed to sound caused by activities in the PNNL RAP.

e.1 – Response to sound from boats and in-water machinery

Salmonids - Use of construction vessels generates noise that can interrupt normal behavior patterns in salmon and steelhead. In particular, we expect that juvenile PS Chinook salmon and HCSR chum salmon migration and foraging would be affected by vessel noise. At most project sites, the projects would last for a few days up to a few weeks. Very few of the projects, if any, will have a vessel idling in place for hours. We expect most fish would avoid the area or enter the area and experience increases stress levels. Although very few fish are expected to die as a result of exposure to noise, a small number of fish would experience a loss of fitness as a result of this exposure. We anticipate that PS Chinook affected will predominantly be from Elwha River and Dungeness River, and the HCSR chum will be from Jimmycomelately Creek, Salmon Creek, Snow Creek, Chimacum Creek based on proximity of natal streams.

The noise related to commercial vessel traffic and recreational boating caused by the proposed action is likely to adversely affect Chinook salmon, HCSR chum, steelhead, eulachon, and rockfish. Increased background noise has been shown to increase stress in fish (Mueller 1980; Scholik and Yan 2002; Picciulin et al. 2010). Recreational boat noise diminished the ability of resident red-mouthed goby (*Gobius cruentatus*) to maintain its territory (Sebastianutto et al. 2011). Xie et al. (2008) report that adult migrating salmon avoid vessels by swimming away. Graham and Cooke (2008) studied the effects of three boat noise disturbances (canoe paddling, trolling motor, and combustion engine (9.9 horsepower) on the cardiac physiology of largemouth bass (*Micropterus salmoides*). Exposure to each of the treatments resulted in an increase in cardiac output in all fish, associated with a dramatic increase in heart rate and a slight decrease in stroke volume, with the most extreme response being to that of the combustion engine treatment (Graham and Cooke 2008). Recovery times were the least with canoe paddling (15 minutes) and the longest with the power engine (40 minutes). Graham and Cooke (2008) postulate that the fishes' reactions demonstrate that the fish experienced sublethal physiological disturbances in response to the noise propagated from recreational boating activities. There are few published studies that assess mortality from vessel traffic on fishes, but studies thus far indicate that ichthyoplankton, which could include rockfish, may be susceptible to mortality because they are unable to swim away from traffic and thus may be harmed by propellers and turbulence. One study found low overall mortality from traffic, but that larvae loss was size dependent and that smaller larvae were more susceptible to mortality (Tonnes et al. 2016).

Some fish that encounter boating noise will likely startle and briefly move away from the area. A study of motorboat noise on damselfish noted an increase in mortality by predation (Simpson et al. 2016). While some fish species have been noted to not respond to outboard engines, others respond with increased stress levels, and sufficient avoidance as to decrease density (Whitfield and Becker, 2014), while others experience reduced forage success (Voellmy et al 2014) either by reducing foraging behavior, or because of less effective foraging behavior. When fish startle and avoid preferred habitats, both the predator and prey detection may be impaired for a short period of time (minutes up to one hour) following that response.

Taken together, it can be assumed that juvenile salmonids are likely to respond to episodes of motor boat noise with a stress and startle reaction that can diminish both predator and prey detection for a short period of time with each episode. Because of the intermittent nature of the disturbance and the ability for fish to recuperate when it occurs, we do not expect this effect to be meaningful to survival in adult or juvenile fish in every location where they encounter noise from recreational boating, though growth and fitness could be slightly diminished if they encounter frequent episodes of boat noise, such as at marinas, public boat launches, or commercial piers or wharfs.

<u>Rockfish and green sturgeon</u> - Juvenile and larval PS/GB bocaccio will be exposed to vessel traffic and will experience sublethal physiological stress. Given that adult yelloweye rockfish and green sturgeon occur along the sea floor in deep water, we do not expect them to be affected by noise from boats or equipment, as noise will attenuate over distance.

<u>Eulachon</u> will be exposed to noise, and we extrapolate from other species that they may have startle response when noise starts.

<u>SRKW</u> - Smaller fishing, recreational and commercial vessels are subject to existing federal regulations prohibiting approach to SRKW closer than 200 yards or positioning in the path of the whales within 400 yards (with exemptions for vessels lawfully engaged in commercial or treaty Indian fishing that are actively setting, retrieving, or closely tending fishing gear). State regulations also mandate protections for SRKWs (see RCW 77.15.740, mandating 300- to 400-yard approach limits, 7 knots or less speed within ½ nautical mile of the whales). Despite this we expect vessel noise to be detected by SRKW.

Most in-water sound will occur at levels that would disrupt normal behaviors such as feeding and sheltering. Vessels used for a variety of purposes (commercial shipping, military, recreation, fishing, whale watching and public transportation) occur in inland waters of the SRKWs' range. Several studies in inland waters of Washington State and British Columbia have linked interactions of vessels and Northern and Southern Resident killer whales with short-term behavioral changes (see review in Ferrara et al. (2017)). These studies concluded that vessel traffic may affect foraging efficiency, communication, and/or energy expenditure through the physical presence of the vessels, underwater sound created by the vessels, or both. In this programmatic, research vessels would be used for transportation, drifting instrumentation, surveying and monitoring, as diver platforms, to tow scientific sampling or acoustic equipment (e.g., underwater video, side scan sonar, hydrophones), to deploy/retrieve moorings and associated buoys or floating platforms, to sample water and sediment, and to deploy/retrieve scientific sampling equipment (e.g., for water quality). Vessels may range in type/size from kayaks or canoes up to 50 ft or 80 ft fully equipped research ships.

Recent evidence indicates there is a higher energetic cost of surface-active behaviors and vocal effort resulting from vessel disturbance in the Salish Sea (Williams et al. 2006; Noren et al. 2012; Noren et al. 2013; Holt et al. 2015). For example, Williams et al. (2006) estimated that changes in activity budgets in Northern Resident killer whales in British Columbia's inland waters in the presence of vessels result in an approximate 3 percent increase in energy expenditure compared to when vessels are not present. Other studies measuring metabolic rates in captive dolphins have shown these rates can increase during the more energetically costly surface behaviors (Noren et al. 2012) that are observed in killer whales in the wild, as well as during vocalizations and the increased vocal effort associated with vessels and noise (Noren et al. 2013; Holt et al. 2015). These studies show an increase in energy expenditure during surface active behaviors and changes in vocal effort may negatively impact the energy budget of an individual, particularly when cumulative impacts of exposure to multiple vessels throughout the day are considered.

However, this increased energy expenditure may be less important than the reduced time spent feeding and the resulting potential reduction in prey consumption (Ferrara et al. 2017). SRKWs spent 17 to 21 percent less time foraging in inland waters in the presence of vessels for 12 hours, depending on vessel distance (see (Ferrara et al. 2017)). Although the impacts of short-term behavioral changes on population dynamics is unknown, it is likely that because SRKWs are exposed to vessels the majority of daylight hours they are in inland waters, and that the whales in general spend less time foraging in the presence of vessels, there may be biologically relevant effects at the individual or population-level (Ferrara et al. 2017).

Vessel-related noise has the potential to result in behavioral disturbance or harassment of SRKWs, including displacement, site abandonment (Gard 1974, Reeves 1977, Bryant et al.1984), masking (Richardson et al. 1995), alteration of diving or breathing patterns, and less responsiveness when feeding. Given the projected level of activity expected under PNL RAP, the amount of any vessel traffic caused by the proposed action is expected to be a small fraction of the vessel traffic in the Salish Sea. In addition, as noted in the beginning of this description of the SRKW response, numerous factors will work to reduce the potential for SRKWs to be exposed to vessel traffic caused by this proposed action. Although vessel and acoustic disturbances by these kinds of vessels has the potential to cause short-term behavioral changes, avoidance, or a decrease in foraging, because of the nature and location of these vessels operations, and the fact that they are not targeting or approaching whales, we expect that any interactions, if they occur, will be transitory in nature and only cause a small amount of disturbance that is not likely to disrupt normal behavioral patterns or distribution, or cause harm to the whales. For other types of vessels, people, powered kayaks and canoes, we expect no impacts. Thus, taking the most conservative approach, although this level of vessel traffic has the potential to disrupt some SRKWs, we expect the exposure and response to be short term and minimal and to not disturb any essential behaviors patterns.

<u>Sunflower sea stars</u> do not have ears or the ability to hear, they are guided by olfaction, so they are not expected to respond when exposed to sound (Garm 2017).

e.2 – Response to sound from acoustic studies

Most projects authorized under PNNL RAP will not include impulsive sound (the bang), but rather non-impulsive sound (the hum). Impulsive sound could occur, but it will in the minority of projects. The program allows only one acoustic operation within a given hearing range of fish or whales to operate at a time.

<u>Fishes</u> -

Most of the sound sources are outside of the hearing range for fish. Sound can still have effects even if it is outside the hearing range. Most of the sound sources for this program have fairly small injury isopleths for fish, and are all are less than 24 m.

Impulsive sound can injure or kill fish (particularly those with a swim bladder, and fish of small size) and alter behavior (Turnpenny et al. 1994; Turnpenny and Nedwell 1994; Popper 2003; Hastings and Popper 2005). The injury effect threshold for fish less than 2 grams is 183 dB SEL and for fish greater than 2 grams is 187 dB_{SEL}. Death from barotrauma can be instantaneous or delayed up to several days after exposure. Even when not enough to kill fish, high sound levels can cause sublethal injuries. Fish suffering damage to hearing organs may suffer equilibrium problems, and may have a reduced ability to detect predators and prey (Turnpenny et al. 1994; Hastings et al. 1996).

Adverse effects on survival and fitness can occur even in the absence of overt injury. Exposure to elevated noise levels can cause a temporary shift in hearing sensitivity (referred to as a temporary threshold shift), decreasing sensory capability for periods lasting from hours to days (Turnpenny et al. 1994; Hastings et al. 1996). Temporary threshold shifts reduce the survival, growth, and reproduction of the affected fish by increasing the risk of predation and reducing foraging or spawning success. This type of impulse sound exposure is expected to be rare during the program, limiting the number of individual fish from any of the ESA-listed species from harmful, injurious, or lethal response.

With regard to non-impulsive sound, the behavioral effects from anthropogenic sound exposure remains poorly understood for fishes, especially in the wild. NMFS applies a conservative threshold of 150 dB rms (re 1 μPa) to assess potential behavioral responses of fishes from acoustic stimuli. Non-impulsive sound can generate sound levels that fish detect and respond to, including above the 150 Db behavioral threshold but well below the thresholds for physical injury (Erbe and McPherson 2017). When non-impulse sound persists for long periods, it can mask sounds relied on by fish to detect prey (increasing the risk of poor growth), and predators (risk of injury or death).

Stadler and Woodbury (2009) make it clear that the thresholds likely overestimate the potential for impacts on fish from non-impulsive sounds (e.g., vibratory pile driving). Non-impulsive sounds have less potential to cause adverse effects in fish than impulsive sounds. Impulsive sources cause short bursts of sound with very fast rise times and the majority of the energy in the first fractions of a second. Whereas, non-impulsive sources cause sound with slower rise times and sound energy that is spread across an extended period of time; ranging from several seconds to many minutes in duration.

Juvenile Chinook will have the most exposure due to their extensive use of nearshore habitats. Juvenile HCSR chum salmon also depend on estuarine and nearshore habitats, but they migrate more rapidly out of Puget Sound. We anticipate that PS Chinook affected will predominantly be from Elwha River and Dungeness River, and the HCSR chum will be from Jimmycomelately Creek, Salmon Creek, Snow Creek, Chimacum Creek based on proximity of natal streams. Adult Chinook, adult and juvenile steelhead, and adult chum salmon make little use of nearshore habitats, and will be exposed to injurious levels of underwater sound in very small numbers. Larval yelloweye rockfish and larval and juvenile PS/GB bocaccio will also be exposed in uncertain numbers. If work occurs during the WDFW in-water work window, all exposed PS Chinook salmon, PS steelhead, and adult HCSR chum individuals will be at least two grams, which reduces the likelihood of lethal response. Larval rockfish, younger juvenile PS/GB bocaccio, and younger chum salmon will be less than two grams, making them more vulnerable to lethal response.

We cannot estimate the number of individuals from any species that will experience adverse effects from underwater sound, nor predict the specific responses among the fish exposed. Not all exposed individuals will experience adverse effects, some will experience sublethal effects, such as temporary threshold shifts, some merely behavior responses such as startle. Physical injury from barotrauma, and death are also possible. However, because the projects will occur across a variety of locations in Puget Sound, we anticipate that multiple individual fish from multiple populations of the various species will be adversely affected, up to and including death of some individuals.

<u>Whales</u> - According to the examples of potential sound emitting devices, by far the largest marine mammal isopleths are associated with the 38 kHz echosounder that operates at a sound pressure level of 215 dB re 1 µPa at 1 m, with isopleths of over 4.5 km for both injury and behavior (Table 37). However, this device produces sound in a narrow arc of between 7 and 18 degrees and can thus be aimed (for instance at Travis Spit) so the actual ensonified area would be much smaller than from an omnidirectional source. Sources such as the 38 kHz echosounder would only be operated when it could be aimed toward a nearby land mass and the ensonified area could be easily monitored by a trained PNNL Protected Species Observer (PSO). Similarly, the eBoss sub-bottom profiler could have marine mammal injury effects out to approximately 76 m and marine mammal behavioral effects out to approximately 215 m. However, this device produces an approximate 180-degree arc of sound, but it is floated approximately 5 m off the substrate and is pointed down, thereby greatly limiting the area ensonified above threshold levels. Most of the remaining sound sources have fairly small isopleths for fish and marine mammals, although because it is a continuous sound source the J-11 sound projector has a relatively large behavioral isopleth.

But for the performance criteria and overarching criteria of this program, SRKWs could be injured or disturbed by sound pressure. NMFS uses conservative thresholds of sound pressure levels from broad band sounds that cause behavioral disturbance (160dBrms re: 1µPa for impulse sound and 120 dBrms re: 1µPa for continuous sound) and injury (for impulsive: peak SPL flat weighted 230 dB, weighted cumulative SEL 185 dB; for non-impulsive: weighted cumulative SEL 198 dB) (NMFS 2018). Hearing for low-frequency cetaceans (humpback whales) is more similar to human hearing than mid-frequency cetaceans (SRKW) and is specialize in hearing low-frequency sounds for long-distance communication. This range makes the humpback particularly susceptible to noise.

However, criteria for marine mammal monitoring and stop-work on sighting of SRKW or humpback whale is intended to ensure that they will not experience duration or intensity of the acoustic study sounds that would result in disturbance or harm to any individual of this species. Operation of sound emitting devices will be discontinued when marine mammals are observed in the surveyed area. Operation may recommence after marine mammals have left the surveyed area. Fish are not subject to observation by PSOs. Thus, tidal work windows will be followed to the maximum extent possible for devices operating at frequencies within the hearing range of fish and at sound pressure levels that exceed fish injury thresholds. Activities only occur during daylight with minimum visibility 1.5 times the range of the largest effect isopleth (of all protected species potentially affected) for the proposed activity.

Sunflower Sea Stars do not have swim bladders that make them susceptible to barotrauma in the same manner as fish. As stated in the section above, this species does not have an auditory system, and we expect exposure to sound will not produce any meaningful response.

Table 37. Examples of Sound Emitting Devices, Operation Frequencies, Source Levels, and Duty Cycles of Acoustic Devices used in PNNL Research (all are considered non-impulsive sources)

Device	**Operating Frequency**	**Max Source Level (dB re 1 µPa at 1 m)**	**Duty Cycle**
Vemco V13 fish tag	69, 180, 307 kHz	150	1 coded pulse (<< 1 s)
DiveNET Autonomous Smart Buoys (ASB)	10–30 kHz	170	5% (203 ms signal every 4 s)
OceanSonics icTalk LF	200 Hz –2.2 kHz	130	user-configurable
OceanSonics icTalk HF	10–200 kHz	140	user-configurable
Surface Acoustic Pingers (SAP)	8–15 kHz	190	1 pulse (<<1 s) every 2 s
EdgeTech eBOSS subbottom profiler2,3	3–30 kHz	195	32%
APL Custom Transmitter3	3–30 kHz	180	32%
Benthos ATM 900 underwater modem2	22–27 kHz	178	0.001s ping at 100Hz (10%)
Kongsberg Underwater Positioning System2	22-30 kHz	189	0.031 s ping at 2 Hz (6%)
Stationary 38 kHz echosounder2, 4	38 kHz	215	~ 0.1%
Navy J11 projector2	30 Hz –10 kHz	158	continuous sound
Bluefin-21 SAS Sonar5 4	4–24 kHz	200	50%
Benthowave spherical transducer6	20–200 kHz	180-200	Up to 50%
Benthowave piston transducer7	3.5–100 kHz	180-200	Up to 50%

The range of sound sources evaluated in Table 37 is representative, but not inclusive, of all sound sources that may be used for PNNL research activities. Instead of attempting to evaluate every possible sound source, the DOE Pacific Northwest Site Office (PNSO) proposes to limit the overall potential effects by: 1) limiting the amount of time that sound sources having potential adverse impacts would be used, and 2) using trained PSOs (see Section 1.3.1, PDC 10, for time limits). The number of trained observers present would depend on the estimated size of the effect isopleths, with more observers required for larger potentially affected areas. It is expected that with these mitigations in place the impacts would be minor to moderate, depending on the size of the resulting isopleths, as described above.

Operation of sound emitting devices will be discontinued when marine mammals are observed in the surveyed area. Operation may recommence after marine mammals have left the surveyed area. Fish are not subject to observation by PSOs. Thus, tidal work windows will be followed to the maximum extent possible for devices operating at frequencies within the hearing range of fish and at sound pressure levels that exceed fish injury thresholds. Activities only occur during daylight with minimum visibility 1.5 times the range of the largest effect isopleth (of all protected species potentially affected) for the proposed activity.

Conclusion on Fish Response to Sound
Vessel noise can disrupt normal behaviors like feeding and sheltering in SRKWs, leading to increased energy expenditure and reduced foraging time. However, the proposed action is expected to contribute a small fraction of the overall vessel traffic. Acoustic studies using devices like echosounders, sub-bottom profilers, and sound projectors can potentially cause injury or behavioral disturbance to marine mammals and fish, depending on the sound levels and frequencies used. Mitigation measures, such as using Protected Species Observers (PSOs), limiting the duration of sound source use, and following tidal work windows, are proposed to minimize impacts on marine species. Additionally, acoustic studies will be performed in a way that minimizes its effects on listed species in the best way possible. This includes, narrowing the arc of sound as much as possible, aiming the sound towards land and away from the greater Strait of Juan de Fuca (to shorten the impacted area). These measures along with PSO, time limits and a MMMP lower the effects to marine mammals. Juvenile salmonids, juvenile bocaccio, and eulachon may be injured or killed by impulse sounds, and could be harmed by non-impulse sounds though the number of fish so affected is not expected in any given year to be high enough to alter population characteristics. Green sturgeon are not expected to be injured due to their large size.

f. Species Response to Benthic Impacts

Shade causing installations and benthic sampling activities each cause effects to benthic communities and the numbers of these projects allowed per year are identified in previous sections.

f.1 – Response to benthic impacts from shading and structures
Shading can significantly impact benthic communities. See the sections on shade, and on predator prey interactions above for more details on the relationship of shade and structures on benthic conditions.

Salmonids - The amount of benthic forage base temporarily diminished by disturbed substrate in any given year under the PNNL Rap would be small compared to the amount of available habitat in any given project area and within the action area. The reduction in benthic prey communities is also brief, because recruits from adjacent areas move via tides and currents, and thus the prey base can re-establish in disturbed areas a matter of weeks. We expect only the cohorts of juvenile PS Chinook salmon, HCSR chum salmon, PS steelhead that are present in the action area to be exposed to this temporary reduction of prey, and we expect that because prey is abundant in close proximity, feeding, growth, development and fitness of the individuals that are present during this brief habitat disruption from construction would not be affected. Therefore, we consider the temporary effects on any fish in the action area to be unlikely to cause injury at the individual scale.

Rockfish - On the other hand, juvenile PS/GB bocaccio feed on the young of other rockfish, surfperch, and jack mackerel in nearshore areas (Love et al. 1991; Leet et al. 1992). Juveniles also eat all life stages of copepods and euphausiids (MacCall et al. 1999). Because juvenile rockfish are less able to access adjacent areas compared with salmon species, reductions in benthic prey communities, and in SAV from disturbance in work areas will reduce available forage for PS/GB bocaccio in their nearshore settlements, reducing growth and fitness of a small number of affected individuals at each location.

Green Sturgeon – Benthic disturbance will also temporarily reduce the availability of benthic prey items for green sturgeon which are bottom feeding fish. Unlike juvenile bocaccio however, this species is larger, present as subadult and adults, with unrestricted access to find adjacent areas with more abundant prey. We do not consider the prey reduction to produce any reduction in growth, health, or fitness to individuals of this species.

Eulachon - feed mainly on euphausiids, a small shrimp-like crustacean commonly referred to as krill. This prey base is not benthic sourced. This species is not likely to respond to benthic disruptions.

SRKW - For SRKWs, the reduction in benthic conditions does not directly affect them. However, a reduction in prey (PS Chinook salmon) from the temporary effects of the proposed action is extremely small even when considered across the action area. As mentioned above, diet data suggest that SRKWs are consuming mostly larger (i.e., generally age 3 and up) Chinook salmon (Ford and Ellis 2006). Given the total quantity of prey available to SRKWs throughout their range, this short-term reduction in prey that results from the temporary project effects is extremely small. It is also likely that only a small percent of impacted juvenile salmon would survive to the age that they would be prey for SRKW. Because the annual reduction would be small, there is also a low probability that any of the Chinook salmon killed from the short-term impacts caused by implementation of the proposed action would be intercepted by the killer whales across their vast range in the absence of the proposed action. Therefore, NMFS anticipates that the short-term reduction of Chinook salmon during work would have little effect on SRKWs.

Humpback Whales are not directly affected by reduction in benthic conditions. Like SRKW, if prey species (e.g. forage fish) were reduced because of benthic impacts, then a small reduction in their prey could result as an indirect effect. Here any such reduction would be so small that we cannot reasonably conclude that individual humpback whales would be appreciably affected.

Sunflower sea stars are primarily carnivorous, feeding on mussels, sea urchins, fish, crustaceans (crabs and barnacles), sea cucumbers, clams, gastropods, sand dollars, and occasionally algae and sponges. For most sunflower stars, sea urchins make up 21-98 percent of their diet. Benthic impacts will affect this species also.

In-water work will temporarily reduce the availability of benthic prey items for salmon, steelhead, green sturgeon, rockfish, and sunflower sea stars. Disturbed areas will be recolonized and the loss of forage is a temporary impact. The annual amount of area with reduced benthic forage due to in water work is very small when compared to the available habitat in project areas (see, for instance, image 9, indicating area of in/and overwater shade-causing structure, relative to Sequim Bay).

f.2 – Response to EMF

Research on EMF impacts is limited, but EMF fields can be detected and responded to by some organisms. Organisms associated with the benthos or with low mobility may be more likely to experience temporary effects from EMF fields.

As reviewed in Gill and Desender (2020), research to date has largely been limited to controlled laboratory simulations of EMF B- or E-fields or surveys of subsea cables using field measurements to study magnetoreception and electroreception in fish, response of marine animals to electric and magnetic emissions, and the potential for environmental impacts from subsea cables. The recent review by Gill and Desender (2020) suggests that there are two different considerations when evaluating impacts: detection and response to B-fields, and detection and response to E fields.

For organisms that detect and respond to E-fields, direct E-fields will only occur in the environment if a cable (AC or DC) is not properly grounded or if the design of the electrical system leads to electrical leaks. Cable runs, whether single phase or multiple phase, virtually always have the return path for current in separate conductors, resulting in a net cancellation of magnetic fields unless detected at extremely close range. Operation of EMF fields may occur intermittently, or for a defined time period.

Organisms that detect and respond to B-fields for EMFs emitted by cables should be considered in relation to the ambient geomagnetic field EMF, the subsequent secondary induced E-fields that occur when an organism passes through a B-field, and what is commonly used in commercial applications. Species that associate with the benthos as primary habitat or foraging habitat in Sequim Bay that are near a benthic EMF field may be temporarily affected, with those of a slow rate of mobility (e.g., sunflower sea star) being somewhat more likely to incur effects. Those with a higher rate of mobility (e.g., green sturgeon) would be somewhat less likely to incur effects. However, adverse effects even to the sea star would be unlikely as the species could move relatively quickly [160 cm per minute [Heady et al. 2022]) beyond the immediate area of attenuation of a magnetic source as noted above. It is also unlikely that the rockfish species would occur near the PNNL-Sequim dock due to lack of preferred habitat and appropriate depth. If the EMF field is generated by a suspended device, pelagic species may be affected by the EMF field temporarily and avoid the EMF field area. The temporary operation of EMF devices (point source) with EMF fields of 1.25T or less in a single, discrete location are not expected to have more than minor adverse impacts, if any. These species could move to nearby unaffected habitat. EMF generated by cable conveyance would also be at levels not likely to cause adverse impacts.

There remains a lack of specific information regarding impact of EMFs associated with subsea cables and the overall risk of EMFs to biota. Klimley et al. 2017 found no impact to the movement of salmonid smolts and green sturgeon around a high voltage DC cable deployed in California. There are reports of sensitivity for some species, but at levels of EMF intensities above marine renewal energy devices (reviewed in Gill and Desender 2020). As described for critical habitats, operation of EMF fields as described is not expected to affect large portions of EFH. The size of the EMF fields is expected to be relatively small due to the upper operating limit of 1.25 T, which results in nearly undetectable levels at 1 m distance from any given device or structure. Longer duration deployments of EMF-producing devices (e.g., cables) would similarly affect a relatively small area, but over a longer period of time.

EMF fields with intensities below 1.25T and small spatial scales are not expected to have significant adverse impacts, as organisms that can detect EMFs (e.g. salmon, green sturgeon) have displayed only temporary behavioral changes when they detect EMFs. EMFs are not expected to significantly alter migratory behavior of these “EMF-sensitive” species (BOEM 2019).

Response to benthic impacts conclusion
Shading from structures can lead to lower benthic invertebrate densities and diversity, impacting food resources and refuges for other organisms. Shading also affects the biomass and cover of macroalgae and the size of sedentary organisms on rocky shores. In-water work temporarily reduces the availability of benthic prey for salmon, steelhead, green sturgeon, rockfish, and sunflower sea stars.

g. Species Response to Entrainment

Entrainment potential exists with autonomous vehicle surveys (up to 30 per year but no more than 10 at one time), benthic surveys (up to 30 per year), water column sampling (up to 30 per year), marine energy devices (up to 150 per year) and turbines (only 1 per year).

g.1 – Response to intakes
<u>Fishes</u> -When a fish gets sucked into a water intake (entrainment) because it is unscreened, or because the lifestage is too small to be excluded by the screen, the consequences can be severe and often fatal. As the fish enters the intake pipe or system, it can experience physical trauma from the high-velocity water flows, turbulence, and potential impacts against hard surfaces like screens or grates. This can result in injuries like abrasions, scale loss, and internal bleeding.

As fish pass through the intake pipes or tunnels, they may experience rapid and extreme changes in pressure and temperature, which can cause barotrauma (injuries from pressure changes), thermal shock, or other physiological stress. If the intake system is not continuously submerged, entrained fish may be exposed to air, leading to desiccation (drying out) and asphyxiation (suffocation) as they are unable to breathe. Additionally, the turbulent and unnatural environment within intake systems can disorient fish, causing them to waste energy swimming against currents or colliding with structures, leading to exhaustion and potentially increasing their vulnerability to predators or other hazards downstream. In most cases, fish that become entrained or impinged at water intakes suffer significant injuries or mortality, either immediately or due to the compounding effects of the stresses they experience. Proper screening, flow management, and fish protection measures are crucial to minimize the impacts of water intakes on fish populations and aquatic ecosystems and is a design criteria of this program. *Larval rockfish are the most at risk of entrainment based on their size.* Juvenile HCSR chum from Jimmycomelately Creek, Salmon Creek, Snow Creek, Chimacum Creek, and eulachon are also small when present in the action area, but considerably larger than larval rockfish, and they have some risk of entrainment.

Larger fish may become impinged or trapped against intake screens or grates by the powerful suction force. This can lead to suffocation, crushing injuries, or exhaustion as the fish struggles to escape. Smaller fish, eggs, larvae, and other aquatic organisms can become entrained, meaning they are pulled through the intake system along with the water flow. This often results in death, as they may be subjected to extreme pressure changes, shearing forces, and potential exposure to biocides or other chemicals used in the intake system. Juvenile salmonids, juvenile rockfish, and eulachon are at risk of impingement; however, the design criteria of this program requires, generators/turbines and/or exposed rotating parts to be housed in a manner to prevent impingement or areas of entrapment, thus lowering the actions impacts, keeping the numbers of fish likely to be impinged low. Green sturgeon are at a size and swim strength making them unlikely to be impinged.

<u>Whales</u> – Neither humpbacks nor SRKW are at risk of entrainment.

<u>Sunflower Sea Stars</u> - Because the water intake is located in the marine environment where sunflower sea star larvae are likely to occur, we expect some larvae will be entrained. While sea star adults and juveniles are uncommon at this time, one adult can produce millions of larvae, thus larvae in the water column are likely to be more plentiful than benthic adults and juveniles.

g.2 – response to sampling/surveys

<u>Fishes</u> - Sediment sampling can entrain slow-moving and sessile benthic epifauna along with burrowing infauna that are removed with the sediments. They also entrain algae and aquatic vegetation. There is little evidence of entrainment of mobile organisms such as fish. In comparison, in the Southeast Region of the US, where heavy dredging operations occur, only two live sturgeon (NMFS 2012) and two live sea turtles (NMFS 2011) are known to have been taken by clamshell dredging since 1990. This is likely due to a combination of factors that make exposure very rare. In order to be entrained in a clamshell bucket, an organism, such as a sturgeon or sea turtle must be directly under the bucket when it drops. The small size of the bucket, compared against the distribution of the organisms across the available habitat make this situation is very unlikely, and that likelihood would decrease after the first few bucket cycles because mobile organisms are most likely to move away from the disturbance. Most fish in the

vicinity of the project at the start of the operation would likely swim away to avoid the sound and activity.

Based on the best available information, NMFS considers it highly unlikely that any of the species considered in this consultation would be struck or entrained by a sediment sampling procedures. To briefly summarize, in order to be entrained by sediment sampling, the fish must be directly under sampling equipment when it drops. The small size of the bucket, compared against the distribution of the organisms across the available habitat make this situation is extremely unlikely, and that likelihood would decrease after the first few bucket cycles because the fish are most likely to move away from the disturbance.

Demersal fish, such as sand lance, sculpins, and pricklebacks are most likely to be entrained as they reside on or in the bottom substrates with life-history strategies of burrowing or hiding in the bottom substrate (Nightingale and Simenstad 2001). Adult salmonids are of sufficient size and speed to avoid entrainment. Consequently, the risk of entrainment of ESA-listed species by the dredge is extremely low and not likely to cause "take."

Whales – neither SRKW nor humpback whales are at risk of entrainment during sediment sampling.

Sunflower Sea Star – If not detected and moved before sampling, it is possible that an adult sunflower sea star could be entrained during a sediment "grab."

g.3 Marine Energy Devices

Fish and Whales - Given the lack of documentation showing an increase in fish or marine mammal collision or blade strike from marine energy devices in general, it is not anticipated that effects will be more than minor, but the possibility remains that site-specific operational and environmental parameters may increase risk of strike or entrainment, especially of smaller biota (e.g., early fish life stages) (Copping and Hemery 2020).

Cetaceans, pinnipeds, birds and larger fish are generally expected to swim away from operating devices, which may cause a temporary and minor impact to foraging or pelagic behavior through active avoidance of the area of deployment. As reviewed in Sparling et al. (2020) and Copping and Hemery (2020), recent field studies around operating marine energy devices indicate that marine mammals can detect the devices acoustically and avoid coming near devices. To minimize the risk of collision and entrainment, PDC requirements will be followed.

Sunflower sea star – As with intakes, larval sunflower sea start could get trapped or pinched in marine energy devices. Adding the correct screen will lower the chance of entrainment.

g.4 Turbines

In a recent, extensive review of the literature on the interaction and collision risks of marine animals, Sparling et al. (2020) concluded that there is no evidence that shows that direct interactions with tidal turbines will cause measurable harm to individual marine animals or populations. Despite the potential for encounters and collisions, knowledge of actual risk is limited because the frequency of occurrence of these events and their consequences are generally unknown (Sparling et al. 2020). Cetaceans, pinnipeds, birds and larger fish are generally expected to swim away from operating devices, which may cause a temporary and minor impact to foraging or pelagic behavior through active avoidance of the area of deployment (Sparling et al. 2020).

For example, recent field studies around operating tidal turbines indicate that marine mammals can detect the devices acoustically and avoid coming near devices. However, species-specific responses would depend on the acoustic characteristics of the signal and the hearing sensitivity of the species (Sparling et al. 2020). In a specific example, no significant change in at sea distribution of harbor seals was detected between pre and post installation of a commercial 4-turbine array and seals showed overt avoidance responses during turbine operations, with a significant decrease in predicted abundance within ~2 km of the array (Onoufriou 2021). Some studies have demonstrated adult and juvenile fish swimming behaviors that resulted in avoidance as they approach operating tidal turbines (Shen et al. 2016, Sparling et al. 2020).

The risk to individual fish from colliding with turbine blades is low (Redden et al. 2014, Shen et al. 2016, Garavelli et al. 2022); if these collisions were to occur, it is unknown whether fish will sustain recoverable injuries or be killed. Equally unknown is the impact these collisions might have on populations, particularly for threatened, endangered, or commercially managed fish species (Garavelli et al. 2022).

Zhang et al. (2017) found that marine current turbines, when tested for operation at 3 different speeds, produced no fish mortalities. Given the lack of documentation showing an increase in fish or marine mammal collision with blades, it is anticipated that effects will not be more than minor, but the possibility remains that site-specific operational and environmental parameters may increase risk of strike, especially of smaller biota (e.g., early fish life stages), although these are less likely to incur damage from strikes due to low mass (Bevelhimer 2016). NMFS and DOE choose to take a conservative approach regarding potential impacts on species and their consequences. Therefore, in addition to inherent intermittent operation and variable tip-speed ratio, the risk of collision to species will be minimized based on adaptive future tidal turbine deployments and information obtained from monitoring (Appendix B). The monitoring protocols were developed in response to perceived collision risk to marine mammals, and fish. Subsea detection devices will be used to monitor for potential collisions and nearfield interactions of marine mammals and fish with turbines.

Response to entrainment conclusion
Larvae and juvenile organisms are particularly vulnerable to entrainment. Sediment removal can entrain slow-moving and sessile benthic organisms, algae, and aquatic vegetation. Entrainment of larger mobile organisms like fish is considered highly unlikely due to their ability to swim away from disturbances.

The risk of collision or blade strike from marine energy devices is generally considered minor, but site-specific conditions may increase the risk, especially for smaller organisms like early fish life stages. Larger animals like cetaceans, pinnipeds, birds, and adult fish are expected to actively avoid operating devices, causing temporary and minor impacts on their behavior.

There is a lack of evidence showing a significant increase in fish or marine mammal collisions with turbine blades. Larger animals are expected to detect and avoid operating turbines, but species-specific responses may vary. The risk of collision, particularly for smaller organisms like early fish life stages, cannot be ruled out, and the consequences are uncertain.

There are many unknowns when it comes to marine energy devices and turbines which naturally leads to skepticism to the proposed project. Without an abundance of information, we cannot say if these devices greatly or minorly impact our listed ESA species. With this being said, we agree to allow PNNL to go forward with a trail run on marine turbines. This requires the greatest caution. A MMMP (Appendix B) has been developed for turbines, requiring an in water integrated monitoring system while the turbine is in operation. Additionally, the first target interaction observed that is designated as a blade strike will be reported to the Services and the turbine shut down until further consultation. One year after signing of the programmatic the Services and DOE/PNNL will meet to discuss the turbine program. As such, continuing monitoring protocols and adaptive management strategies are recommended to minimize potential impacts and gather more information on the effects of turbines on marine life.

h. Species Response to Capture and Release

h.1 Incidental Capturing during Sampling and Surveys and *h.2 Incidental Capture in Devices*
As described in the section on entrainment and impingement, these are episodes of "incidental capture" that are reasonably expected during sampling, and where intakes exist. Devices could occasionally cause a similar entrapment or "capture."

Entrainment is unlikely to afford an opportunity for successful release of live/uninjured fish. However, impinged fish, if detected, could possibly be freed from the impinging force and released, but it is uncertain if detection would occur often enough that the specimens would be unharmed. Several factors, such as flow, volume, screen angle, screen size, influence survival of impinged juvenile fishes. We expect that fish injured by impingement, even if 'captured' and released, will not have one hundred percent survival, as their injuries may make them less likely to forage, or avoid predators, successfully. For the purpose of this analysis, we anticipate lethal outcomes for 85% of released fish (Kerr, 1953).

It is possible that when equipment or devices are about to be located or removed that a survey of conditions may indicate a sunflower sea star is present, in which case "capture" with the intent to relocate to avoid injury or death could occur, and the relocation would be considered a "release." Despite due care in handling that any such captured and released sea star could be stressed and even experience minor injury to an extent that diminishes its overall condition.

Capture and Release Conclusion
Fish 'capture and release' might occur during any of the activities, but might primarily occur during benthic surveys and marine energy device operations. Fish relocation, which involves moving fish from one location to another, can have several significant impacts, thus fish relocation in marine environments during construction is not without risks. The relocation process itself can cause stress and mortality to the fish, and introducing them to a new environment, particularly if injured by impingement, may expose them to new predators,

competitors, or diseases. As indicated above, mortality among released fish is estimated at 85 percent of fish so handled.

Fish relocation should be carefully planned and executed, considering the potential impacts on both the fish and the receiving environment. It should be part of a comprehensive mitigation strategy that includes minimizing habitat disturbance, implementing best practices for sediment and pollution control, and incorporating long-term habitat restoration or creation measures.

2.6 Cumulative Effects

"Cumulative effects" are those effects of future state or private activities, not involving federal activities, that are reasonably certain to occur within the action area of the federal action subject to consultation (50 CFR 402.02 and 402.17(a)). 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.

Some continuing non-federal activities are reasonably certain to contribute to climate effects within the action area. However, it is difficult if not impossible to distinguish between the action area's future environmental conditions caused by global climate change that are properly part of the environmental baseline *vs.* cumulative effects. Therefore, all relevant future climate-related environmental conditions in the action area are described in the environmental baseline (Section 2.4.3).

The action area is influenced by actions in the nearshore, along the shoreline, and also in tributary watersheds of which effects extend into the action area. Future actions in the nearshore and along the shoreline are reasonably certain to include marina expansions, residential and commercial development, shoreline modifications, road and agricultural development. Changes in tributary watersheds that are reasonably certain to affect the action area include reductions in water quality, water quantity, and sediment transport. Future actions in the tributary watersheds whose effects are reasonably certain to extend into the action area include operation of timber harvest, land conversions, effects of transportation infrastructure, and growth-related commercial and residential development. Some of these developments will occur without a federal nexus.

All such future non-federal actions, in the nearshore as well as in tributary watersheds, will cause long-lasting environmental changes and will continue to harm ESA-listed species and their critical habitats. Especially relevant effects include the loss or degradation of nearshore habitats, pocket estuaries, estuarine rearing habitats, wetlands, floodplains, riparian areas, and water quality.

As the human population continues to grow, demand for agricultural, commercial, and residential development and supporting public infrastructure is also reasonably certain to grow. We believe the majority of environmental effects related to future growth will be linked to these activities, in particular land clearing, associated land-use changes (i.e., from forest to impervious, lawn or pasture), increased impervious surface, and related contributions of contaminants to area waters. Land use changes and development of the built environment that are detrimental to salmonid habitats are reasonably certain to continue under existing regulations. Though the existing regulations minimize future potential adverse effects on salmon habitat, as currently constructed and implemented, they still allow systemic, incremental, additive degradation to occur.

Derelict fishing gear can continue "ghost" fishing and is known to kill rockfish (Palsson et al., 2009). Nets and other gear in waters deeper than 100 feet have been incidentally encountered in habitat surveys, though the overall extent and impact of nets in deeper waters is unknown. In addition, during removal efforts nets have been documented to drape over slopes deeper than 100 feet, but current guidelines require the net to be cut off at 100 feet. Current guidelines also do not allow "mechanical advantage," such as grappling hooks attached to vessel hydraulic systems, to remove nets that are too entangled in bottom substrate or rock for hand removal. Because habitats deeper than 100 feet are most readily used by adult yelloweye rockfish and bocaccio, there is an unknown but potentially large impact from deepwater derelict gear on each population within the DPS. Approximately 20 percent of lost nets reported by fishermen are not recovered because the net drifts away and becomes submerged before responders arrive. There are no devices installed on nets to track their location after they are lost, further complicating the recovery effort.

In June 2005, the Shared Strategy presented its recovery plan for PS Chinook salmon and the Hood Canal Coordinating Council presented its recovery plan for HCSR chum salmon to NMFS who adopted and expanded the recovery plans to meet its obligations under the ESA. Together, the joint plans comprise the 2007 PS Chinook and HCSR chum Recovery Plan. Several not-for-profit organizations and state and federal agencies are implementing recovery actions identified in these recovery plans.

Multiple non-federal activities are reasonably certain to occur that impact SRKW interactions with vessels in the Salish Sea. These additional actions are designed to further reduce impacts from vessels on SRKW by limiting the potential for interactions including:

1. Washington State law (Senate Bill 5577) established a commercial whale watching license program and charged WDFW with administering the licensing program and developing rules for commercial whale watching for inland Washington waters (see RCW 77.65.615 and RCW 77.65.620). The new rules were adopted in December 2020, and became effective May 12, 2021, and include limitations on the time, distance, and area that SRKW can be viewed within ½ nautical mile, in an effort to reduce vessel and nose disturbance:
    a. The commercial whale watching season is limited to three months/year for viewing SRKW closer than ½ nautical mile, and is limited to four hours per day in the vicinity of SRKW.
    b. Up to three commercial whale watching vessels are allowed within ½ nautical mile of SRKW at a given time, with exclusion from approaching within ½ nautical mile of SRKW groups containing a calf.
    c. Year-round closure of the "no-go" Whale Protection Zone along the western side of San Juan Island to commercial whale watching vessels, excluding a 100-yard corridor along the shoreline for commercial kayak tours.

2. Continued implementation and enforcement of the 2019 restrictions on speed and buffer distance around SRKW for all vessels.

3. Increased effort dedicated to outreach and education programs. This includes educational material for boating regulations, Be Whale Wise guidelines, the voluntary no-go zone, and the adjustment or silencing of sonar in the presence of SRKWs. Outreach content was created in the form of video, online (including social media), and print advertising targeting recreational boaters. On-site efforts include materials distributed at pump out and re-fueling stations along Puget Sound, during Enforcement orca patrols, and signage at WA State Parks and WDFW water access sites. Additionally, State Parks integrated materials on whale watching regulations and guidelines in their boating safety education program to ensure all boaters are aware of current vessel regulations around SRKW.

4. Promotion of the Whale Report Alert System (WRAS) in Puget Sound, developed by the Ocean Wise Research Institute, which uses on-the-water reporting to alert large ships when whales are nearby. Reporting SRKW to WRAS is required for commercial whale watching license holders, and on-the-water staff are also being trained to report their sightings.

5. Piloting a new program ("Quiet Sound") that will have topic-area working groups to lead projects and programs on vessel operations, incentives, innovations, notification, monitoring, evaluation, and adaptive management. This effort was developed with partners including Commerce, WA State Ferries, and the Puget Sound Partnership in collaboration with the Ports, NOAA, and others. Funding is anticipated to be secured in the 2021 state legislative session.

6. Currently WDFW enforcement boats conduct coordinated patrols with the U.S. Coast Guard, NOAA Office of Law Enforcement, San Juan County Sheriff's Office, Sound Watch, and other partners year-round that include monitoring and enforcement of fisheries and Marine Mammal Protection Act requirements related to vessel operation in the presence of marine mammals throughout Puget Sound. Patrols in the marine areas of northern Puget Sound are specifically targeted to enforce regulations related to killer whales. Outreach and enforcement of vessel regulations will reduce the vessel effects (as described in Ferrara et al. (2017)) of recreational and commercial whale watching vessels in U.S. waters of the action area.

On March 14, 2018, WA Governor's Executive Order 18-02 was signed and it ordered state agencies to take immediate actions to benefit SRKW and established a Task Force to identify, prioritize, and support the implementation of a longer-term action plan needed for SRKW recovery. The Task Force provided recommendations in a final Year 1 report in November 2018.[10] In 2019, a new state law was signed that increases vessel viewing distances from 200 to 300 yards to the side of the whales and reduces vessel speed within ½ nautical mile of the whales to seven knots over ground. SB 5918 amends RCW 79A.60.630 to require the state's boating

[10] Available at: https://www.governor.wa.gov/sites/default/files/OrcaTaskForce_reportandrecommendations_11.16.18.pdf, last visited May 26, 2019.

safety education program to include information about the Be Whale Wise guidelines, as well as all regulatory measures related to whale watching, which is expected to decrease the effects of vessel activities to whales in state waters.

On November 8, 2019, the task force released its Year 2 report[11] that assessed progress made on implementing Year 1 recommendations, identified outstanding needs and emerging threats, and developed new recommendations. Some of the progress included increased hatchery production to increase prey availability. In response to recommendations of the Washington State Southern Resident Killer Whale Task Force, the Washington State Legislature provided approximately $13 million in funding "prioritized to increase prey abundance for southern resident orcas" (Engrossed Substitute House Bill 1109) for the 2019-2021 biennium (July 2019 through June 2021)

On March 7, 2019, the state passed House Bill 1579 that addresses habitat protection of shorelines and waterways (Chapter 290, Laws of 2019 (2SHB 1579)), and funding was included for salmon habitat restoration programs and to increase technical assistance and enforcement of state water quality, water quantity, and habitat protection laws. Other actions included providing funding to the Washington State Department of Transportation to complete fish barrier corrections. Although these measures won't improve prey availability in 2020/2021, they are designed to improve conditions in the long-term.

Notwithstanding the beneficial effects of ongoing habitat restoration actions, the cumulative effects associated with continued development are reasonably certain to have adverse effects on all the listed species populations addressed in this Opinion. Only improved, low-impact development actions together with increased numbers of restoration actions, watershed planning, and recovery plan implementation would be able to address growth related impacts into the future. To the extent that non-federal recovery actions are implemented and offset ongoing development actions, adverse cumulative effects may be minimized, but will probably not be completely avoided.

2.7 Integration and Synthesis

The Integration and Synthesis section is the final step in our assessment of the risk posed to species and critical habitat as a result of implementing the proposed action. In this section, we add the effects of the action (Section 2.5) to the environmental baseline (Section 2.4) and the cumulative effects (Section 2.6), taking into account the status of the species and critical habitat (Section 2.2), to formulate the agency's biological opinion as to whether the proposed action is likely to: (1) reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing its numbers, reproduction, or distribution; or (2) appreciably diminish the value of designated or proposed critical habitat as a whole for the conservation of the species.

[11] Available at:
https://www.governor.wa.gov/sites/default/files/OrcaTaskForce_FinalReportandRecommendations_11.07.19.pdf, last visited May 26, 2019.

2.7.1 Integration for Critical Habitat

The effects of projects covered would impact critical habitats for PS Chinook salmon, HCSR chum salmon, PS/GB bocaccio, PS/GB yelloweye rockfish, southern DPS of green sturgeon, and the SRKW (eulachon and humpback whales do not have CH in the action area).

Modification of nearshore habitat in Puget Sound has resulted in a substantial decrease in critical habitat quality for designated critical habitats of several of the listed species (not including yelloweye rockfish, or humpback whales). Once developed, shoreline and nearshore areas tend to remain developed due to the high residential, commercial, and industrial demand for use of these areas. New development continues and as infrastructure deteriorates, it is rebuilt. Marinas, residential piers, ramps, floats, and port facilities are quickly replaced as needed. Same is the case for this programmatic, but on a smaller scale. We expect that as one project goes in, another comes out, and yet another prepares to go in. The cycle is shorter, but persistent. Although designs are often more environmentally friendly, replacement of these structures ensures their physical presence will cause adverse impacts on nearshore habitat into the future. This is evidenced by the continued requests for consultation on these types of actions. Although some projects will require offsets which will ultimately improve nearshore habitat quality in the San Juan de Fuca basin, the area impacted by these projects is tiny compared to the developed area. The general trend of nearshore habitat quality is downward and is unlikely to change given current management of these areas.

Most critical habitat for PS Chinook is degraded but nonetheless maintains a high importance for conservation of the species, based largely on its restoration potential. Loss of freshwater and nearshore critical habitat quality is a limiting factor for this species. Development of estuary areas is expected to continue to adversely impact the quality of critical habitat PBFs for PS Chinook salmon.

Nearshore habitat modification has caused broad-scale ecological changes, reducing the ability of critical habitat to support PS Chinook salmon juvenile migration and rearing. The loss of submerged aquatic vegetation, including eelgrass and kelp, has reduced cover, an important PBF of critical habitat for PS Chinook salmon. Degradation of sand lance and herring spawning habitat has reduced the quality of the forage PBF. Construction of overwater structures throughout Puget Sound has degraded PS Chinook salmon critical habitat by creating artificial obstructions to free passage in the nearshore marine area. Habitat modification that have occurred in Puget Sound to date have reduced juvenile survival and, in some cases, eliminated PS Chinook salmon life history strategies that rely on rearing in nearshore areas during early life history.

Critical habitat for HCSR chum salmon is designated in stream, rivers, and nearshore areas. Although some critical habitat for this species is degraded, several nearshore areas of critical habitat remain in good condition. Implementation of recovery plan actions for HCSR chum salmon, including development of an in-lieu fee program for projects that impact critical habitat for this species, represent positive steps toward addressing habitat limiting factors for this species.

Critical habitat for PS/GB bocaccio and yelloweye rockfish includes deep-water areas and areas of nearshore habitat (but only for juvenile bocaccio). Juvenile bocaccio use shallow nearshore areas extensively during life history while yelloweye rockfish do not. The quality of nearshore critical habitat for PS/GB bocaccio has been degraded by nearshore development and in-water construction, the removal of soil, and pollution and runoff.

Direct studies on the effect of climate variability on rockfish are rare, but all the studies performed to date suggest that climate plays an extremely important role in population dynamics (Drake et al., 2010). The negative effect of the warm water conditions associated with El Niño appear to be common across rockfishes (Moser et al., 2000).

The Strait of Juan de Fuca as an area of high conservation value for southern DPS green sturgeon. Sturgeon use estuaries for rest after long coastal migrations, but may also simply hold in these relatively predator-free and physiologically benign zones (Moser and Lindley 2007). Data from a 2021 study (Moser 2021) indicated that green sturgeon use the Strait of Juan de Fuca as a corridor, residing at receiver sites for relatively short periods as they pass through the strait. Acoustic detection data indicated that green sturgeon from both the northern and southern DPSs can occur in Puget Sound and at Admiralty Inlet, but at low rates relative to their presence in the Strait of Juan de Fuca. The duration of green sturgeon exposure to Puget Sound waters and sediments is unknown.

Within Puget Sound, the quality of critical habitat for SRKWs has been negatively affected by degradation of water quality, sound/acoustics, and a reduction of prey availability. Over the past several years, the reduced and declining SRKW status has become a serious concern. PS Chinook salmon, a key part of the prey PBF for SRKW critical habitat, is a concern for this programmatic consultation and conference.

The programmatic action for PNNL is a mix of activity types with a number of adverse effects on the quality of Puget Sound nearshore habitat critical habitat for PS Chinook salmon, HCSR chum, bocaccio, yelloweye rockfish, green sturgeon, and SRKWs including:

- In the short-term, the proposed activities can reduce the critical habitat's ability to support survival, growth, maturation or reproduction of species close to the project site.
- New overwater structures could create shade, suppress submerged aquatic vegetation, interrupt migration of salmon, and provide cover for predatory fish that eat juvenile salmon.
- Sediment work (seabed installations, sediment sampling, etc.) would removes benthic substrate and reduce forage PBF for juvenile salmonids and rockfish. Sediment sampling could convert a small amount of shallow nearshore habitat to deep- water habitat, reducing its quality for listed species.

The design of the PNNL RAP action is a critical factor in our assessment. The activity types and associated design criteria were carefully selected to ensure that environmental outcomes of each activity can be readily predicted. As described in the analysis of the effects of the action (Section 2.5), the effects of the proposed activities primarily cause localized, and minor effects. These effects are mostly caused by in- and near-water activities and last, at most two years without reverification. General construction measures required by the PNNL RAP ensure minimization of short-term effects and recovery of function of aquatic and riparian habitat at disturbed sites.

The location of projects covered under PNNL RAP will be spread across Sequim Bay and a portion of the Strait of the Juan de Fuca. Although there could be some clumping of projects, the geographic extent of short-term adverse effects from projects do not typically overlap. Some effects of structures on habitat quality must be compensated through conservation offsets. By including this requirement in PNNL RAP, we expected no-net loss of nearshore habitat or critical habitat conservation value over time. Therefore, the effects of the proposed action on critical habitat, when added to the baseline, factoring cumulative effects, and considering the status of the critical habitat will not reduce the conservation role of critical habitat designated in the action area, or at the larger designation scale for PS Chinook salmon, HCSR chum salmon, PS/GB bocaccio, PS/GB yelloweye rockfish, southern DPS of green sturgeon, or SRKW.

2.7.2 Integration for Species

The status of each species considered here is threatened with the exception of bocaccio and SRKW, which are endangered. Sea stars are a proposed species at this time.

Puget Sound Chinook salmon have generally negative recent trends in status. Widespread negative trends in natural-origin spawner abundance across the ESU have been observed since 1980. Productivity remains low in most populations, and hatchery-origin spawners are present in high fractions in most populations outside of the Skagit watershed. Most populations are consistently below the spawner-recruit levels identified by the recovery plan for this ESU. Development of shoreline and estuary areas of Puget Sound is expected to continue to adversely impact the quality of marine habitat for PS Chinook salmon. Here, the project effects are most likely among the Elwha and Dungeness populations of Puget Sound Chinook salmon, which are part of the Strait of Juan de Fuca MPG. The Dungeness population has remained relatively stable in abundance and productivity since 1990-1994 review. The Elwha population has had larger fluctuations, with a general decline in abundance, however a positive trend in abundance in the last review period (2015-2019). We do not expect harm, injury or death resulting from the proposed activities to modify current trends or impair potential increases in productivity at the species level, in part because of habitat offsets associated with the proposed action.

The loss of submerged aquatic vegetation, including eelgrass and kelp, has reduced cover, an important feature of habitat for PS Chinook salmon. Degradation of sand lance and herring spawning habitat has reduced the quantity of the forage for PS Chinook salmon. Construction of overwater structures throughout Puget Sound has degraded PS Chinook salmon habitat by creating artificial obstructions to free passage in the nearshore marine area. Habitat modification that have occurred in Puget Sound to date have reduced juvenile survival and, in some cases, have eliminated PS Chinook salmon life history strategies that rely on rearing in nearshore areas during early life history.

Puget Sound steelhead complete much of their early life history in freshwater and do not rely on nearshore areas of Puget Sound for rearing as Chinook and chum salmon do. Short-term construction- related impacts such as elevated sound and turbidity would likely injure or kill a small number of PS steelhead but not enough to result in any population-level effects.

Considering both short-term and potential long-term impacts, the proposed actions would not have any meaningful effects on PS steelhead population abundance, productivity, spatial structure, or diversity. The populations affected by harm, injury or death from the proposed activities each come from the Hood Canal Strait of Juan de Fuca MPG. Dungeness Winter-Run Strait of Juan de Fuca Tributaries Winter-Run both had declining trends compared to the prior review period; the Sequim/Discovery Bay Tributaries Winter-Run has insufficient information to provide trends. Because the proposed action includes offsetting habitat measures (which are designed to improve habitat conditions for juvenile lifestages of Puget Sound salmonids) we do not expect the adverse consequences of the proposed action to reduce viability parameters (productivity, spatial structure or diversity) at the species level.

Hood Canal Summer Run chum salmon have made substantive gains towards meeting this species' recovery plan viability criteria. The most recent 5-year review for this ESU notes improvements in abundance and productivity for both populations that make up this ESU. However, the ESU still does not meet all of the recovery criteria for population viability at this time. Implementation of recovery plan actions for HCSR chum salmon, including development of an in-lieu fee program for projects that impact critical habitat for this species, represent positive steps toward addressing habitat limiting factors for this species. The populations affected here are each from the Strait of Juan de Fuca MPG, which has shown abundance viability gains in the last review period. Take in the form of harm, injury, or death from the proposed array of are unlikely to reverse the trend in MPG or species-level productivity or abundance.

Green sturgeon are wide-ranging migrants, spawning in California and appearing in Washington's coastal waters, estuaries and watersheds in late summer. Although they may be sensitive to hydrological and temperature shifts in their natal watersheds, vulnerability to climate change in Washington is likely linked with changes in the marine environment. Limited information is available regarding the sensitivity of green sturgeon to climate change (particularly in Washington).

In general, water temperatures influence fish distribution, physiology, and biology. Green sturgeon likely exhibit some physiological sensitivity to water temperature increases. A study in the Klamath and Rogue River basins found that bioenergetic performance peaked at water temperatures between 15-19°C. A separate study theorized that green sturgeon utilize warmer estuarine habitats in Washington during summer to maximize growth potential. Climate change impacts (e.g., decreased pH) may also affect green sturgeon prey (e.g., benthic organisms - shrimp, amphipods, small fish, mollusks). An additional risk to listed fishes during construction is entrainment during sediment sampling. Entrainment is likely to result in mortality, and is most likely to occur among green sturgeon. Green sturgeon have the greatest increased risk of mortality when sediment investigation activities are ongoing because they rest and forage near the bottom where they could encounter equipment, but we expect, based on information from other locations, that the number of sturgeon injured or killed in this manner will be very few.

Eulachon present status, timing, and migration routes of Eulachon that spawn in the Elwha River are not well-known. There is evidence that spawning is increasing following the removal of the

Elwha dams over the past decade. Spawning typically occurs in February to May and may result in large aggregations of Eulachon in the northern part of the action area.

Puget Sound/Georgia Basin bocaccio are listed as endangered and abundance of this species likely remains low. PS/GB yelloweye rockfish are listed as threatened but likely persist at abundance levels somewhat higher than bocaccio. Lack of specific information on rockfish abundance in Puget Sound makes it difficult to generate accurate abundance estimates and productivity trends for these two DPSs. Available data does suggest that total rockfish declined at a rate of 3.1 to 3.8 percent per year from 1977 to 2014 or a 69 to 76 percent total decline over that period. The two listed DPSs declined over-proportional compared to the total rockfish assemblage.

Juvenile yelloweye rockfish are not typically found in nearshore habitat and adults are found solely in deep water areas of Puget Sound. Larval yelloweye rockfish are found in nearshore areas and would likely be exposed to the short-term effects of the proposed construction. However, the projects authorized under PNNL RAP would only result in impacts to larval rockfish. Given the low overall level of impact, the proposed action will not have any meaningful effect on the numbers, reproduction, or distribution of yelloweye rockfish.

After taking into account the present status of listed fish and their critical habitat, we add the effects of the action and cumulative effects to the environmental baseline. The effects include exposure to multiple types of habitat reductions that cause responses ranging from behavioral (startle, avoidance, longer foraging forays, decreased predator detection) to sublethal effects (hearing reduction, reduced foraging success, reduced growth or fitness) to injury or death (barotrauma, entrainment, impingement). The most frequent of these effects are behavioral and we expect injury or death to occur among low numbers of the affected fish species each year. Juveniles of the species are the most likely to have the greatest amount of exposure and response. Of the fishes considered PS Chinook, HCSR chum, eulachon, and bocaccio are the most vulnerable to the array of effects (though the current abundance of bocaccio is low, making exposure to the effects likely only among a very small number). Given the character of effects, the lifestages exposed, and the expected amount of exposure, we expect a decrease in abundance as some individuals will have lethal response, but we do not expect the number to be large enough in any given year, nor over the duration of the program, to reduce other population level characteristics of any of the affected species.

Southern Resident killer whales are listed as endangered under the Endangered Species Act. NMFS considers SRKWs to be currently among nine of the most at-risk species as part of the Species in the Spotlight initiative because of their endangered status, declining population trend, and they are high priority for recovery based on conflict with human activities and recovery programs in place to address threats. The population has relatively high mortality and low reproduction unlike other resident killer whale populations that have generally been increasing since the 1970s (Carretta et al. 2021). Reduced prey availability is a major limiting factor for this species. When the project effects are added to the baseline, this species is most likely to experience brief exposure to noise, brief exposure to reduced water quality, and a very slight reduction abundance of preferred prey species as a result of the proposed action. We expect some possibility of behavioral responses among individual SRKW exposed to sound, and these behavioral responses may briefly include reduced foraging. However, we do not expect these behavioral responses to subsequently result in or constitute any injury, harassment, harm, or reduced fitness of any individual of this species.

Humpback whales have been listed as a state endangered species in Washington since 1981. In 2016, the NMFS revised the federal Endangered Species Act listing for the humpback whale to identify 14 DPSs worldwide, three of which visit Washington's waters. These include (1) the Hawaii DPS, which comprises the largest percentage (63 percent) of humpback whales present in the state and is not federally listed, (2) the Mexico DPS, which comprises about 28 percent of Washington's humpbacks and is federally threatened, and (3) the Central America DPS, which contributes the fewest animals (9 percent) and is federally endangered. Threats to humpbacks include: overharvesting of biological resources, ship strikes, entanglement in fisheries gear (netting, pots, and traps), and climate vulnerability. Actions needed to reduce threats and help to recover the population include: identifying areas of greatest concern for ship strikes and work with the shipping industry to reduce this threat, determine ongoing sources of bycatch and manage those fisheries to reduce bycatch, stop climate change. Based on presence data provided above, the listed populations are less likely than the non-listed DPS to be exposed to effects of the proposed action. Additionally, based on size of this species and the duration of their presence, when the effects of the proposed action are considered, humpback whales are the least likely of the species considered in this opinion to be exposed to direct effects of the proposed action, and if exposed directly or indirectly, are expected to have the least amount of response based on limited duration of exposure. The most notable effect is expected to be behavioral response. We do not expect any population level consequences do any DPS of humpback whales.

The sunflower sea star is proposed for listing throughout its range, and no data exist to suggest anything other than a single, panmictic population, so, to reach a determination of jeopardy, a proposed action would have to impact range-wide population dynamics. We are not currently aware of any habitat types or locations used by sunflower sea stars for mating or spawning, larvae are planktonic, and newly settled juveniles appear in a variety of habitats. We do not expect any single site-specific action to result in jeopardy, but broad-scale programmatic actions occurring over a substantial portion of the range might result in appreciable reductions in the number, distribution, or reproduction of sea stars. Each action will need to be evaluated on a case-by-case basis. Despite multiple pathways of exposure from the proposed action we expect the number of individuals so exposed to be very low, and most responses to not result in injury or death, with the exception of entrainment or capture. We do not expect the effects of this proposed action, even when considered over the duration of the program, will impact enough individuals to impair population trends or impede improving productivity.

2.8 Conclusion

After reviewing the current status of the listed and proposed species, the environmental baseline within the action area, the effects of the PNNL RAP proposed action, and cumulative effects, it is NMFS's biological opinion that the proposed action is not likely to jeopardize the continued existence of PS Chinook salmon, HCSR chum salmon, PS steelhead, PS/GB yelloweye rockfish, PS/GB bocaccio rockfish, Southern DPS green sturgeon, eulachon, SRKW, humpback whales or the sunflower sea star, nor result in the destruction or adverse modification of critical habitat that has been designated for these species.

2.9 Incidental Take Statement

Section 9 of the ESA and federal regulations pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without a special exemption. “Take” is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. “Harm” is further defined by regulation to include significant habitat modification or degradation that actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including breeding, spawning, rearing, migrating, feeding, or sheltering (50 CFR 222.102). “Harass” is further defined by interim guidance as to “create the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering.” “Incidental take” is defined by regulation as takings that result from, but are not the purpose of, carrying out an otherwise lawful activity conducted by the Federal agency or permittee (50 CFR 402.02). Section 7(b)(4) and section 7(o)(2) provide that taking that is incidental to an otherwise lawful agency action is not considered to be prohibited taking under the ESA if that action is performed in compliance with the terms and conditions of this ITS.

2.9.1 Amount or Extent of Take

Each of the 13 activity types will, in some combination, expose individuals from each of the listed fishes, whales, and the proposed sea star species to effects that can result in harm, injury or death to some of those exposed individuals. Given the variability in species presence over time, the complexity of their life histories, and the inability to observe the exposed individuals to ascertain delayed responses to such exposures, we cannot provide a reliable estimate of the numbers to be exposed. In such a circumstance, we provide an extent of take, rather than an amount of take. The extent of take is typically an observable spatial or temporal measure, causally linked to the type of take expected. We will provide here an extent of take for each project type. We provide here a copy of Table 35 in order to restate for the reader’s convenience a summary presentation of species’ likely exposure to each effect pathway**.**

Effect Pathway	PS Steelhead	PS Chinook	HCSR Chum	PS/GB Yelloweye Rockfish	PS/GB Bocaccio	Eulachon	Green Sturgeon	SRKW	Humpback Whale	Sunflower sea star
(a) Shade	x	x	x		x					x
(b) Migration Obstruction	x	x	x		x	x	x			
(c) Water Quality	x	x	x	x	x	x	x			x
(d) Loss of Aquatic Habitat	x	x	x	x	x					x
(e) Sound	x	x	x	x	x	x	x	x	x	
(f) Benthic Effects					x		x			x
(g) Entrainment				x	x					x
(h) Capture and Release	x	x	x	x	x	x	x			x

Extent of take from In-Water and Overwater Projects (Shade, Migration Obstruction)
Take from the presence of in or overwater structures occurs with activity types 1, 2, 3, 12 and 13 (see Table 38). The DOE provided information on the expected frequency of activities covered under the proposed action. Based on that information we expect PNNL RAP to implement a maximum of 455 projects involving structures (floats, buoys, dock installations, seabed installations, and marine energy devices) in or above water in a year. Based on that same analysis, we expect these projects would likely result in the installation of up to approximately 144,705 square feet of overwater and in-water structures installed in each year. This extent is causally related to the extent of harm of each fish species (except yelloweye that are expected to be located in deeper/darker aquatic areas) because reducing available forage via shade, and/or migratory obstruction, increases the harm as the number of projects and space affected increases. This can be reliably monitored by through the program's implementation process.

The total extent of potential take via the surrogate measure was determined as follows. Projects authorized under PNNL RAP will take place beside and within aquatic habitats that are reasonably certain to be occupied by individuals of the ESA-listed species considered in this opinion. We considered information from the DOEs consultation request, information from completed consultations, and information from consultation requests to project the future level of activity expected under PNNL RAP. In developing indicators or surrogates to express the extent of incidental take, the values of the metrics used to project levels of activity were round up or down to a relevant whole number (e.g., 699 linear was rounded to 700 linear feet).

As described below, the proposed action may cause incidental in the form of harm from shade, and/or benthic impacts among *of one or more individuals of all species considered in this opinion except yelloweye rockfish and humpback whales (SRKW are indirectly affected by the prey reduction, but are only expected to exhibit behavioral response).*

We expect that the amount or extent of take described below is for a typical year of work that would be authorized under PNNL RAP. The amount or extent of incidental take identified below, in Table 38, includes estimates expected to occur in a typical year, for each year of the programmatic.

Table 38. Project Limits Per Year

No.	Activity	Max Size: Square Feet	Max # per year (OWS)	Total Square Footage per Year (OWS)	Max # at a time (OWS)	Total Square Footage at a time (OWS)
1A	Buoys	100	25	2,500	15	1,500
1A	Grated Floats	400	25	10,000	5	2,000
1A	Solid Floats	400	25	10,000	3	1,200
2	Dock Installations	6	40	240	20	120
3	Seabed Installations: Equipment and Sensors	50	35	1,750	15	750
12A	Community and Research Scale Marine Energy Devices (excluding tidal turbines) - w/ BMPS	400	150	60,000	150	60,000
12B	Community and Research Scale Marine Energy Devices (excluding tidal turbines) - w/o BMPS	400	150	60,000	150	60,000
13	Tidal Turbine Research (Largest Possible Scenario)	215	1	215	1	215
	Total:	1,965	455	**144,705**	359	125,785

Extent of take from water quality impact activities (suspended sediment/turbidity, low DO, dyes)

Juvenile salmonids (HCSR chum, PS Chinook salmon) and juvenile bocaccio are likely to experience take in the form of harm by turbid conditions and corollary low DO. Turbidity occurs device or equipment installations on the seabed, and with activities 5 (benthic study), 7 (dye and particulate release) and 8 (seagrass study). Because this take cannot be reasonably quantified or reliably observed, the extent of take will use a surrogate measure, as follows:

1) The extent of incidental take caused by sediment removal is the maximum volume of material removed annually. The extent of take is that associated with up to 30 benthic sediment sampling surveys per year, at 27 cubic feet per survey or 810 cubic feet per year.
2) The extent of take from seagrass study is that associated with up to 216 square feet of seagrass disturbed during studies per year, including:
   – Up to 108 square feet in Sequim Bay
   – Up to 108 square feet per year in the Strait of Juan de Fuca
   – No more than 10 percent of the total seagrass area to be disturbed in each area.
3) The extent of take from installation of equipment or devices is that associated with up to a 300-foot mixing zone per project.
4) The extent of take from dyes interfering with vision to detect prey or predators is that associated with up to 20 ppb per dye test.

These metrics are easily observed and are causally linked to the anticipated harm because as each source of water quality reduction increases, the number of exposed individuals will also increase.

Each of the metrics will be the subject of programmatic notification and verification requirements outlined in the administrative section of this document.

Extent of Harm from Loss of Aquatic Habitat (including exclusion via sound, light, and EMF)

In addition to the habitat interference noted above, other activities that may cause take in the form of harm due to habitat unavailability (disturbance and avoidance) are activities 9, 10 and 11 (lights, noise, and emf, respectively). Take by these effects cannot be reliably observed or quantified, and therefore NMFS will rely on a surrogate extent of take as follows:

1. Harm due to non-eye safe light emitting devices will cause take to the extent associated with the use of up to 5 devices at one time.
2. Harm due to acoustic device operations within hearing rage will cause take to the extent associated with no more than one device per species within hearing range at a time
3. Harm due to EMF operations will cause take to the extent associated with up to 10 operations at one time.

The above described extent from loss of or exclusion of aquatic habitat are observable metrics that are causally linked to the form of take (harm) that will occur among the salmonids and sunflower sea stars, as an increase in the extent would result in greater potential for exposure of more individuals from the listed species. Each of them will be monitored by the notification and verification requirements of this program.

Extent of take from entrainment, capture and release

Activities 4A, 5A, 6, 12 and 13 all have the potential to entrain in (or impinge on) equipment or devices (collectively presented here as entrainment). This type of take results in injury or death, which is likely among larval rockfish and larval sunflower sea stars, as well as juvenile Chinook salmon, juvenile chum salmon, and eulachon. Some individuals of these species will be entrained, (injured, or killed) when projects that have an intake system are in use. This take cannot be reliably observed or quantified, and therefore NMFS will rely on a surrogate measure of take, as follows:

1. The extent of entrainment take from sampling activities (4A, 5A, 8) is that associated with the removal of up to 1,026 square feet of material annually.

2. The extent of entrainment take from Activities 12 is that associated with the use of up to 150 devices per year, and for Activity 13, up to one device per year.

These numbers forming the extent of entrainment are a rational and reliable surrogate as they are easily observable, and causally linked to the form of take, as any increase in the numbers of such entraining projects increases the potential for more individuals of the listed species to be entrained. The extent of take can be reliably monitored by employing the program's notification verification processes.

Table 39 provides a summary presentation of the several extents of take described above.

Table 39. Incidental take pathways and associated indicators of the amount or extent of incidental take.

Incidental Take Pathway	Amount or Extent of Incidental Take
Structure-caused shade, migration disruption, loss of aquatic habitat, and/or benthic impacts	1) No more than 455 structures totaling 144,705 square feet to be installed/in place annually 1) No more than 359 totaling 125,785 square feet to be installed/in place at one time
Entrainment, injury, or death from ground sampling operations (square feet)	1) Sampling No more than 1,026 square feet of sediment/SAV/seagrass/macroalgae removed on one year. 2) Devices limits: – 150 for Activity 12 – 1 for Activity 13
Water quality reductions	1) No more than 30 benthic sediment sampling surveys per year, at 27 cubic feet per survey or 810 cubic feet per year 2) No more than 216 square feet per year: – 108 square feet in Sequim Bay – 108 square feet per year in the Strait of Juan de Fuca – No more than 10 percent of the total seagrass area 3) 300-foot mixing zone per installation 4) Dyes – No more the 20 ppb per release
Habitat loss or exclusion	1) Structures (See Table 1) 2) Disturbance (light, sound, emf): – Non-eye safe light emitting devices – no more than 5 at one time – Acoustic device operations within hearing rage – 1 per species hearing range at one time – EMF operations – no more than 10 at one time

2.9.2 Effect of the Take

In the biological opinion, NMFS determined that the amount or extent of anticipated take, coupled with other effects of the proposed action, is not likely to result in jeopardy to the species or destruction or adverse modification of critical habitat.

2.9.3 Reasonable and Prudent Measures

"Reasonable and prudent measures" are measures that are necessary or appropriate to minimize the impact of the amount or extent of incidental take (50 CFR 402.02).

The following measures are necessary and appropriate to minimize the impact of incidental take of listed species from the PNNL RAP proposed action.

1. Ensure completion of a monitoring and reporting program

2.9.4 Terms and Conditions

In order to be exempt from the prohibitions of section 9 of the ESA, the Federal action agency must comply (or must ensure that any permittee complies) with the following terms and conditions. The DOE has a continuing duty to monitor the impacts of incidental take and must report the progress of the action and its impact on the species as specified in this ITS (50 CFR 402.14). If the entity to whom a term and condition is directed does not comply with the following terms and conditions, protective coverage for the proposed action would likely lapse.

1. To implement reasonable and prudent measure #1:
    a. The DOE shall follow Program Administration # 11 (Monitoring and reporting)
    b. The DOE shall ensure that amount and extent of incidental take as expressed above are not exceeded by tracking and reporting the on metrics in Tables 38 and 39, annually.
    c. Report to NMFS when:
        i. monitoring for incidental take pathways identifies elements that exceed the performance or design criteria.
        ii. Monitoring or incidental observation reveals distressed, injured, or dead listed fish or mammals;
        iii. Sunflower sea stars are present in any areas where they require capture and release to avoid injury or death.
    d. Reports shall be sent to projectreports.wcr@noaa.gov, with a cc to Lisa.Abernathy@noaa.gov.
    e. Reports shall include "WCRO-2020-02569 PNNL RAP" in the regarding line.

2.10 Conservation Recommendations

Section 7(a)(1) of the ESA directs federal agencies to use their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of the threatened and endangered species. Specifically, "conservation recommendations" are suggestions regarding discretionary measures to minimize or avoid adverse effects of a proposed action on listed species or critical habitat or regarding the development of information (50 CFR 402.02).

1. The DOE should hold trainings, with or without NMFS participation, every 3 years to update and educate researchers and staff on why ESA compliance is important and required.
2. Prioritize for approval projects that can be installed and removed during the preferred work window.

2.11 Reinitiation of Consultation

This concludes formal consultation for PNNL RAP. Under 50 CFR 402.16(a): "Reinitiation of consultation is required and shall be requested by the Federal agency or by NMFS where discretionary Federal agency involvement or control over the action has been retained or is authorized by law and: (1) If the amount or extent of taking specified in the incidental take statement is exceeded; (2) If new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not previously considered; (3) If the identified action is subsequently modified in a manner that causes an effect to the listed species or critical habitat that was not considered in the biological opinion or written concurrence; or (4) If a new species is listed or critical habitat designated that may be affected by the identified action."

3 MAGNUSON–STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT ESSENTIAL FISH HABITAT RESPONSE

Section 305(b) of the MSA directs federal agencies to consult with NMFS on all actions or proposed actions that may adversely affect EFH. Under the MSA, this consultation is intended to promote the conservation of EFH as necessary to support sustainable fisheries and the managed species' contribution to a healthy ecosystem. For the purposes of the MSA, EFH means "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity", and includes the physical, biological, and chemical properties that are used by fish (50 CFR 600.10). Adverse effect means any impact that reduces quality or quantity of EFH, and may include direct or indirect physical, chemical, or biological alteration of the waters or substrate and loss of (or injury to) benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality or quantity of EFH. Adverse effects on EFH may result from actions occurring within EFH or outside of it and may include site-specific or EFH-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 CFR 600.810). Section 305(b) of the MSA also requires NMFS to recommend measures that can be taken by the action agency to conserve EFH. Such recommendations may include measures to avoid, minimize, mitigate, or otherwise offset the adverse effects of the action on EFH [CFR 600.905(b)].

This analysis is based, in part, on the PNNL RAP proposed action provided by the DOE and descriptions of EFH for Pacific Coast groundfish (Pacific Fishery Management Council (PFMC 2019), coastal pelagic species (CPS) (PFMC 2019) and, Pacific Coast salmon (PFMC 2016); contained in the fishery management plans developed by the PFMC and approved by the Secretary of Commerce.

3.1 Essential Fish Habitat Affected by the Project

The entire action area of the fully overlaps with identified EFH for Pacific Coast groundfish, coastal pelagic species, and Pacific Coast salmon.

3.2 Adverse Effects on Essential Fish Habitat

All of the PDC's included in the PNNL RAP have the ability to degrade the quality of EFH (Table 40). Some of the activities require conservation offsets to compensate for the loss of habitat quality in nearshore areas. These nearshore areas are EFH for multiple species. Although the offsets are intended to avoid the net-loss of habitat quality, the adverse effects still result from the activity categories identified above. The EFH recommendations below are intended to provide avoidance and minimization measures that go beyond the PNNL RAP proposed action.

Alterations to the nearshore light, wave energy, and substrate regimes affect the nature of EFH and nearshore food webs that are important to a wide variety of marine finfish and shellfish (Armstrong et al.1987, Beal 2018; Burdick and Short 1995, Cardwell and Koons 1981, Kenworthy and Haunert 1991, Olson et al. 1996, Parametrix and Battelle 1996, Penttila and Doty 1990, Shafer 1999; Simenstad et al. 1979, Thom and Shreffler 1996, Weitkamp 1991).

Table 40. EFH and PDC Effect Table

No.	PDC/Activity	Salmon EFH Effect	Groundfish EFH Effect	Coastal Pelagic EFH Effect
1	Floats and Buoys	x	x	x
2	Dock Installations			
3	Seabed Installations	x	x	
4	Autonomous Vehicles	x	x	
5	Benthic Surveys	x	x	
6	Water Column Sampling	x	x	x
7	Dye and Particulates			
8	Seagrass, microalgae Studies	x	x	x
9	Light Emitting Studies	x	x	x
10	Acoustic Studies	x	x	x
11	EMF Studies	x	x	x
12	Marine Energy Devices	x	x	x
13	Turbines	x	x	x

The effects of the proposed action on ESA-listed species are described in Section 2.5 of the ESA analysis above. The same mechanisms of effect are likely to affect all Pacific Coast groundfish, coastal pelagic species, and Pacific Coast salmon to varying degrees. Some additional adverse effects include:

1. Water quality – both temporary and permanent. Examples include sound, light, EMF, turbidity, and run off contaminants.

Additionally, copper-based paints are frequently used on vessel hulls in marine environments as an antifouling agent. These pesticidal paints slowly leach copper from the hull in order to deter attachment of fouling species, which may slow boats and increase fuel consumption. Copper that is leached into the marine environment does not break down and may accumulate in aquatic organisms, particularly in systems with poor tidal flushing. At low concentrations, metals such as copper may inhibit development and reproduction of marine organisms, and at high concentrations they can directly contaminate and kill fish and invertebrates. In coho salmon, low levels of copper have been shown to cause olfactory impairment, affecting their predator avoidance and survival (McIntyre 2012). These metals have been found to adversely impact phytoplankton (NEFMC 1998), larval development in haddock, and reduced hatch rates in winter flounder (Bodammer 1981, Klein-MacPhee et al. 1984). Other animals can acquire elevated levels of copper indirectly through trophic transfer, and may exhibit toxic effects at the cellular level (DNA damage), tissue level (pathology), organism level (reduced growth, altered behavior and mortality), and community level (reduced abundance, reduced species richness, and reduced diversity) (Weis et al. 1998, Weis and Weis 2004, Eisler 2000).

2. Forage reduction – disturbance and shading of SAV can result in reduction in SAV density and abundance, and related primary production. Designated EFH will experience temporary, episodic, and enduring declines in forage or prey communities.

Whitney and Darley (1983) found that microalgal communities in shaded areas are generally less productive than unshaded areas, with productivity positively correlated with ambient irradiance. Stutes et al. (2006) found a significant effect of shading on both sediment primary production and metabolism (i.e. sediment respiration). Intertidal salt marsh plants are also impacted by shading: the density of *Spartina alterniflora* was significantly lower under docks than adjacent to docks in South Carolina estuaries, with stem densities decreased by 71 percent (Sanger et al. 2004). Kearny et al. (1983) found the *S. alterniflora* was completely shaded out under docks that were less than 40 cm high and that the elimination of the macrophytic communities under the docks ultimately led to increased sediment erosion. Thom et al. (2008) evaluated the effects of short- and long-term reductions in submarine light reaching eelgrass in the Pacific Northwest, especially related to turbidity and overwater structures. They found that lower light levels may result in larger and less dense plants and provided light requirements for the protection and restoration of eelgrass.

Reductions in benthic primary productivity may in turn adversely affect invertebrate distribution patterns. For example, Struck et al. (2004) observed invertebrate densities under bridges at 25-52 percent of those observed at adjacent unshaded sites. These results were found to be correlated with diminished macrophyte biomass, a direct result of increased shading. Overwater structures that attenuate light may adversely affect estuarine marsh food webs by reducing macrophyte growth, soil organic carbon, and altering the density and diversity of benthic invertebrates (Whitcraft and Levin 2007). Reductions in primary and invertebrate productivity may additionally limit available prey resources to federally managed fish species and other important commercial and recreational species. Prey resource limitations likely impact movement patterns and the survival of many juvenile fish species. Adverse impacts to estuarine productivity may, therefore, have effects that cascade through the nearshore food web.

Fishes rely on visual cues for spatial orientation, prey capture, schooling, predator avoidance, and migration. Juvenile and larval fish are primarily visual feeders with starvation being the major cause of larval mortality in marine fish populations. Survival at early life history stages is often critical in determining recruitment and survival at subsequent life stages, with survival linked to the ability to locate and capture prey and to avoid predation (Britt 2001). The reduced-light conditions found under overwater structures limit the ability of fishes, especially juveniles and larvae, to perform these essential activities. For example, Able et al. (1999) found that caged fish under piers had growth rates similar to those held in a laboratory setting without food. In contrast, growth rates of fish caged in pile fields and open water were significantly higher. Able et al. (1998) also demonstrated that juvenile fish abundance and species richness was significantly lower under piers in an urban estuary. Although some visual predators may use alternative modes of perception, feeding rates sufficient for growth in dark areas usually demand high prey concentrations and encounter rates (Grecay and Targett 1996). As coastal development and overwater structure expansion continues, the underwater light environment will continue to degrade, resulting in adverse effects to EFH and nearshore ecosystems.

3. Migration and passage - Designated salmon EFH will experience enduring incremental diminishment of safe migration. As mentioned in Section 2.5 above, in the marine nearshore, there is substantial evidence that OWS impede the nearshore movements of juvenile salmonids.

As described for critical habitats, operation of light sources as described is not expected to affect large portions of EFH as the operation would be restricted to the project areas. Temporary operation could temporarily affect the associated groundfish benthic EFH or the CPS and Salmon species pelagic EFH. However, the small relative area and temporary operations are expected to have minimal effects on use of EFH in the project areas as nearby unaffected habitat could be used for foraging or migration.

EFH Adverse Effects Determination

Based upon the analysis presented above and in Section 2 of this document, NMFS has determined that the activities that would be authorized under this programmatic consultation would adversely affect EFH for various federally-managed fish species under the Pacific Coast groundfish species, coastal pelagic species, and Pacific Coast salmon species FMPs. Moreover, projects authorized under PNNL RAP will adversely affect estuary and seagrass HAPCs for Pacific Coast salmon and Pacific Coast groundfish.

3.3 Essential Fish Habitat Conservation Recommendations

NMFS determined that the following conservation recommendations are necessary to avoid, minimize, mitigate, or otherwise offset the impact of the proposed action on EFH.

General Recommendations

1. Projects resulting in an impacts to eelgrass habitat should be required to follow eelgrass survey guidelines put forth in the Washington Department of Fish and Wildlife "Eelgrass/Macroalgae Habitat Interim Survey Guidelines"[12].

2. As part of its application, permittees should describe how their proposal addresses the specific conservation recommendations identified below. NMFS recognizes that not all conservation recommendations will be relevant in all situations. Therefore, the proponent should clearly articulate when a particular recommendation is not applicable to the proposed project. Based upon the project application, the DOE should determine if the project implements appropriate conservation recommendations and, therefore, can be covered by this consultation.

3. Conduct, or have recent equivalate analysis, of forage fish surveys (sand lance and surf smelt) for projects that impact beach/shoreline areas (i.e. crawlers, sediment sampling, cable laying, etc.).

[12] https://wdfw.wa.gov/sites/default/files/publications/00714/wdfw00714.pdf

Floats and Buoys

For all projects, the project proponent should strive to implement avoidance measures to the extent feasible. When avoidance measures are not feasible, minimization measures should be implemented. Although PNNL RAP requires conservation offsets for some overwater structures, avoidance and minimization of effects are preferable. We recommend the following.

Avoidance:

4. Floats and buoys should be anchored in areas where SAV (e.g., eelgrass, kelp) habitat is absent. This will reduce adverse impacts to SAV. Additionally, all buoys and floats should, to the maximum extent practicable, be in waters deep enough so that the bottom remains a minimum of 18 inches off the substrate during extreme low tide events. This will reduce adverse grounding impacts to benthic habitat.

Minimization:

5. Floats and buoys located within SAV habitat should be of the type that use midline floats, where appropriate, to prevent chain scour to the substrate. This will reduce adverse impacts to SAV and other benthic habitat.

Over- and in- water Structures

For all projects, the project proponent should strive to implement minimization measures to the extent feasible.

Avoidance:

6. Avoid use of ACZA treated wood and rubber tires would at all times.

Minimization:

7. Minimize, to the maximum extent practicable, the footprint of the overwater structure.

8. Design longer term structures in a north-south orientation, to the maximum extent practicable, to minimize persistent shading over the course of a diurnal cycle.

3.4 Statutory Response Requirement

As required by section 305(b)(4)(B) of the MSA, the DOE must provide a detailed response in writing to NMFS within 30 days after receiving these EFH conservation recommendations. Such a response must be provided at least 10 days prior to final approval of the action if the response is inconsistent with any of NMFS' EFH conservation recommendations unless NMFS and the federal agency have agreed to use alternative timeframes for the federal agency response. The response must include a description of measures proposed by the agency for avoiding, mitigating, or offsetting the impact of the activity on EFH. In the case of a response that is inconsistent with the conservation recommendations, the federal agency must explain its reasons for not following the recommendations, including the scientific justification for any disagreements with NMFS over the anticipated effects of the action and the measures needed to avoid, minimize, mitigate, or offset such effects (50 CFR 600.920(k)(1)). If it is not possible to provide a substantive response within 30 days, the DOE should provide an interim response to NMFS, to be followed by the detailed response. The detailed response should be provided in a manner to ensure that it is received by NMFS at least 10 days prior to the final approval of the action. In the case of this programmatic, the EFH conservation recommendations will be provided on the notification/verification form, Appendix C, and the appropriate boxes should be checked at form submission. If an EFH CR is applicable for the action, but not applied, a justification must be provided.

In response to increased oversight of overall EFH program effectiveness by the Office of Management and Budget, NMFS established a quarterly reporting requirement to determine how many conservation recommendations are provided as part of each EFH consultation and how many are adopted by the action agency. Therefore, we ask that in your statutory reply to the EFH portion of this consultation, again, via the Appendix C form, you clearly identify the number of conservation recommendations accepted.

3.5 Supplemental Consultation

The DOE must reinitiate EFH consultation with NMFS if the proposed action is substantially revised in a way that may adversely affect EFH, or if new information becomes available that affects the basis for NMFS' EFH conservation recommendations (50 CFR 600.920(l)).

4 DATA QUALITY ACT DOCUMENTATION AND PRE-DISSEMINATION REVIEW

The Data Quality Act (DQA) specifies three components contributing to the quality of a document. They are utility, integrity, and objectivity. This section of the opinion addresses these DQA components, documents compliance with the DQA, and certifies that this opinion has undergone pre-dissemination review.

4.1 Utility

'Utility' principally refers to ensuring that the information contained in this consultation is helpful, serviceable, and beneficial to the intended users. The intended user of this Opinion is the DOE. Other interested users could include permit applicants, citizens of affected areas, and other parties interested in the conservation of the affected ESUs/DPS. Individual copies of this Opinion were provided to the DOE. The document will be available at the NOAA Library Institutional Repository [https://repository.library.noaa.gov/welcome]. The format and naming adhere to conventional standards for style.

4.2 Integrity

This consultation was completed on a computer system managed by NMFS in accordance with relevant information technology security policies and standards set out in Appendix III, 'Security of Automated Information Resources,' Office of Management and Budget Circular A-130; the Computer Security Act; and the Government Information Security Reform Act.

4.3 Objectivity

Information Product Category: Natural Resource Plan

Standards: This consultation and supporting documents are clear, concise, complete, and unbiased; and were developed using commonly accepted scientific research methods. They adhere to published standards including the NMFS ESA Consultation Handbook, ESA regulations, 50 CFR 402.01 et seq., and the MSA implementing regulations regarding EFH, 50 CFR part 600.

Best Available Information: This consultation and supporting documents use the best available information, as referenced in the References section. The analyses in this Opinion and the EFH consultation, contain more background on information sources and quality.

Referencing: All supporting materials, information, data and analyses are properly referenced, consistent with standard scientific referencing style.

Review Process: This consultation was drafted by NMFS staff with training in ESA and MSA implementation, and reviewed in accordance with West Coast Region ESA quality control and assurance processes.

5. REFERENCES

Able, K. W., J.P. Manderson, and A.L. Studholme. 1998. The distribution of shallow water juvenile fishes in an urban estuary: The effects of manmade structures in the lower Hudson River. Estuaries. 21:731-744.

Able, K. W., J. P. Manderson, and A. L. Studholme. 1999. Habitat quality for shallow water fishes in an urban estuary: The effects of manmade structures on growth. Marine Ecology-Progress Series 187:227–235

Agne, M.C., P.A. Beedlow, D.C. Shaw, D.R. Woodruff, E.H. Lee, S.P. Cline, and R.L. Comeleo. 2018. Interactions of predominant insects and diseases with climate change in Douglas-fir forests of western Oregon and Washington, U.S.A. Forest Ecology and Management 409(1). https://doi.org/10.1016/j.foreco.2017.11.004

Ahn, J.H. 2012. Size distribution and settling velocities of suspended particles in a tidal embayment, Water Research, Volume 46, Issue 10. Pages 3219-3228. ISSN 0043-1354, https://doi.org/10.1016/j.watres.2012.03.038.

Alizedeh, M.R., J.T. Abatzoglou, C.H. Luce, J.F. Adamowski, A. Farid, and M. Sadegh. 2021. Warming enabled upslope advance in western US forest fires. PNAS 118(22) e2009717118. https://doi.org/10.1073/pnas.2009717118

Anderson, J. J., E. Gurarie, and R.W. Zabel. 2005. Mean free-path length theory of predator-prey interactions: Application to juvenile salmon migration. Ecological Modelling. 186:196-211.

Anderson, S. C., J. W. Moore, M. M. McClure, N. K. Dulvy, and A. B. Cooper. 2015. Portfolio conservation of metapopulations under climate change. Ecological Applications 25:559-572.

Aquino CA, Besemer RM, DeRito CM, Kocian J, Porter IR, Raimondi PT, Rede JE, Schiebelhut LM, Sparks JP, Wares JP et al. 2021. Evidence that microorganisms at the animal-water interface drive sea star wasting disease. Frontiers in Microbiology. 11(3278).

Armstrong, D. A., J. A. Armstrong, and P. Dinnel. 1987. Ecology and population dynamics of Dungeness crab, Cancer Magister in Ship Harbor, Anacortes, Washington. FRI-UW-8701. UW, School of Fisheries, Fisheries Research Institute, Seattle, WA

Au, W. W., J. K. Horne, and C. Jones. 2010. Basis of acoustic discrimination of Chinook salmon from other salmons by echolocating Orcinus orca. The Journal of the Acoustical Society of America. 128: 2225-32.

Augustine, C., Bain, R., Chapman, J., Denholm, P., Drury, E., Hall, D.G., Lantz, E., Margolis, R., Thresher, R., Sandor, D. and Bishop, N.A., 2012. Renewable electricity futures study. volume 2. renewable electricity generation and storage technologies (No. NREL/TP-6A20-52409-2). National Renewable Energy Lab.(NREL), Golden, CO (United States).

Bain, D. 1990. Examining the validity of inferences drawn from photo-identification data, with special reference to studies of the killer whale (Orcinus orca) in British Columbia. Report of the International Whaling Commission, Special Issue 12:93- 100.

Baird RW. The killer whale. Cetacean societies: field studies of dolphins and whales. 2000;127:153.

Barlow, J., J. Calambokidis, E.A. Falcone, C.S. Baker, A.M. Burdin, P.J. Clapham, J.K.B. Ford, C.M. Gabriele, R. LeDuc, D.K. Mattila, T.J. Quinn, L. Rojas-Bracho, J.M. Straley, B.L. Taylor, J. Urban-R., P. Wade, D. Weller, B. Witteveen, and M. Yamaguchi. 2011. Humpback whale abundance in the North Pacific estimated by photographic capture-recapture with bias correction from simulation studies. . Marine Mammal Science. 27(4):793-818.

Barnett, H.K., T.P. Quinn, M. Bhuthimethee, and J.R. Winton. 2020. Increased prespawning mortality threatens an integrated natural- and hatchery-origin sockeye salmon population in the Lake Washington Basin. Fisheries Research 227. https://doi.org/10.1016/j.fishres.2020.105527

Barnett-Johnson, R., C. B. Grimes, C.F. Royer, and C. J. Donohoe. 2007. Identifying the contribution of wild and hatchery Chinook salmon (Oncorhynchus tshawytscha) to the ocean fishery using otolith microstructure as natural tags. Canadian Journal of Fisheries and Aquatic Sciences, 2007, 64(12): 1683-1692

Bax, N. J., E. O. Salo, B. P. Snyder, C. A. Simenstad, and W. J. Kinney. 1978. Salmonid outmigration studies in Hood Canal. Final Report, Phase III. January - July 1977, to U.S. Navy, Wash. Dep. Fish., and Wash. Sea Grant. Fish. Res. Inst., Univ. Wash., Seattle, WA. FRI-UW-7819. 128 pp.

Beale, D.J., Crosswell, J., Karpe, A.V., Metcalfe, S.S., Morrison, P.D., Staley, C., Ahmed, W., Sadowsky, M.J., Palombo, E.A. and Steven, A.D.L., 2018. Seasonal metabolic analysis of marine sediments collected from Moreton Bay in South East Queensland, Australia, using a multi-omics-based approach. Science of the Total Environment, 631, pp.1328-1341.

Beechie, T., E. Buhle, M. Ruckelshaus, A. Fullerton, and L. Holsinger. 2006. Hydrologic regime and the conservation of salmon life history diversity. Biological Conservation, 130(4), pp.560-572.

Benton, T.G, C. Bieg, H. Harwatt, R. Pudasaini, L. Wellesley. 2021. Food system impacts on biodiversity loss Three levers for food system transformation in support of nature. Energy, Environment and Resources Programme, Chatham House, the Royal Institute of International Affairs, London UK.

Bevelhimer, M.S., G.F. Cada , A.M. Fortner , P.E. Schweizer, K. Riemer. 2013. Behavioral Responses of Representative Freshwater Fish Species to Electromagnetic Fields, Transactions of the American Fisheries Society, 142:3, 802-813, DOI: 10.1080/00028487.2013.778901

Bevelhimer, M.S., J. Colby. M. Adonizio, C. Tomichek, and C.C. Scherelis. 2016. Informing a Tidal Turbine Strike Probability Model through Characterization of Fish Behavioral Response using Multibeam Sonar Output. Technical Report. Oak Ridge National Laboratory, Oak Ridge, TN.

Bigg, M. 1982. An assessment of killer whale (Orcinus orca) stocks off Vancouver Island, British Columbia. Report of the International Whaling Commission 32:655-666.

Bigg, M.A., P.F. Olesiuk, G.M. Ellis, J.K.B. Ford, and K.C. Balcomb. 1990. Social organization and genealogy of resident killer whales (Orcinus orca) in the coastal waters of British Columbia and Washington State. Report of the International Whaling Commission, Special Issue 12:383-398.

Black, B.A., P. van der Sleen, E. Di Lorenzo, D. Griffin, W.J. Sydeman, J.B. Dunham, R.R. Rykaczewski, M. García-Reyes, M. Safeeq, I. Arismendi, and S.J. Bograd. 2018. Rising synchrony controls western North American ecosystems. Global change biology, 24(6), pp. 2305-2314.

Bodammer, J.E. 1981. The cytopathological effects of copper on the olfactory organs of larval fish (Pseudopleuronectes americanus and Melanogrammus aeglefinus). Copenhagen (Denmark): ICES CM-1981/E: 46

Boehlert, G. W. 1984. Abrasive effects of Mt. St. Helens ash upon epidermis of yolk-sac larvae of Pacific herring, Clupea harengus pallasi. Mar. envir. Res. 12: 113–126.

Boehlert, G. W. and Morgan, J.B. 1985. Turbidity enhances feeding abilities of larval Pacific herring, Clupea harengus pallasi . Hydrobiologia 123, 161–170.

BOEM (Bureau of Ocean Management). 2019. Evaluation of potential EMF effects on Fish Species of Commercial or Recreational Fishing Importance in Southern New England. OCS study BOEM 2019-049. Authors: David B. Snyder, William H. Bailey, Ph.D., Katherine Palmquist, Ph.D., Benjamin R.T. Cotts, Ph.D., and Kimberley R. Olsen

Bonefeld-Jørgensen, E. C., H. R. Andersen, T. H. Rasmussen, and A. M. Vinggaard. 2011. Effect of highly bioaccumulated polychlorinated biphenyl congeners on estrogen and androgen receptor activity. Toxicology 158:141–153.

Bradford, A. L., D. W. Weller, A. E. Punt, Y. V. Ivashchenko YV, A. M. Burdin, G. R. VanBlaricom, and R. L. Brownell. 2012. Leaner leviathans: body condition variation in critically endangered whale population. J. Mammal. 93(1):251-266.

Braun, D.C., J.W. Moore, J. Candy, and R.E. Bailey. 2016. Population diversity in salmon: linkages among response, genetic and life history diversity. Ecography, 39(3), pp.317-328.

Brennan, J.S., K.F. Higgins, J.R. Cordell, and V.A .Stamatiou. 2004. Juvenile salmon composition, timing, distribution, and diet in marine nearshore waters of central Puget Sound in 2001-2002. King county Department of Natural Resources and Parks, Seattle, WA. 164 pp.

Britt, L.L. 2001. Aspects of the vision and feeding ecology of larval lingcod (Ophiodonelongatus) and Kelp Greenling (Hexagrammos decagrammus). M.Sc. Thesis, University of Washington

Bryant, P. J., Lafferty, C.M. and Lafferty, S.K. 1984. Reoccupation of Laguna Guerrero Negro, Baja California, Mexico, by gray whales. pp. 375-387. In: M.L. Jones, S.L. Swartz, S. Leatherwood (eds.). The Gray Whale Eschrichtius robustus. Academic Press, San Diego, California. xxiv+600p

Burdick, D. M. and F.T. Short. 1995. The effects of boat docks on eelgrass beds in coastal waters of Massachusetts. Environmental Management 23: 231-240.

Burke, B.J., W.T. Peterson, B.R. Beckman, C. Morgan, E.A. Daly, M. Litz. 2013. Multivariate Models of Adult Pacific Salmon Returns. PLoS ONE 8(1): e54134. https://doi.org/10.1371/journal.pone.0054134

Burns, R. 1985. The shape and forms of Puget Sound. Published by Washington Sea Grant, and distributed by the University of Washington Press. 100 pages.

Burns, J.J., and G.A. Seaman. 1985. Investigations of belukha whales in coastal waters of western and northern Alaska II—Biology and ecology. U.S. National Oceanic and Atmospheric Administration, 129 pp.

Calambokidis, J., E.A. Falcone, T.J. Quinn, A.M. Burdin, P.J. Clapham, J.K.B. Ford, C.M. Gabriele, R. LeDuc, D.K. Mattila, L. Rojas-Bracho, J.M. Straley, B.L. Taylor, J. Urbán-Ramirez, R.D. Weller, B.H. Witteveen, M. Yamaguchi, A. Bendlin, D. Camacho, K. Flynn, A. Havron, J. Huggins, and N. Maloney. 2008. SPLASH: Structure of Populations, Levels of Abundance and Status of Humpback Whales in the North Pacific. Cascadia Research.

Calambokidis, J. and J. Barlow. 2020. Updated abundance estimates for blue and humpback whales along the U.S. west coast using data through 2018, U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-634.

Caltrans (2015). Technical guidance for assessment and mitigation of the hydroacoustic effects of pile driving on fish. Sacramento, California, Caltrans, Division of Environmental Analysis: 532.

Cardwell, R. D., and R.R. Koons. 1981. Biological considerations for the siting and design of marinas and affiliated structures in Puget Sound. Technical Report No. 60. Washington Dept. of Fisheries, Olympia, WA.

Carr, M. H. 1983. Spatial and temporal patterns of recruitment of young-of-the-year rockfishes (genus Sebastes) into a central California kelp forest. Master's thesis. San Francisco State Univ., Moss Landing Marine Laboratories, Moss Landing, CA.

Carr-Harris, C.N., J.W. Moore, A.S. Gottesfeld, J.A. Gordon, W.M. Shepert, J.D. Henry Jr, H.J. Russell, W.N. Helin, D.J. Doolan, and T.D. Beacham. 2018. Phenological diversity of salmon smolt migration timing within a large watershed. Transactions of the American Fisheries Society, 147(5), pp.775-790.

Carretta, J.W., E.M. Olson, K.A. Forney, M.M. Muto, D.W. Weller, A.R. Lang, J. Baker, B. Hanson, A.J. Orr, J. Barlow, J.E. Moore, R.L. Brownell. 2021. U.S. Pacific Marine Mammal Stock Assessments: 2020. NOAA- TM-NMFS-SWFSC-646. https://media.fisheries.noaa.gov/2021-07/Pacific%202020%20SARs%20Final%20Working%20508.pdf?null%09

Celedonia, M.T., R.A. Tabor, S. Sanders, S. Damm, D.W. Lantz, T.M. Lee, Z. Li, J.-M. Pratt, B.E. Price, and L. Seyda. 2008. Movement and Habitat Use of Chinook Salmon Smolts, Northern Pike minnow, and Smallmouth Bass near the SR 520 Bridge, 2007 Acoustic Tracking Study. U.F.a.W. Service, editor. 139.

Celedonia, M.T., R.A. Tabor, S. Sanders, D.W. Lantz, and I. Grettenberger. 2008b. Movement and Habitat Use of Chinook Salmon Smolts and Two Predatory Fishes in Lake Washington and the Lake Washington Ship Canal, Western WS Fish and Wildlife Office Lacey, WA.

Center for Whale Research. 2019. https://www.whaleresearch.com/.

Chasco, B. E., B. J. Burke, L. G. Crozier, and R. W. Zabel. 2021. Differential impacts of freshwater and marine covariates on wild and hatchery Chinook salmon marine survival. PLoS ONE 16:e0246659. https://doi.org/0246610.0241371/journal.pone.0246659.

Clallam County. 2005. Elwha-Dungeness Water Shed Plan, "Chapter 2.10 Sequim Bay and Drainages." Port Angeles, Washington. Accessed December 19, 2019, at http://www.clallam.net/environment/assets/applets/W18_2.10-SequimBay.pdf. TN289

Clark, D.B., L. Lenain, F. Feddersen, E. Boss, and R.T. Guza. 2014. "Aerial Imaging of Fluorescent Dye in the Near Shore." Journal of Atmospheric and Ocean Technology 31:1410–1421. DOI: 10.1175/JTECH-D-13-00230.1.

Clark, T. D., Raby, G.D., Roche, D.G., Binning, S.A., Speers-Roesch, B., Jutfelt, F. and Sundin, J., 2020. Ocean acidification does not impair the behaviour of coral reef fishes. Nature, 577(7790), pp.370-375.

Clutton-Brock, T. H. 1988. Reproductive Success. Studies of individual variation in contrasting breeding systems. University of Chicago Press, Chicago, Illinois.

Cooper, M.G., J. R. Schaperow, S. W. Cooley,S. Alam,L. C. Smith, D. P. Lettenmaier. 2018. Climate Elasticity of Low Flows in the Maritime Western U.S. Mountains. Water Resources Research. https://doi.org/10.1029/2018WR022816

Copping, A.E. and Hemery, L.G., editors. 2020. OES-Environmental 2020 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World. Report for Ocean Energy Systems (OES). DOI: 10.2172/1632878.

Cordell, J. R., Munsch, S.H., Shelton, M.E. and Toft, J.D., 2017. Effects of piers on assemblage composition, abundance, and taxa richness of small epibenthic invertebrates. Hydrobiologia, 802(1), pp.211-220.

Coulson, T., Benton, T. G., Lundberg, P., Dall, S. R., Kendall, B. E., & Gaillard, J. M. 2006. Estimating individual contributions to population growth: evolutionary fitness in ecological time. Proceedings. Biological sciences, 273(1586), 547–555. https://doi.org/10.1098/rspb.2005.3357

Cowardin, L.M., V. Carter, F.C. Golet, E.T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States U.S . Fish and Wildlife Service Northern Prairie Wildlife Research Center Jamestown, North Dakota

Cox, S.L., B.E. Scott, and C.J. Camphuysen. 2012. Combined Spatial and Tidal Processes Identify Links between Pelagic Prey Species and Seabirds. Marine Ecology Progress Series 479: 203-221.

Crozier, L. 2015. Impacts of Climate Change on Columbia River Salmon: A review of the scientific literature published in 2014. Pages D1-D50 in Endangered Species Act Section 7(a)(2) supplemental biological opinion: consultation on remand for operation of the Federal Columbia River Power System. U.S. National Marine Fisheries Service, Northwest Region.

Crozier, L. 2016. Impacts of Climate Change on Columbia River Salmon: A review of the scientific literature published in 2015. Pages D1-D50 in Endangered Species Act Section 7(a)(2) supplemental biological opinion: consultation on remand for operation of the Federal Columbia River Power System. U.S. National Marine Fisheries Service, Northwest Region.

Crozier, L. 2017. Impacts of Climate Change on Columbia River Salmon: A review of the scientific literature published in 2016. Pages D1-D50 in Endangered Species Act Section 7(a)(2) supplemental biological opinion: consultation on remand for operation of the Federal Columbia River Power System. U.S. National Marine Fisheries Service, Northwest Region.

Crozier, L. G., and J. Siegel. 2018. Impacts of Climate Change on Columbia River Salmon: A review of the scientific literature published in 2017. Pages D1-D50 in Endangered Species Act Section 7(a)(2) supplemental biological opinion: consultation on remand for operation of the Federal Columbia River Power System. U.S. National Marine Fisheries Service, Northwest Region.

Crozier, L. G., M. M. McClure, T. Beechie, S.J. Bograd, D.A. Boughton, M. Carr, et al. 2019. Climate vulnerability assessment for Pacific salmon and steelhead in the California Current Large Marine Ecosystem. PLoS ONE 14(7): e0217711.

Crozier, L.G. and R.W. Zabel. 2006. Climate impacts at multiple scales: evidence for differential population responses in juvenile Chinook salmon. Journal of Animal Ecology. 75:1100-1109.

Crozier, L., R.W. Zabel, S. Achord, and E.E. Hockersmith. 2010. Interacting effects of density and temperature on body size in multiple populations of Chinook salmon. Journal of Animal Ecology. 79:342-349.

Crozier L.G., M.M. McClure, T. Beechie, S.J. Bograd, D.A. Boughton, M. Carr, T. D. Cooney, J.B. Dunham, C.M. Greene, M.A. Haltuch, E.L. Hazen, D.M. Holzer, D.D. Huff, R.C. Johnson, C.E. Jordan, I.C. Kaplan, S.T. Lindley, N.Z. Mantua, P.B. Moyle, J.M. Myers, M.W. Nelson, B.C. Spence, L.A. Weitkamp, T.H. Williams, and E. Willis-Norton. 2019. Climate vulnerability assessment for Pacific salmon and steelhead in the California

Crozier, L.G., B.J. Burke, B.E. Chasco, D.L. Widener, and R.W. Zabel. 2021. Climate change threatens Chinook salmon throughout their life cycle. Communications biology, 4(1), pp.1-14.

Daan, S., C. Deerenberg and C. Dijkstra. 1996. Increased daily work precipitates natural death in the kestrel. The Journal of Animal Ecology 65(5): 539 - 544.

Darnerud, P. O. 2003. Toxic effects of brominated flame retardants in man and in wildlife Environment. 29:841–853.

Darnerud, P. O. 2008. Brominated flame retardants as possible endocrine disruptors. Int. J. Androl. 31:152–160.

de Almeida Rodrigues, P., R.G. Ferrari, J.V. da Anunciação de Pinho, D.K. Alves do Rosário, C. Couto de Almeida, T. Dillenburg Saint'Pierre, R.A. Hauser-Davis, L. Neves dos Santos, C.A. Conte-Junior, Baseline titanium levels of three highly consumed invertebrates from an eutrophic estuary in southeastern Brazil, Marine Pollution Bulletin, Volume 183, 2022, 114038, ISSN 0025-326X, https://doi.org/10.1016/j.marpolbul.2022.114038.

de Boer, J., K. de Boer, and J. P. Boon. 2000. Toxic effects of brominated flame retardants in man and wildlife. Environ. Int. 29:841–853.

de Guise, S., M. Levin, E. Gebhard, L. Jasperse, L. B. Hart, C. R. Smith, S. Venn-Watson, F. Townsend, R. Wells, B. Balmer, E. Zolman, T. Rowles, and L. Schwacke. 2017. Changes in immune functions in bottlenose dolphins in the northern Gulf of Mexico associated with the Deepwater Horizon oil spill. Endangered Species Research. 33: 291–303.

da Silva, C.L.D.L., P.H.C.B. Dagola, M.A.C. Moreira, and L.F.U. dos Santos. 2022. Environmental Impacts on Marine Energy: Collision Risks for Marine Animals and Priority Species for Monitoring in Brazil. J. Integrated Coastal Zone Management 22(2): 127-143.

de Swart, R. L., P. S. Ross, J. G. Vos, and A.Osterhaus. 1996. Impaired immunity in habour seals (Phoca vitulina) exposed to bioaccumulated environmental contaminants: Review of long-term feeding study. Environ. Health Perspect. 104:823–828.

Deagle, B.E., D.J. Tollit, S.N. Jarman, M.A. Hindell, A.W. Trites, and N.J. Gales. 2005. Molecular scatology as a tool to study diet: analysis of prey DNA in scats from captive Steller sea lions. Mol. Ecol. 14:1831-1842.

Dorner, B., M.J. Catalano, and R.M. Peterman. 2018. Spatial and temporal patterns of covariation in productivity of Chinook salmon populations of the northeastern Pacific Ocean. Canadian Journal of Fisheries and Aquatic Sciences, 75(7), pp.1082-1095.

Drake, J., R. Emmett, K. Fresh, R. Gustafson, M. Rowse, D. Teel, M. Wilson, P. Adams, E.A.K. Spangler, and R. Spangler. 2008. Summary of scientific conclusions of the review of the status of eulachon (*Thaleichthys pacificus*) in Washington, Oregon and California (Draft). U. S. Department of Commerce, Northwest Fisheries Science Center. Seattle.

Drake, J. S., E.A. Berntson, J.M. Cope, R.G. Gustafson, E.E. Holmes, P.S. Levin, N. Tolimieri, R.S. Waples, S.M. Sogard, and G.D. Williams. 2010. Status review of five rockfish species in Puget Sound, Washington: bocaccio (Sebastes paucispinis), canary rockfish (S. pinniger), yelloweye rockfish (S. ruberrimus), greenstriped rockfish (S. elongatus), and redstripe rockfish (S. proriger). U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-NWFSC-108, 234 pp.

Durban, J., H. Fearnbach, D. Ellifrit, and K. Balcomb. 2009. Size and Body Condition of Southern Resident Killer Whales. Contract report to National Marine Fisheries Service, Order No. AB133F08SE4742, February 2009.

Durban, J. W., H. Fearnbach, L. Barrett-Lennard, M. Groskreutz, W. Perryman, K. Balcomb, D. Ellifrit, M. Malleson, J. Cogan, J. Ford, and J. Towers. 2017. Photogrammetry and Body Condition. Availability of Prey for Southern Resident Killer Whales. Technical Workshop Proceedings. November 15-17, 2017.

Eisler, R. 2000. Handbook of Chemical Risk Assessment: Health Hazards to Humans, Plants and Animals, Volume 1: Metals. First CRC Press LLC Printing 2000. 738 p.

Elwha-Dungeness Planning Unit. 2005. Elwha-Dungeness Watershed Plan, Water Resource Inventory Area 18 (WRIA 18) and Sequim Bay in West WRIA 17. Clallam County, Port Angeles, Washington. Accessed August 4, 2020, at http://www.clallam.net/environment/elwhadungenesswria.html.

Erbe, C. and C. McPherson. 2017. Radiated noise levels from marine geotechnical drilling and standard penetration testing. The Journal of the Acoustical Society of America 141, 3847

Erickson, D. L. and J.E. Hightower. 2007. Oceanic distribution and behavior of green sturgeon. American Fisheries Society Symposium 56:197-211.

Fay, R.R. 1988. Hearing in vertebrates: A psychophysics databook. Hill-Fay Associates, Winnetka, IL.

Fearnbach, H., J. W. Durban, D. K. Ellifrit, and K. C. Balcomb. 2018. Using aerial photogrammetry to detect changes in body condition of endangered southern resident killer whales. Endangered Species Research. 35: 175–180.

Feist, B. E., J. J. Anderson, and R. Miyamoto. 1996. Potential impacts of pile driving on juvenile pink (Oncorhynchus gorbuscha) and chum (O. keta) salmon behavior and distribution. Fisheries Research Institute Report No. FRI-UW-9603. 67p.

Ferrara, G. A., T. M. Mongillo, and L. M. Barre. 2017. Reducing Disturbance from Vessels to Southern Resident Killer Whales: Assessing the Effectiveness of the 2011 Federal Regulations in Advancing Recovery Goals. December 2017. NOAA Technical Memorandum NMFS-OPR-58. 82p.

Fisher, W.K. 1928. Asteroidea of the North Pacific and adjacent waters. US Government Printing Office.

Fisheries and Oceans Canada. 2013. Recovery Strategy for the North Pacific Humpback Whale (Megaptera novaeangliae) in Canada. Species at Risk Act Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa. x + 67 pp.

FitzGerald, A.M., S.N. John, T.M. Apgar, N.J. Mantua, and B.T. Martin. 2020. Quantifying thermal exposure for migratory riverine species: Phenology of Chinook salmon populations predicts thermal stress. Global Change Biology 27(3).

Fonnum, F., E. Mariussen, and T. Reistad. 2006. Molecular mechanisms involved in the toxic effects of polychlorinated biphenyls (PCBs) and brominated flame retardants (BFRs). J. Toxicol. Environ. Health A 69:21–35.

Ford, J. K. B., G. M. Ellis, L. G. Barrett-Lennard, A. B. Morton, R. S. Palm, and K. C. B. III. 1998. Dietary specialization in two sympatric populations of killer whales (Orcinus orca) in coastal British Columbia and adjacent waters. Canadian Journal of Zoology. 76(8): 1456-1471.

Ford, J. K. B., G. M. Ellis, and K. C. Balcomb. 2000. Killer whales: the natural history and genealogy of Orcinus orca in British Columbia and Washington State. 2nd ed. UBC Press, Vancouver, British Columbia.

Ford, J. K. B. 2002. Killer whale Orcinus orca. Pages 669-676 in W. F. Perrin, B. Würsig, and J. G. M. Thewissen, editors. Encyclopedia of marine mammals. Academic Press, San Diego, California.

Ford, J. K. B. and G.M. Ellis. 2006. Selective foraging by fish-eating killer whales Orcinus orca in British Columbia. Marine Ecology Progress Series 316:185-199.

Ford J.K.B., A.L. Rambeau, R.M. Abernethy, M.D. Boogaards, L.M. Nichol, and L.D. Spaven. 2009. An Assessment of the Potential for Recovery of Humpback Whales off the Pacific Coast of Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/015. iv + 33 p

Ford, M. J., (ed.). 2011. Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-NWFSC-113, 281pp.

Ford, M. 2015. Results of NOAA BRT review of new genetics information, memo from the NWFSC to PRD, December 9, 2015.

Ford, M. J., J. Hempelmann, B. Hanson, K. L. Ayres, R. W. Baird, C. K. Emmons, J. I. Lundin, G. S. Schorr, S. K. Wasser, and L. K. Park. 2016. Estimation of a killer whale (Orcinus orca) population’s diet using sequencing analysis of DNA from feces. PLoS ONE. 11(1): 1-14.

Ford, M. J., (ed.). 2022. Biological Viability Assessment Update for Pacific Salmon and Steelhead Listed Under the Endangered Species Act: Pacific Northwest. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-171. https://doi.org/10.25923/kq2n-ke70

Forest Ecosystem Management Assessment Team (FEMAT). 1993. Forest ecosystem management: An ecological, economic, and social assessment. Report of the Forest Ecosystem Management Assessment Team. 1993-793-071. U.S. Gov. Printing Office.

Fresh, K. L. 2006. Juvenile Pacific Salmon in Puget Sound. Puget Sound Nearshore Partnership Report No. 2006. Published by Seattle District, U.S. Army Corps of Engineers, Seattle, Washington.

Fresh, K. L., Wyllie-Echeverria, T., Wyllie-Echeverria, S. and Williams, B.W., 2006b. Using light-permeable grating to mitigate impacts of residential floats on eelgrass Zostera marina L. in Puget Sound, Washington. ecological engineering, 28(4), pp.354-362.

Freshwater, C., S. C. Anderson, K. R. Holt, A. M. Huang, and C. A. Holt. 2019. Weakened portfolio effects constrain management effectiveness for population aggregates. Ecological Applications 29:14.

Furness, R.W., H.M. Wade, A.M.C. Robbins, and E.A. Masden. 2012. Assessing the Sensitivity of Seabird Populations to Adverse Effects from Tidal Stream Turbines and Wave3 Energy Devices. J. Marine Science 69(8): 1466-1479.

Gamel, C. M., R.W. Davis, J.H.M. David, M.A. Meyer and E. Brandon. 2005. Reproductive energetics and female attendance patterns of Cape fur seals (Arctocephalus pusillus pusillus) during early lactation. American Midland Naturalist 153(1): 152-170

Garavelli, L., D. Rose, G. Staines, and A. Copping. 2022. Towards Resolving the risk of Turbine Collisions on Fish. Report No. 33654 by Pacific Northwest National Laboratory for the U.S. Department of Energy.

Gard, R. 1974. Aerial census of gray whales in Baja California Lagoons, 1970 and 1973, with notes on behavior, mortality, and conservation. Calif. Fish and Game. 60(3):132-143.

Garm, A., Sensory Biology of Starfish—With Emphasis on Recent Discoveries in their Visual Ecology, Integrative and Comparative Biology, Volume 57, Issue 5, November 2017, Pages 1082–1092, https://doi.org/10.1093/icb/icx086

Gaydos, J. K., and S. Raverty. 2007. Killer Whale Stranding Response, August 2007 Final Report. Report under UC Davis Agreement No. C 05-00581 V, August 2007.

Gearin, P. J., S. J. Jeffries, M. E. Gosho, J. R. Thomason, R. DeLong, M. Wilson, and S.R. Melin. 1996. Report on capture and marking of California sea lions in Puget Sound, Washington during 1994-95: Distribution, abundance and movement patterns. NMFS NWR Report, 26 p. (Available from Northwest Regional Office, Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE, Seattle, WA 98115.)

Geraci, J. R., D.J. St. Aubim. 1990. Sea mammals and oil : confronting the risks / Joseph R. Includes bibliographical references. ISBN 0-12-280600-X (alk. paper). Marine mammals-Effect of oil spills on. 2. Oil spills--Environmental aspects. I. St. Aubin, D. J. II. Title. QL713.2.G47 1990

599.5'045222--dc20Gill, A.B. and M. Desender. 2020. "Risk to Animals from Electromagnetic Fields Emitted by Electric Cables and Marine Renewable Energy Devices." Chapter 5 in 2020 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World. Ocean Energy Systems, Lisbon, Portugal. Accessed August 3, 2020, at https://www.osti.gov/biblio/1633088.

Gilpin, M. E., and M. E. Soulé. 1986. Minimum viable populations: Processes of species extinction. Conservation biology: the science of scarcity and diversity. 19-34.

Gliwicz, Z.M., E. Babkiewicz, R. Kumar, S. Kunjiappan, and K. Leniowski, 2018. Warming increases the number of apparent prey in reaction field volume of zooplanktivorous fish. Limnology and Oceanography, 63(S1), pp.S30-S43.

Goetz, F. A., Jeanes, E., Moore, M. E., and Quinn, T. P. 2015. Comparative migratory behavior and survival of wild and hatchery steelhead (Oncorhynchus mykiss) smolts in riverine, estuarine, and marine habitats of Puget Sound, Washington. Environmental Biology of Fishes, 98(1), 357-375. doi:http://dx.doi.org/10.1007/s10641-014-0266-3

Gombert, P., Biaudet H., de Seze R., Pandard P. and Carré J., 2017. Toxicity of fluorescent tracers and their degradation byproducts. International Journal of Speleology, 46 (1), 23-31. Tampa, FL (USA) ISSN 0392-6672 https://doi.org/10.5038/1827-806X.46.1.1995

Gordon, J. and A. Moscrop. 1996. Underwater noise pollution and its significance for whales and dolphins. Pages 281-319 in M. P. Simmonds and J. D. Hutchinson, editors. The conservation of whales and dolphins: science and practice. John Wiley & Sons, Chichester, United Kingdom.

Gosselin, J. L., Buhle, E. R., Van Holmes, C., Beer, W. N., Iltis, S., & Anderson, J. J. 2021. Role of carryover effects in conservation of wild Pacific salmon migrating regulated rivers. Ecosphere, 12(7), e03618.

Gourtay, C., D. Chabot, C. Audet, H. Le Delliou, P. Quazuguel, G. Claireaux, and J.L. Zambonino-Infante. 2018. Will global warming affect the functional need for essential fatty acids in juvenile sea bass (*Dicentrarchus labrax*)? A first overview of the consequences of lower availability of nutritional fatty acids on growth performance. Marine Biology, 165(9), pp.1-15.

Graham, A. L. and S. J. Cooke. 2008. The effects of noise disturbance from various recreational boating activities common to inland waters on the cardiac physiology of a freshwater fish, the largemouth bass (Micropterus salmoides). Aquatic Conservation: Marine and Freshwater Ecosystems, 18, 1315-1324.

Grange, Briana. 2016. Evaluation of Impacts to Proposed Critical Habitat for the Atlantic Sturgeon (Acipenser oxyrinchus oxyrinchus). Indian Point Nuclear Generating Units 2 and 3 Proposed License Renewal. U.S. Nuclear Regulatory Commission Rockville, Maryland.

Gravem, S.A., Heady, W.N., Saccomanno, V.R., Alvstad, K.F., Gehman, A.L.M., Frierson, T.N. Hamilton, S.L. 2020. Pycnopodia helianthoides. The IUCN Red List of Threatened Species 2020: e.T178290276A178341498.

Grecay, P.A., and T.E. Targett. 1996. Spatial patterns in condition and feeding of juvenile weakfish in Delaware Bay. Transactions of the American Fisheries Society 125(5): 803-808

Greene, C. and A. Godersky. 2012. Larval rockfish in Puget Sound surface waters. Northwest Fisheries Science Center, NOAA. December 27.

Haas, M. E., C.A. Simenstad, J.R. Cordell, D.A. Beauchamp, and B.S. Miller. 2002. Effects of Large Overwater Structures on Epibenthic Juvenile Salmon Prey Assemblages in Puget Sound, WA.

Haggerty, M.J., A.C. Ritchie, J.G. Shellberg, M.J. Crewson, and J. Jalonen. 2009. Lake Ozette sockeye limiting factors analysis. Prepared for the Makah Indian Tribe and NOAA Fisheries in cooperation with the Lake Ozette Sockeye Steering Committee. Port Angeles, Washington.

Halderson, L. and L. J. Richards. 1987. Habitat use and young of the year copper rockfish (Sebastes caurinus) in British Columbia. Pages 129 to 141 in Proceedings of the International Rockfish Symposium, Anchorage, Alaska. Alaska Sea Grant Report, 87-2, Fairbanks, AK.

Halofsky, J.S., D.R. Conklin, D.C. Donato, J.E. Halofsky, and J.B. Kim. 2018. Climate change, wildfire, and vegetation shifts in a high-inertia forest landscape: Western Washington, U.S.A. PLoS ONE 13(12): e0209490. https://doi.org/10.1371/journal.pone.0209490

Halofsky, J.E., Peterson, D.L. and B. J. Harvey. 2020. Changing wildfire, changing forests: the effects of climate change on fire regimes and vegetation in the Pacific Northwest, USA. Fire Ecology 16(4). https://doi.org/10.1186/s42408-019-0062-8

Hamilton S.L., Saccomanno, V.R., Heady, W.N., Gehman, A.L., Lonhart, S.I., Beas-Luna, R., Francis, F.T., Lee, L., Rogers-Bennett, L., Salomon, A.K., Gravem, S.A. 2021. Disease-driven mass mortality event leads to widespread extirpation and variable recovery potential of a marine predator across the eastern Pacific. Proc. R. Soc. B 288: 20211195.

Hanson, M. B., and C. K. Emmons. 2010. Annual Residency Patterns of Southern Resident Killer Whales in the Inland Waters of Washington and British Columbia. Revised Draft - 30 October 10. 11p.

Hanson, M. B., C. K. Emmons, E. J. Ward, J. A. Nystuen, M. O. Lammers. 2013. Assessing the coastal occurrence of endangered killer whales using autonomous passive acoustic recorders. Journal of the Acoustical Society of America, 134(5):3486-3495.

Hard, J. J., J.M. Myers, M.J. Ford, R G. Cope, G.R. Pess, R S. Waples, G.A. Winans, B.A. Berejikian, F.W. Waknitz, P.B. Adams, P.A. Bisson, D.E. Campton, and R.R. Reisenbichler. 2007. Status review of Puget Sound steelhead (Oncorhynchus mykiss). U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-81.

Hard, J. J., J.M. Myers, E.J. Connor, R.A. Hayman, R.G. Kope, G. Lucchetti, A.R. Marshall, G.R. Pess, and B.E. Thompson. 2015. Viability criteria for steelhead within the Puget Sound distinct population segment. U.S. Dept. of Commerce, NOAA Tech. Memo. NMFS-NWFSC-129. May. 367 pp

Harris, D.D. 2021. Effects of Laser Power and Exposure Time on the Avian Eye: Implications for the Use of Bird Deterrents. MS Thesis, Purdue University. file:///C:/Users/d3h367/Downloads/2021.12.10%20Deona%20Harris.pdf

Hartman, G.F., J.C. Scrivener, and M.J. Miles. 1996. Impacts of logging in Carnation Creek, a high-energy coastal stream in British Columbia, and their implication for restoring fish habitat. Canadian Journal of Fisheries and Aquatic Sciences 53(Suppl. 1):237-251.

Harvell, C.D., Montecino-Latorre, D., Caldwell, J.M., Burt, J.M., Bosley, K., Keller, A., Heron, S.F., Salomon, A.K., Lee, L., Pontier, O., Pattengill-Semmens, C., Gaydos, J.K. 2019. Disease epidemic and a marine heat wave are associated with the continental-scale collapse of a pivotal predator (Pycnopodia helianthoides). Science Advances 5(1): 1-9.

Hastings, M. C., A.N. Popper, J.J. Finneran, and P. Lanford. 1996. Effects of low-frequency underwater sound on hair cells of the inner ear and lateral line of the teleost fish Astronotus ocellatus. Journal of the Acoustical Society of America 99(3): 1759-1766

Hastings, M. C., and A. N. Popper. 2005. Effects of sound on fish. Final Report # CA05-0537 – Project P476 Noise Thresholds for Endangered Fish. For: California Department of Transportation, Sacramento, CA. January 28, 2005, August 23, 2005 (Revised Appendix B). 85 pp.

Hauser, D. D. W., M.G. Logsdon, E.E. Holmes, G.R. VanBlaricom, R.W. Osborne. 2007. Summer distribution patterns of southern resident killer whales Orcinus orca: core areas and spatial segregation of social groups. Marine Ecology Progress Series 351:301-310.

Hayden-Spear, J. 2006. Nearshore habitat Associations of Young-of-Year Copper (Sebastes caurinus) and quillback (S. maliger) rockfish in the San Juan Channel, Washington. Unpublished Master of Science Dissertation. University of Washington.

Heady, W.N., R. Beas-Luna, M.N Dawson, N. Eddy, K. Elsmore, F. T. Francis, T. Frierson, A.L. Gehman, T. Gotthardt, S.A. Gravem, J. Grebel, S. L. Hamilton, L. Hannah, C.D. Harvell, J. Hodin, I. Kelmartin, C. Krenz, L. Lee, J. Lorda, D. Lowry, S. Mastrup, E. Meyer, P. T. Raimondi, S. S. Rumrill, V. R. Saccomanno, L. M. Schiebelhut, C. Siddon. 2022. Roadmap to recovery for the sunflower sea star (Pycnopodia helianthoides) along the west coast of North America. The Nature Conservancy, Sacramento, CA, US. 44 pages.

Healey, M., 2011. The cumulative impacts of climate change on Fraser River sockeye salmon (Oncorhynchus nerka) and implications for management. Canadian Journal of Fisheries and Aquatic Sciences, 68(4), pp.718-737.

Heiser, D.W., and E.L. Finn 1970. Observations of Juvenile Chum and Pink Salmon in Marina and Bulkheaded Areas. State of Washington Department of Fisheries.

Hemery, L.G., Marion, S.R., Romsos, C.G., Kurapov, A.L., Henkel, S.K. 2016. Ecological niche and species distribution modelling of sea stars along the Pacific Northwest continental shelf. Diversity and Distributions 22(12): 1314-1327.

Herlinveaux, R.H., and J. P. Tully. 1961. Some Oceanographic Features of Juan de Fuca Strait. Journal of the Fisheries Research Board of Canada. **18**(6): 1027-1071. https://doi.org/10.1139/f61-065

Herring, S. C., N. Christidis, A. Hoell, J. P. Kossin, C. J. Schreck III, and P. A. Stott, Eds., 2018: Explaining Extreme Events of 2016 from a Climate Perspective. Bull. Amer. Meteor. Soc., 99 (1), S1–S157.

Herrlinger, T.J. 1983. The diet and predator-prey relationships of the sea star Pycnopodia helianthoides (Brandt) from a Central California kelp forest. Faculty of Moss Landing Marine Laboratories, San Jose State University.

Hewson I, Bistolas KSI, Quijano Cardé EM, Button JB, Foster PJ, Flanzenbaum JM, Kocian J, Lewis CK. 2018. Investigating the complex association between viral ecology, environment, and Northeast Pacific sea star wasting. Frontiers in Marine Science. 5.

Hilborn, R., S. P. Cox, F. M. D. Gulland, D. G. Hankin, N. T. Hobbs, D. E. Schindler, A. W. Trites. 2012. The effects of salmon fisheries on Southern Resident killer whales: Final report of the Independent Science Panel. Prepared with the assistance of D. R. Marmorek and A. W. Hall, ESSA Technologies Ltd., Vancouver, BC. National Marine Fisheries Service, Seattle, WA, and Fisheries and Oceans Canada, Vancouver, BC.

Hochachka, W. M. 2006. Unequal lifetime reproductive success, and its implication for small isolated populations. Pages: 155-173. In: Biology of small populations: the song sparrows of Mandarte Island. Edited by J.N.M. Smith, A.B. Marr, L.F. Keller and P. Arcese. Oxford University Press, Oxford, United Kingdom.

Hodin, J., A. Pearson-Lund, F.P. Anteau, P. Kitaeff, and S. Cefalu. 2021. Progress toward complete Life-Culce Culturing of the Enandgered Sunflower Star, *Pyncopodia Helianthoides.* The Biological Bulletin, Col 241, No. 3.

Holt, M. M. 2008. Sound Exposure and Southern Resident Killer Whales (Orcinus orca): A Review of Current Knowledge and Data Gaps. February 2008. NOAA Technical Memorandum NMFS-NWFSC-89, U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-89. 77p.

Holt, M. M., D. P. Noren, R. C. Dunkin, and T. M. Williams. 2015. Vocal performance affects metabolic rate in dolphins: implications for animals communicating in noisy environments. Journal of Experimental Biology. 218: 1647–1654.

Hood Canal Coordinating Council (HCCC). 2005. Hood Canal and Eastern Strait of Juan de Fuca summer chum salmon recovery plan. Version November 15, 2005. 339 pp.

Horne, M., R.M. Culloch, P. Schmitt, B. Wilson, A.C. Dale, J.D.R. Houghton, and L.T. Kregting. 2022. Providing a Detailed Estimate of Mortality Using a Simulation-Based Collision Risk Model. PLoS ONE 17(11): 1-14.

Hoyt, E. 2001. Whale watching 2001: worldwide tourism numbers, expenditures, and expanding socioeconomic benefits. International Fund for Animal Welfare, Yarmouth, Massachusetts.

Hudspith, M., Amanda Reichelt-Brushett, and Peter L. Harrison. "Factors affecting the toxicity of trace metals to fertilization success in broadcast spawning marine invertebrates: A review." *Aquatic toxicology* 184 (2017): 1-13.

Huff, D. D., S. T. Lindley, B. K. Wells and F. Chai. 2012. Green sturgeon distribution in the Pacific ocean estimated from modeled oceanographic features and migration behavior. PLoS ONE 7(9): e45852. doi:10.1371/journal.pone.0045852.

Hunter, M.A. 1992. Hydropower flow fluctuations and salmonids: A review of the biological effects, mechanical causes, and options for mitigation. Washington Department of Fisheries. Technical Report No. 119. Olympia, Washington.

Hutchings, J. A. and J. D. Reynolds. 2004. Marine Fish Population Collapses: Consequences for Recovery and Extinction Risk. BioScience, Vol. 54(4): 297-309

Intergovernmental Panel on Climate Change (IPCC) Working Group I (WGI). 2021. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. V. Masson-Delmotte, P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou editor. Cambridge University Press (https://www.ipcc.ch/report/ar6/wg1/#FullReport).

IPCC Working Group II (WGII). 2022. Climate Change 2022: Impacts, Adaptation and Vulnerability: Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. H.O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, and B. Rama (eds.) Cambridge University Press (https://report.ipcc.ch/ar6wg2/pdf/IPCC_AR6_WGII_FinalDraft_FullReport.pdf)

Isaak, D.J., C.H. Luce, D.L. Horan, G. Chandler, S. Wollrab, and D.E. Nagel. 2018. Global warming of salmon and trout rivers in the northwestern U.S.: Road to ruin or path through purgatory? Transactions of the American Fisheries Society. 147: 566-587. https://doi.org/10.1002/tafs.10059

Isaksson, N., E.A. Masden, B.J. Williamson, M.M. Costagliogla-Ray, J. Slingsby, J.D.R. Houghton, and J. Wilson. 2020. Assessing the Effects of Tidal Stream Marine Renewable Energy on Seabirds: a Conceptual Framework. Marine Pollution Bulletin 157:1-49.Long, C. 2017. Analysis of the Possible Displacement of Bird and Marine Mammal Species Related to the Installation and Operation of Marine Energy Conversion Systems. Scottish Natural Heritage Commissioned Report No. 947.

Jacox, M. G., Alexander, M. A., Mantua, N. J., Scott, J. D., Hervieux, G., Webb, R. S., & Werner, F. E. 2018. Forcing of multi-year extreme ocean temperatures that impacted California Current living marine resources in 2016. Bull. Amer. Meteor. Soc, 99(1).

Jarvela-Rosenberger, A. L., M. MacDuffee, A.G.J. Rosenberger, and P.S. Ross. 2017. Oil spills and marine mammals in British Columbia, Canada: Development and application of a risk-based conceptual framework. Arch. Environ. Contam. Toxicol. 73:131-153.

Jeffries, S. J., Scordino J. 1997. Efforts to protect a winter steelhead run from California sea lions at the Ballard Locks. In: Ston G, Goebel J, Webster S, editors. Pinniped populations, eastern north Pacific: status, trends, and issues. Monterey, CA: Monterey Bay Aquarium. 107–115

Jerlov, N.G. 1976. Marine Optics. Volume 14: iii-vii, 1-231, Elsevier Scientific Publishing Company, Amsterdam, The Netherlands.

Joblon, M. J., M. A. Pokra, B. Morse, C. T. Harry, K. S. Rose, S. M. Sharp, M. E. Niemeyer, K. M. Patchett, W. B. Sharp, and M. J. Moore. 2014. Body condition scoring system for delphinids based on short-beaked common dolphins (Delphinus delphis). J Mar Anin Ecol 7(2):5-13.

Johnson, O. W., S. W. Grant, R. G. Kope, K. Neely, and F. W. Waknitz. 1997. Status review of chum salmon from Washington, Oregon, and California. U.S. Department of Commerce NOAA Tech Memo NMFS NWFSC 32, Seattle, WA.

Johnson, B.M., G.M. Kemp, and G.H. Thorgaard. 2018. Increased mitochondrial DNA diversity in ancient Columbia River basin Chinook salmon Oncorhynchus tshawytscha. PLoS One, 13(1), p.e0190059.

Joint Columbia River Management Staff. 2009. 2010 joint staff report concerning stock status and fisheries for sturgeon and smelt. Oregon Department of Fish and Wildlife and Washington Department of Fish and Wildlife.

JSKT, Jamestown S'Klallam Tribe, 2013. Protecting and Restoring the Waters of Sequim Bay. A Watershed-Based Plan Prepared in Compliance with Section 319 of the Clean Water Act

Kagley, A., J.M. Smith, M.C. Arostegui, J.W. Chamberlin, D. Spilsbury-Pucci, K. L. Fresh, K.E. Frick, and T.P. Quinn. 2016. Movements of sub-adult Chinook salmon (Oncorhynchus tshawytscha) in Puget Sound, Washington, as indicated by hydroacoustic tracking. Presented at Salish Sea Ecosystem Conference, Vancouver, BC, Canada.

Kashef, N. S., S. M. Sogard, R. Fisher, and J. Largier. 2014. Ontogeny of critical swimming speeds for larval and pelagic juvenile rockfishes (Sebastes spp., family Scorpaenidae). Marine Ecology Progress Series. 500. 231-243. 10.3354/meps10669.

Kearny, V., Y. Segal, and M.W. Lefor. 1 983. The effects of docks on saltmarsh vegetation. The Connecticut State Department of Environmental Protection, Water Resources Unit, Hartford, CT. 06 1 06. 22p.

Keefer, M. L., Stansell RJ, Tackley SC, Nagy WT, Gibbons KM, et al. 2012. Use of radiotelemetry and direct observations to evaluate sea lion predation on adult Pacific salmonids at Bonneville Dam. T Am Fish Soc 141: 1236–1251.

Keefer M.L., T.S. Clabough, M.A. Jepson, E.L. Johnson, C.A. Peery, C.C. Caudill. 2018. Thermal exposure of adult Chinook salmon and steelhead: Diverse behavioral strategies in a large and warming river system. PLoS ONE 13(9): e0204274. https://doi.org/10.1371/journal.pone.0204274

Kellar, N. M., T. R. Speakman, C. R. Smith, S. M. Lane and others. 2017. Low reproductive success rates of common bottlenose dolphins Tursiops truncatus in the northern Gulf of Mexico following the Deepwater Horizon disaster (2010-2015). Endang Species Res 33:143-158.

Kelly, J.T., Klimley, A.P. & Crocker, C.E. Movements of green sturgeon, Acipenser medirostris, in the San Francisco Bay estuary, California. Environ Biol Fish **79**, 281–295 (2007). https://doi.org/10.1007/s10641-006-0036-y

Kelty, R., and S. Bliven. 2003. Environmental and aesthetic impacts of small docks and piers workshop report: Developing a science-based decision support tool for small dock management, phase 1: Status of the science. In Decision Analysis Series No. 22. N.C.O. Program, editor.

Kemp, P. S., M.H. Gessel, and J.G. Williams. 2005. Seaward migrating subyearling Chinook salmon avoid overhead cover. Journal of Fish Biology. 67:10.

Kendall, A. W. Jr., and S. J. Picquelle. 2003. Marine protected areas and the early life history of fishes. AFSC Processed Rep. 2003-10, 30 p. Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., Seattle, WA.

Kenworthy, W. J., and D.E. Haunert (eds.). 1991. The light requirements of seagrasses: proceedings of a workshop to examine the capability of water quality criteria, standards and monitoring programs to protect seagrasses. NOPA Technical Memorandum NMFS-SEFC 287.

Kerr, J. E. 1953. Studies on Fish Preservation at the Contra Costa Steam Plant of the Pacific Gas and Electric Company. State of California Department of Fish and Game Fish Bulletin no. 92. Bechtel Corporation.

Kilduff, P., L. W. Botsford, and S. L. H. Teo. 2014. Spatial and temporal covariability in early ocean survival of Chinook salmon (Oncorhynchus tshawytscha) along the west coast of North America. ICES Journal of Marine Science. 71. 10.1093/icesjms/fsu031.

Klein-MacPhee, G., Cardin J.A., Berry W.J. 1984. Effects of silver on eggs and larvae of the winter founder. Transactions of the American Fisheries Society 113(2): 247-251.

Klimley, A. P., Wyman, M. T., and R. Kavet. (2017). Chinook salmon and green sturgeon migrate through San Francisco Estuary despite large distortions in the local magnetic field produced by bridges. PLoS One, 12(6), e0169031

Kondolf, G.M. 1997. Hungry water: Effects of dams and gravel mining on river channels. Environmental Management 21(4):533-551.

Konkler, M. and Morrell, J.J., 2017. Migration of pentachlorophenol and copper from a preservative treated bridge. Journal of environmental management, 203, pp.273-277.

Koontz, E.D., E.A. Steel, and J.D. Olden. 2018. Stream thermal responses to wildfire in the Pacific Northwest. Freshwater Science, 37, 731 - 746.

Krahn MM, Wade PR, Kalinowski ST, Dahlheim ME and others (2002) Status review of Southern Resident killer whales (Orcinus orca) under the Endangered Species Act. NOAA Tech Memo NMFS-NWFSC-54, Northwest Fisheries Science Center, Seattle, WA

Krahn, M. M., M.J. Ford, W.F. Perrin, P.R. Wade, R.B. Angliss, M.B. Hanson, B.L. Taylor, G.M. Ylitalo, M.E. Dahlheim, J.E. Stein, and R.S. Waples. 2004. 2004 status review of Southern Resident killer whales (Orincus orca) under the Endangered Species Act, U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC-62, 73p.

Krahn, M. M., M.B. Hanson, R.W. Baird, R.H. Boyer, D.G. Burrows, C.K. Emmons, J.K.B. Ford, L.L. Jones, D.P. Noren, P.S. Ross, G.S. Schorr, and T.K. Collier. 2007. Persistent organic pollutants and stable isotopes in biopsy samples (2004/2006) from Southern Resident killer whales. Marine Pollution Bulletin 54:1903-1911.

Krahn, M. M., M.B. Hanson, G.S. Schorr, C.K. Emmons, D.G. Burrows, J.L. Bolton, R.W. Baird, and Gina Ylitalo. 2009. Effects of age, sex and reproductive status on persistent organic pollutant concentrations in "Southern Resident" killer whales. Marine Pollution Bulletin 58:1522-1529.

Krosby, M. D.M. Theobald, R. Norheim, and B.H. McRae. 2018. Identifying riparian climate corridors to inform climate adaptation planning. PLoS ONE 13(11): e0205156. https://doi.org/10.1371/journal.pone.0205156

Lacy, R.C., Williams, R., Ashe, E. *et al.* Evaluating anthropogenic threats to endangered killer whales to inform effective recovery plans. *Sci Rep* **7**, 14119 (2017). https://doi.org/10.1038/s41598-017-14471-0

Lambert, P. 2000. Sea stars of British Columbia, Southeast Alaska, and Puget Sound. UBC Press.

Leet, W.S., A Dewees, C.M., A Haugen, C.W. 1992. California's Living Marine Resources and Their Utilization. University of California, Davis. Wildlife and Fisheries Biology. Sea Grant Extension Program, Department of Wildlife and Fisheries Biology, University of California

Legler, J. 2008. New insights into the endocrine disrupting effects of brominated flame retardants. Chemosphere 73:216–222.

Legler, J., and A. Brouwer. 2003. Are brominated flame retardants endocrine disruptors? Environ. Int. 29:879–885.

Levin, P. S. and Williams, J.G. 2002. Interspecific effects of artificially propagated fish: An additional conservation risk for salmon. Conservation Biology 16: 1581-1587.

Levenson, D.H. and R.J. Schusterman. 1999. "Dark Adaptation and Visual Sensitivity in Shallow and Deep-diving Pinnipeds." Marine Mammal Science 15(4):1302–1313.

LIA (Laser Institute of America). 2014. American National Standard for Safe Use of Lasers. ANSI Z136.1-2014, Orlando, Florida.

Limburg, K., R. Brown, R. Johnson, B. Pine, R. Rulifson, D. Secor, et al. 2016. Round-the-coast: Snapshots of estuarine climate change effects. Fisheries 41(7):392-394. https://doi.org/10.1080/03632415.2016.1182506.

Lindley, S. T., Schick, R.S., Mora, E., Adams, P.B., Anderson, J.J., Greene, S., Hanson, C., May, B.P., McEwan, D., MacFarlane, R.B. and Swanson, C., 2007. Framework for assessing viability of threatened and endangered Chinook salmon and steelhead in the Sacramento–San Joaquin Basin. San Francisco Estuary and Watershed Science, 5(1).

Lindley, S. T., M .L. Moser, D. L. Erickson, M. Belchik, D. W. Welch, E. Rechisky, J. T. Kelly, J. C. Heublein and A. P. Klimley. 2008. Marine migration of North American green sturgeon. Transactions of the American Fisheries Society 137:182-194.

Lindley S.T., C.B. Grimes, M.S. Mohr, W. Peterson, J. Stein, J.T. Anderson, et al. 2009. What caused the Sacramento River fall Chinook stock collapse? NOAA Fisheries West Coast Region, Santa Cruz, CA. U.S. Department of Commerce NOAA-TM-NMFS-SWFSC-447.

Lindley, S. T., D. L. Erickson, M .L. Moser, G. Williams, O. P. Langness, B. W. McCovey Jr., M. Belchik, D. Vogel, W. Pinnix, J. T. Kelly, J. C. Heublein and A. P. Klimley. 2011. Electronic tagging of green sturgeon reveals population structure and movement among estuaries. Transactions of the American Fisheries Society 140:108-122.

Love, M. S., M. H. Carr, and L. J. Haldorson. 1991. The ecology of substrate-associated juveniles of the genus Sebastes. Environ. Biol. Fishes 30:225–243.

Love, M. S., M. Yoklavich, and L. Thorsteinson. 2002. The Rockfishes of the Northeast Pacific. University of California Press. 404 p.

Lowry, D, Wright, S, Neuman, M, Stevenson, D, Hyde, J, Lindeberg, M, Tolimieri, N, Lonhart, S, Traiger, S, and R Gustafson. 2022. Endangered Species Act Status Review Report: Sunflower Sea Star (Pycnopodia helianthoides). Final Report to the National Marine Fisheries Service, Office of Protected Resources. October 2022. 89 pp. + App.

Lundin, J. I., R.L. Dills, G.M. Ylitalo, M.B. Hanson, C.K. Emmons, G.S. Schorr, J. Ahmad, J.A. Hempelmann, K.M. Parsons and S.K. Wasser. 2016. Persistent Organic Pollutant Determination in Killer Whale Scat Samples: Optimization of a Gas 3 Chromatography/Mass Spectrometry Method and Application to Field Samples. Archives of Environmental Contamination and Toxicology 70: 9-19.

Lusseau, D., D. E. Bain, R. Williams, and J. C. Smith. 2009. Vessel traffic disrupts the foraging behavior of southern resident killer whales Orcinus orca. Endangered Species Research. 6: 211-221.

MacCall, A. D., S. Ralston, D. Pearson and E. Williams. 1999. Status of bocaccio off California in 1999 and outlook for the next millennium. In: Appendices to the Status of the Pacific Coast Groundfish Fishery through 1999 and Recommended Acceptable Biological Catches for 2000. Pacific Fishery Management Council, 2000 SW First Ave., Portland, OR, 97201.

Marchesana, Mara, M. Spotob, L. Verginellab, E.A. Ferreroa. 2005. Behavioural effects of artificial light on fish species of commercial interest. Fisheries Research 73 (2005) 171–185

Malek, K., J.C. Adam, C.O. Stockle, and R.T. Peters. 2018. Climate change reduces water availability for agriculture by decreasing non-evaporative irrigation losses. Journal of Hydrology 561:444-460.

Malme, C.I., P.R. Miles, P. Tyack, C.W. Clark, and J.E. Bird. 1985. Investigation of the potential effects of underwater noise from petroleum industry activities on feeding humpback whale behavior. BBN Report 5851, OCS Study MMS 85-0019. Report from BBN Laboratories Inc., Cambridge, MA, for U.S. Minerals Management Service, NTIS PB86218385. Bolt, Beranek, and Newman, Anchorage, AK.

Matkin, C. O., E.L. Saulitis, G. M. Ellis, P. Olesiuk, S.D. Rice. 2008. Ongoing population- level impacts on killer whales Orcinus orca following the ‘Exxon Valdez’ oil spill in Prince William Sound, Alaska. Marine Ecology Progress Series. 356: 269-281.

Matthews, K. R. 1989. A comparative study of habitat use by young-of-the year, sub-adult, and adult rockfishes on four habitat types in Central Puget Sound. Fishery Bulletin, U.S. volume 88, pages 223-239

Masson, D. and P. F. Cummins, 1999. Numerical Simulations of a Buoyancy- Driven Coastal Countercurrent off Vancouver Island, *Journal of Physical Oceanography*, **29**, pp. 418-435.

Mauger, G. S., J. H. Casola, H. A. Morgan, R. L. Strauch, B. Jones, B. Curry, T. M. B. Isaksen, L. W. Binder, M. B. Krosby, and A. K. Snover. 2015. State of Knowledge: Climate Change in Puget Sound. Report prepared for the Puget Sound Partnership and the National Oceanic and Atmospheric Administration. Climate Impacts Group, University of Washington, Seattle. November 2015. 309p.

Mauzey, K.P., Birkeland, C., Dayton, P.K. 1968. Feeding behavior of asteroids and escape responses of their prey in the Puget Sound Region. Ecology 49(4): 603-619.

McElhany, P., M.H. Ruckelshaus, M.J. Ford, T.C. Wainwright, and E.P. Bjorkstedt. 2000. Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-42. June 2000. 156 pp.

McIntyre, J. K., D. H. Baldwin, D. A. Beauchamp, and N. L. Scholz. 2012. Low-level copper exposures increase visibility and vulnerability of juvenile coho salmon to cutthroat trout predators. Ecological Applications, 22, 1460–1471.

Melbourne, B. A., and A. Hastings. 2008. Extinction risk depends strongly on factors contributing to stochasticity. Nature. 454(7200): 100-103.

Miller, B. S., C.A. Simenstad, L.L. Moulton, K.L. Fresh, F.C. Funk, W.A. Karp, and S.F. Borton. 1978. Puget Sound Baseline Program, Nearshore Fish Survey. Final Report, July 1974- June 1977 to Washington Department of Ecology. University of Washington Fisheries Research Institute Report FRI-UW-7710. 220 p.

Miller, B. and S. Borton. 1980. Geographical distribution of Puget Sound fishes: Maps and data source sheets. Wash. Sea Grant and Fish. Res. Inst. Publ., Univ. Washington, Seattle.

Mongillo, T. M., G. M. Ylitalo, L. D. Rhodes, S. M. O'Neill, D. P. Noren, M. B. Hanson. 2016. Exposure to a mixture of toxic chemicals: Implications to the health of endangered Southern Resident killer whales. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-X8.

Moore, M. E., B. A. Berejikian, and E. P. Tezak. 2013. A Floating Bridge Disrupts Seaward Migration and Increases Mortality of Steelhead Smolts in Hood Canal, Washington State. PloS one. September 2013. Vol 8. Issue 9. E73427. 10 pp.

Morgan, J. D. and C. D. Levings. 1989. Effects of suspended sediment on eggs and larvae of lingcod Ophiodon elongatus, Pacific herring Clupea harengus pallasi, and surf smelt Hypomesus pretiosus. Canadian Technical Report of Fisheries & Aquatic Sciences, 1729:I-VII; 1-31.

Moser, H. G., R. L. Charter, W. Watson, D. A. Ambrose, J. L. Butler, J. Charter, and E. M. Sandknop. 2000. Abundance and distribution of rockfish (*Sebastes*) larvae in the southern California Bight in relation to environmental conditions and fishery exploitation. California Cooperative Oceanic Fisheries Investigations Report. 41: 132-147.

Moser, M. and S. T. Lindley. 2007. Use of Washington estuaries by subadult and adult green sturgeon. Environmental Biology of Fishes 79: 243-253.

Moser, M.L., K.S. Andrews, S. Corbett, B.E. Feist and M.E. Moore. 2021. Occurrence of green sturgeon in Puget Sound and the Strait of Juan de Fucal: A review of detection data from 2002 to 2019. Report of the National Marine Fisheries Service to the U.S. Navy Pacific Fleet Environmental Readiness Division. Pearl Harbor, Hawaii

Morrison, W., M. Nelson, J. Howard, E. Teeters, J.A. Hare, R. Griffis. 2015. Methodology for assessing the vulnerability of fish stocks to changing climate. National Marine Fisheries Service, Office of Sustainable Fisheries, Report No.: NOAA Technical Memorandum NMFS-OSF-3.

Moulton, L. L. 1977. AN ECOLOGICAL ANALYSIS OF FISHES INHABITING THE ROCKY NEARSHORE REGIONS OF NORTHERN PUGET SOUND, WASHINGTON. University of Washington ProQuest Dissertations Publishing, 1977. 7814475.

Moser, M. and S. Lindley. 2007. Use of Washington estuaries by subadult and adult green sturgeon. Environmental Biology of Fishes 79:243-253.

Mueller, G. 1980. Effects of Recreational River Traffic on Nest Defense by Longear Sunfish. Transactions of the American Fisheries Society, 109, 248-251.

Munday, P. L., D.L. Dixson, J.M. Donelson, G.P. Jones, M.S. Pratchett, G.V. Devitsina, et al. 2009. Ocean acidification impairs olfactory discrimination and homing ability of a marine fish. Proceedings of the National Academy of Sciences of the United States of America. 106(6):1848–52. https://doi.org/10.1073/pnas.0809996106 ISI:000263252500033. PMID: 19188596

Munsch, S. H., J.R. Cordell, J.D. Toft, and E.E. Morgan. 2014. Effects of Seawalls and Piers on Fish Assemblages and Juvenile Salmon Feeding Behavior. North American Journal of Fisheries Management. 34:814-827.

Munsch, S. H., C. M. Greene, N. J. Mantua, and W. H. Satterthwaite. 2022. One hundred-seventy years of stressors erode salmon fishery climate resilience in California's warming landscape. Global Change Biology.

Murphy, M.L., and J.D. Hall. 1981. Varied effects of clear-cut logging on predators and their habitat in small streams of the Cascade Mountains, Oregon. Canadian Journal of Fisheries and Aquatic Sciences 38:137-145.

Musick, J. A. 1999. Criteria to define extinction risk in marine fishes: The American Fisheries Society Initiative. Fisheries. Volume 24, pages 6-14.

Myers, J.M., J.J. Hard, E.J. Connor, R.A. Hayman, R.G. Kope, G. Lucchetti, A.R. Marshall, G.R. Pess, and B.E. Thompson. 2015. Identifying historical populations of steelhead within the Puget Sound distinct population segment. U.S. Dept. Commer., NOAA Tech. Memo. NMFSNWFSC- 128. doi:10.7289/V5/TM-NWFSC-128.

Myers, J.M., J. Jorgensen, M. Sorel, M. Bond, T. Nodine, and R. Zabel. 2018. Upper Willamette River Life Cycle Modeling and the Potential Effects of Climate Change. Draft Report to the U.S. Army Corps of Engineers. Northwest Fisheries Science Center. 1 September 2018.

Naish, K. A., J.E. Taylor, III, P.S. Levin, T.P. Quinn, J.R. Winton, D. Huppert, and R. Hilborn. 2007. An evaluation of the effects of conservation and fishery enhancement hatcheries on wild populations of salmon. Advances in Marine Biology 53: 61-194.

National Marine Fisheries Service (NMFS). 2002. Biological opinion on the collection, rearing, and release of salmonids associated with artificial propagation programs in the middle Columbia River steelhead evolutionarily significant unit (ESU). National Marine Fisheries Service. Portland, Oregon. February 14, 2002.

National Marine Fisheries Service (NMFS). 2006. Final supplement to the Shared Strategy's Puget Sound salmon recovery plan. National Marine Fisheries Service, Northwest Region. Seattle

National Marine Fisheries Service (NMFS). 2007. Final Supplement to the Hood Canal and Eastern Strait of Juan de Fuca Summer Chum Salmon Recovery Plan. National Marine Fisheries Service (NMFS) Northwest Region

National Marine Fisheries Service (NMFS). 2008. Recovery plan for Southern Resident killer whales (Orcinus orca). National Marine Fisheries Service, Northwest Region, Seattle, Washington.

National Marine Fisheries Service (NMFS). 2010. Biological Opinion on the Effects of the Pacific Coast Salmon Plan and U.S. Fraser Panel Fisheries in 2010 and 2011 on the Lower Columbia River ChinookEvolutionarily Significant Unit and Puget Sound/Georgia Basin Rockfish Distinct Populations Segments Listed Under the Endangered Species Act and Magnuson-Stevens Act Essential Fish Habitat Consultation. April 30, 2010. Consultation No.: NWR-2010-01714. 155p.

National Marine Fisheries Service (NMFS). 2010b. Draft Puget Sound Chinook Salmon Population Recovery Approach (PRA). NMFS Northwest Region Approach for Distinguishing Among Individual Puget Sound Chinook Salmon ESU Populations and Watersheds for ESA Consultation and Recovery Planning Purposes. November 30, 2010. Puget Sound Domain Team, NMFS, Seattle, Washington. 19p.

National Marine Fisheries Service (NMFS). 2011. Evaluation of and recommended determination on a Resource Management Plan (RMP), pursuant to the salmon and steelhead 4(d) Rule comprehensive management plan for Puget Sound Chinook: Harvest management component. Salmon Management Division, Northwest Region, Seattle, Washington.

NMFS (National Marine Fisheries Service). 2011b. Humpback Whale (Megaptera novaeangliae): California/Oregon/Washington Stock. Silver Spring, Maryland. Accessed August 4, 2020, at https://www.afsc.noaa.gov/nmml/PDF/sars/po2010whhb-cow.pdf.

NMFS (National Marine Fisheries Service). 2012. Rangewide Status of Yelloweye Rockfish, Canary Rockfish, and Bocaccio. Silver Spring, Maryland. Accessed August 4, 2020, at https://www.fws.gov/wafwo/Documents/RangewideSOS/NMFS/Rangewide%20Status%20of%20Rockfish.pdf.

National Marine Fisheries Service (NMFS). 2015. Workshop to Assess Causes of Decreased Survival and Reproduction in Southern Resident Killer Whales: Priorities Report. December 2015. 18p.

National Marine Fisheries Service (NMFS). 2016. Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat (EFH) Consultation and Fish and Wildlife Coordination Act Recommendations. NOAA's National Marine Fisheries Service's Response for the Regional General Permit 6 (RGP6): Structures in Inland Marine Waters of Washington State. September 13, 2016. NMFS Consultation No.: WCR-2016-4361. 115p.

National Marine Fisheries Service (NMFS). 2016b. Southern Resident Killer Whales (Orcinus orca) 5-Year Review: Summary and Evaluation. December 2016. NMFS, West Coast Region, Seattle, Washington. 74p. https://www.fisheries.noaa.gov/resource/document/southern-resident-killer-whales-orcinus-orca-5-year-review-summary-and-evaluation

National Marine Fisheries Service (NMFS). 2017a. Rockfish Recovery Plan: Puget Sound / Georgia Basin yelloweye rockfish (Sebastes ruberrimus) and bocaccio (Sebastes paucispinis). National Marine Fisheries Service. Seattle, WA.

National Marine Fisheries Service (NMFS). 2017b. Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat (EFH) Consultation. NOAA's National Marine Fisheries Service's implementation of the Mitchell Act Final Environmental Impact Statement preferred alternative and administration of Mitchell Act hatchery funding. January 15, 2017. NMFS Consultation No.: WCR-2014-697. 535p.

National Marine Fisheries Service (NMFS). 2017c. The 2016 5-Year Review: Summary and Evaluation of Puget Sound Chinook Salmon, Hood Canal Summer-Run Chum Salmon, and Puget Sound Steelhead. National Marine Fisheries Service, West Coast Region, Portland, OR. April 6, 2017

National Marine Fisheries Service (NMFS). 2018. 2018 Revisions to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts. U.S. Dept. of Commer., NOAA. NOAA Technical Memorandum NMFS-OPR-59, 167 p.

National Marine Fisheries Service (NMFS). 2018b. Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response. Consultation on effects of the 2018-2027 U.S. v. Oregon Management Agreement. February 23, 2018. NMFS Consultation No.: WCR-2017-7164. 597p.

National Marine Fisheries Service (NMFS). 2018c. Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response. Impacts of the Role of the BIA Under its Authority to Assist with the Development of the 2018-2019 Puget Sound Chinook Harvest Plan, Salmon Fishing Activities Authorized by the U.S. Fish and Wildlife Service, and Fisheries Authorized by the U.S. Fraser Panel in 2018. May 9, 2018. NMFS, West Coast Region. NMFS Consultation No.: WCR-2018-9134. 258p.

National Marine Fisheries Service (NMFS). 2019. ESA Recovery Plan for the Puget Sound Steelhead Distinct Population Segment (Oncorhynchus mykiss). National Marine Fisheries Service. Seattle, WA. Retrieved from https://www.fisheries.noaa.gov/resource/document/esa-recovery-plan-puget-sound-steelhead-distinct-population-segment-oncorhynchus

National Marine Fisheries Service (NMFS). 2019b. Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson Stevens Fishery Conservation and Management Act Essential Fish Habitat Response Consultation on the Delegation of Management Authority for Specified Salmon Fisheries to the State of Alaska. NMFS Consultation No.: WCR-2018-10660. April 5, 2019. 443p.

National Marine Fisheries Service (NMFS). 2019c. ESA Recovery Plan for the Puget Sound Steelhead Distinct Population Segment (Oncorhynchus mykiss). National Marine Fisheries Service. Seattle, WA. December. 174p.

National Marine Fisheries Service (NMFS). 2020. Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the Continued Operation and Maintenance of the Columbia River System. NMFS Consultation Number: WCRO 2020-00113.

National Marine Fisheries Service (NMFS). 2021. Southern Resident killer whales (Orcinus orca) 5-year review: summary and evaluation. National Marine Fisheries Service. West Coast Region. Seattle, WA. 103p.

National Marine Fisheries Service (NMFS). 2021c. Southern Distinct Population Segment of North American Green Sturgeon (acipenser medirostris) 5 year review: Summary and Evalaution. NMFS California Centeral Valley Office, Sacramento, CA National Research Council (NRC). 2009. Urban Stormwater Management in the United States. National Research Council. The National Academies Press. Washington, D.C.

NMFS. 2022. 2021 Southern Resident Killer Whales (Orcinus orca) 5-Year Review: Summary and Evaluation January 04, 2022

National Marine Fisheries Service (NOAA NMFS). 2023. Puget Sound Nearshore Habitat Conservation Calculator. https://www.fisheries.noaa.gov/west-coast/habitat-conservation/pugetsound-nearshore-habitat-conservation-calculator

National Research Council. 2003. Ocean noise and marine mammals. National Academies Press, Washington, DC.

National Research Council. 2003b. Committee on Potential Impacts of Ambient Noise in the Ocean on Marine Mammals. Ocean Noise and Marine Mammals. Washington (DC): National Academies Press (US). Effects of Noise on Marine Mammals. Available from: https://www.ncbi.nlm.nih.gov/books/NBK221255/

NEFMC. 1998. Final amendment #11 to the northeast multispecies fishery management plan, Amendment #9 to the Atlantic sea scallop fishery management plan, and components of the proposed Atlantic herring fishery management plan for EFH, incorporating the environmental assessment. Newburyprot (MA): NEFMC Vol. 1

Newcombe, C.P., and J.O.T. Jensen. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management. 16:34.

Nickelson, T.E., Solazzi, M.F., and S.L. Johnson. 1986. Use of hatchery coho salmon (Oncorhynchus kisutch) presmolts to rebuild wild populations in Oregon coastal streams. Canadian Journal of Fisheries and Aquatic Sciences 43: 2443-2449.

Nightingale, B., and C.A. Simenstad. 2001b. Overwater Structures: Marine Issues. University of Washington, Washington State Transportation Center. 133.

NOAA Fisheries. 2005. Final assessment of NOAA Fisheries' Critical Habitat Analytical Review Teams for 12 evolutionarily significant units of west coast salmon and steelhead. National Oceanic and Atmospheric Administration, NMFS-Protected Resources Division, Portland, OR. August 2005.

NOAA Fisheries. 2011. Biennial report to Congress on the recovery program for threatened and endangered species October 1, 2008 – September 30, 2010. National Oceanic and Atmospheric Administration, National Marine Fisheries Service. Washington, D.C.

NOAA (National Oceanic and Atmospheric Administration). 2013. "NOAA Nautical Chart 18471." Office of Coast Survey, Silver Spring, Maryland. Accessed August 3, 2020, at https://charts.noaa.gov/OnLineViewer/18471.shtml.

NOAA (National Oceanic and Atmospheric Administration). 2018a. 2018 Revision to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0). Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts. Silver Spring, Maryland. Accessed August 4, 2020, at https://www.fisheries.noaa.gov/resource/document/technical-guidance-assessing-effectsanthropogenic-sound-marine-mammal-hearing.

NOAA (National Oceanic and Atmospheric Administration). 2018b. Manual for Optional User Spreadsheet Tool (Version 2.0) for: 2018 Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0), Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts. Office of Protected Resources, Silver Spring, Maryland. Accessed August 4, 2020, at https://www.fisheries.noaa.gov/action/usermanual-optional-spreadsheet-tool-2018-acoustic-technical-guidance.

NOAA (National Oceanic and Atmospheric Administration). 2020. "Protected Resource App, West Coast Region." Silver Spring, Maryland. Accessed August 5, 2020, at https://www.webapps.nwfsc.noaa.gov/portal/apps/webappviewer/index.html?id=7514c715b8594944a6e468dd25aaacc9.

NOAA National Centers for Environmental Information (NCEI), State of the Climate: Global Climate Report for Annual 2021, published online January 2022, retrieved on February 28, 2022 from https://www.ncdc.noaa.gov/sotc/global/202113.

Noren, D. P., A. H. Johnson, D. Rehder, and A. Larson. 2009. Close approaches by vessels elicit surface active displays by Southern Resident killer whales. Endangered Species Research. 8:179-192.

Noren, D. P., R. C. Dunkin, T. M. Williams, and M. M. Holt. 2012. Energetic cost of behaviors performed in response to vessel disturbance: One link the in population consequences of acoustic disturbance model. In: Anthony Hawkins and Arthur N. Popper, Eds. The Effects of Noise on Aquatic Life, pp. 427–430.

Noren, D. P., M. M. Holt, R. C. Dunkin, and T. M. Williams. 2013. The metabolic cost of communicative sound production in bottlenose dolphins (*Tursiops truncatus*). The Journal of Experimental Biology. 216: 1624-1629.

Norman, S.A., C.E. Bowlby, M.S. Brancato, J. Calambokidis, D. Duffield, P.J. Gearin, T.A. Gornall, M.E. Gosho, B. Hanson, J. Hodder, S.J. Jeffries, B. Lagerquist, D.M. Lanbourn, B. Mate, B. Norberg, R.W. Osborne, J.A. Rash, S. Riemer, and J. Scordino. 2004. Cetacean strandings in Oregon and Washington between 1930 and 2002. Journal of Cetacean Research and Management 6: 87-99.

Northwest Fisheries Science Center (NWFSC). 2015. Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest.

O'Connor, S., R. Campbell, H. Cortez, and T. Knowles. 2009. Whale Watching Worldwide: Tourism numbers, expenditures and expanding economic benefits, a special report from the International Fund for Animal Welfare. Economists at Large, Yarmouth, MA.

O'Neill, S. M. and J.E. West. 2009. Marine Distribution, Life History Traits, and the Accumulation of Polychlorinated Biphenyls in Chinook Salmon from Puget Sound, Washington. Transactions of the American Fisheries Society 138: 616-632.

O'Neill, S.M., G. M. Ylitalo, and J. E. West. 2014. Energy content of Pacific salmon as prey of northern and southern resident killer whales. Endanger. Species Res. 25:265–281.

Ohlberger, J., E. J. Ward, D. E. Schindler, and B. Lewis. 2018. Demographic changes in Chinook salmon across the Northeast Pacific Ocean. Fish and Fisheries. 19(3): 533-546.

Olesiuk, P. F., M. A. Bigg, and G. M. Ellis. 1990. Life history and population dynamics of resident killer whales (Orcinus orca) in the coastal waters of British Columbia and Washington State. Pages 209-244 in International Whaling Commission, Individual Recognition of Cetaceans: Use of Photo-Identification and Other Techniques to Estimate Population Parameters (Special Issue 12), incorporating the proceedings of the symposium and workshop on individual recognition and the estimation of cetacean population parameters.

Olesiuk, P. F., G. M. Ellis, and J. K. B. Ford. 2005. Life history and population dynamics of northern resident killer whales (Orcinus orca) in British Columbia (pages 1-75). Canadian Science Advisory Secretariat.

Olmos M., M.R. Payne, M. Nevoux, E. Prévost, G. Chaput, H. Du Pontavice, J. Guitton, T. Sheehan, K. Mills, and E. Rivot. 2020. Spatial synchrony in the response of a long range migratory species (*Salmo salar*) to climate change in the North Atlantic Ocean. Glob Chang Biol. 26(3):1319-1337. doi: 10.1111/gcb.14913. Epub 2020 Jan 12. PMID: 31701595.

Olson, A.M., S.D. Visconty, and C.M. Sweeney. 1996. Modeling the shade cast by overwater structures. Pacific Estuarine Research Society, 19th Annual Meeting. Washington Department of Ecology, Olympia, Washington. SMA 97-1 School Mar. Affairs, Univ. Wash., Seattle, WA.

Olson, J. K., J. Wood, R.W. Osborne, L. Barrett-Lennard, and S. Larson. 2018. Sightings of southern resident killer whales in the Salish Sea 1976‒2014: the importance of a long-term opportunistic dataset. Endang. Species Res. Col 37: 105-118.

Ono, K. 2010. Assessing and Mitigating Dock Shading Impacts on the Behavior of Juvenile Pacific Salmon (Oncorhynchus spp.): can artificial light mitigate the effects? In School of Aquatic and Fishery Sciences. Vol. Master of Science. University of Washington.

Onoufriou, J., D.J.F. Russell, D. Thompson, S.E. Moss, and Quantifying the Effects of Tidal Turbine Array Operations on the Distribution of Marine Mammals: Implications for Collision Risk. Renewable Energy 180: 157-165.

Orr, J. W., M. A. Brown, and D. C. Baker. 2000. Guide to rockfishes (Scorpaenidae) of the genera Sebastes, Sebastolobus, and Abelosebastes of the northeast Pacific Ocean, Second Edition. NOAA Technical Memorandum NMFS-AFSC-117. 56 pages.

Osborne, R. W. 1999. A historical ecology of Salish Sea “resident” killer whales (Orcinus orca): with implications for management. Doctoral dissertation. University of Victoria, Victoria, British Columbia.

Ou, M., T.J. Hamilton, J. Eom, E.M. Lyall, J. Gallup, A. Jiang, et al. 2015. Responses of pink salmon to CO2-induced aquatic acidification. Nature Climate Change. 5(10). https://doi.org/10.1038/nclimate2694 WOS:000361840600017.

Oulhen N, Byrne M, Duffin P, Gomez-Chiarri M, Hewson I, Hodin J, Konar B, Lipp EK, Miner BG, Newton AL, Schiebelhut LM, Smolowitz R, Wahltinez SJ, Wessel GM, Work TM, Zaki HA, Wares JP. A Review of Asteroid Biology in the Context of Sea Star Wasting: Possible Causes and Consequences. Biol Bull. 2022 Aug;243(1):50-75. doi: 10.1086/719928. Epub 2022 Jul 22. PMID: 36108034; PMCID: PMC10642522.

Pacific Northwest National Laboratory (PNNL). 2023. Conversation between Jim Becker (PNNL Biological Resources Program Manager) and Lorenz Sollmann (Washington Maritime National Wildlife Refuge Complex). April 2023.

Pacunski, R. E., W. A. Palsson, and H. G. Greene. 2013. Estimating Fish Abundance and Community Composition on Rocky Habitats in the San Juan Islands Using a Small Remotely Operated Vehicle. FPT 13-02. Retrieved from https://wdfw.wa.gov/publications/01453/

Palsson, W.A., T. Tsou, G.G. Bargmann, R. M. Buckley, J. E. West, M. L. Mills, Y. W Cheng, and R. E. Pacunski. 2009. The Biology and Assessment of Rockfishes in Puget Sound. Washington Department of Fish and Wildlife. 208 p.

Parametrix and Battelle Marine Sciences Laboratory. 1996. Anacortes Ferry Terminal eelgrass, macroalgae, and macrofauna habitat survey report. Report for Sverdrup Civil, Inc. and WSDOT

Penttila, D., and D. Doty. 1990. Results of 1989 eelgrass shading studies in Puget Sound, Progress Report Draft. WDFW Marine Fish Habitat Investigations Division.

Perrin, W, B. Wursig, and J.G.M. Thewissen. 2002. Encyclopedia of Marine Mammals. Academic Press, New York, New York.

Pettis, H. M., R. M. Rolland, P. K. Hamilton, S. Brault, A. R. Knowlton, S. D. Kraus. 2004. Visual health assessment of North Atlantic right whales (Eubalaena glacialis) using photographs. Can J Zool 82:8-19.

PFMC (Pacific Fishery Management Council). 2016. Pacific Coast Salmon Fishery Management Plan for Commercial and Recreational Salmon Fisheries off the Coasts of Washington, Oregon, and California as Revised Through Amendment 19. Portland, Oregon. Accessed August 4, 2020, at https://www.pcouncil.org/documents/2016/03/salmon-fmp-through-amendment-19.pdf/.

PFMC (Pacific Fishery Management Council). 2019b. Pacific Coast Groundfish Fishery Management Plan for the California, Oregon, and Washington Groundfish Fishery. Portland, Oregon. Accessed August 4, 2020, at https://www.pcouncil.org/documents/2016/08/pacificcoast-groundfish-fishery-management-plan.pdf/.

PFMC (Pacific Fishery Management Council). 2019c. Status of the Pacific Coast Coastal Pelagic Species Fishery and Recommended Acceptable Biological Catches: Stock Assessment and Fishery Evaluation 2018 Including Information Through June 2018. Portland, Oregon.

Picciulin, M., Sebastianutto, L., Codarin, A., Farina, A. & Ferrero, E.A. 2010. In situ behavioural responses to boat noise exposure of Gobius cruentatus (Gmelin, 1789, fam. Gobiidae) and Chromis (Linnaeus, 1758, fam. Pomacentridae) living in a Marine Protected Area. Journal of Experimental Marine Biology and Ecology, 386, 125-132.

PNPTC (Point No Point Treaty Council). 2006. Historical Changes to Estuaries, Spits, and Associated Tidal Wetland Habitats in the Hood Canal and Strait of Juan de Fuca Regions of Washington State. PNPTC Technical Report 06-1, Kingston, Washington. December. Accessed December 16, 2019, at http://www.pnptc.org/Historical_Nearshore.html. TN249

PNPTC (Point No Point Treaty Council). 2006. "Sequim Bay Sub-Region." Appendix B-4 in Historical Changes to Estuaries, Spits, and Associated Tidal Wetland Habitats in the Hood Canal and Strait of Juan de Fuca Regions of Washington State. PNPTC Technical Report 06-1, Kingston, Washington. December. Accessed December 16, 2019, at http://www.pnptc.org/Historical_Nearshore.html. TN248.

Point No Point Treaty Tribes (PNPTT) and Washington Department of Fish and Wildlife (WDFW). 2014. Five-year review of the Summer Chum Salmon Conservation Initiative for the period 2005 through 2013. Supplemental report No. 8, Summer Chum Salmon Conservation Initiative – an implementation plan to recover summer chum salmon in the Hood Canal and Strait of Juan de Fuca region. Washington Department of Fish and Wildlife. Olympia, WA. 244 p., including Appendices.

Popper, A. N. 2003. Effects of Anthropogenic Sounds on Fishes. Available in Fisheries 28(10):24-31·October 2003.

Popper, A.N. and M.C. Hastings. 2009. “The Effects of Anthropogenic Sources of Sound on Fishes.” Journal of Fish Biology 75(3):455–489. doi.org/10.1111/j.1095-8649.2009.02319.x.

Puget Sound Partnership (PSP). 2018. 2018-2022 Action Agenda and Comprehensive Plan. Puget Sound Partnership, Olympia, WA. December 2018. https://psp.wa.gov/action_agenda_center.php

PSI and UW (Puget Sound Institute and University of Washington). 2019. "Rockfish." Section 2, Subsection 7, In Puget Sound Science Review, Encyclopedia of Puget Sound, Seattle, Washington. Accessed August 4, 2020, at https://www.eopugetsound.org/science-review/7-rockfish.

Quinn, T. P. 2005. The Behavior and Ecology of Pacific Salmon and Trout. UW Press.

Raymond, E.H. and E.A. Widder. 2007. "Behavioral Responses of Two Deep-sea Fish Species to Red, Far-red, and White Light." Marine Ecology Progress Series 350:291-298.

Redden, A.M., J. Broome, F. Keyser, M. Stokesbury, R. Bradford, J. Gibson, and E. Halfyard. 2014. Use of Animal Tracking Technology to Assess Potential Risks of Tidal Turbine Interactions with Fish. Proceedings of the 2nd International Conference on Environmental Interactions of Marine Renewable Energy Technologies.

Reddy, M. L., J. S. Reif, A. Bachand, and S. H. Ridgway. 2001. Opportunities for using Navy marine mammals to explore associations between organochlorine contaminants and unfavorable effects on reproduction. Sci. Total Environ. 274:171–182.

Reeves, R. R. 1977. The problem of gray whale (Eschrichtius robustus) harassment: At the breeding lagoons and during migration. Unpublished report to U.S. Marine Mammal Commission, Washington, D.C., under contract MM6AC021. Available from U.S. National Technical Information Service, Springfield, Virginia, PB 272 506.

Reijnders, P. J. 1986. Reproductive failure in common seals feeding on fish from polluted coastal waters. Nature 324:456–457.

Rice, C. A. 2006. Effects of shoreline modification on a northern Puget Sound beach: microclimate and embryo mortality in surf smelt (Hypomesus pretiosus). Estuaries and Coasts. 29(1): 63-71

Rice, C. A., C.M. Greene, P. Moran, D.J. Teel, D.R. Kuligowski, R.R. Reisenbichler, E.M. Beamer, J.R. Karr, and K.L. Fresh. 2011. Abundance, Stock Origin, and Length of Marked and Unmarked Juvenile Chinook Salmon in the Surface Waters of Greater Puget Sound. Transactions of the American Fisheries Society. 140:170-189.

Richardson, W.J., and C.I. Malme. 1993. Man-made noise and behavioral responses. Pp. 631-700 in The Bowhead Whale, J.J. Burns et al., editor. , eds. Special Publication No. 2, Society for Marine Mammalogy. Lawrence, KS.

Richardson, W. J., C. R. Greene, C. I. Malme Jr., and D. H. Thomson. 1995. Marine Mammals and Noise. Academic Press, 525 B Street, Ste. 1900, San Diego, California 92101-4495.

Romano, T.A., M.J. Keogh, C. Kelly, P. Feng, L. Berk, C.E. Schlundt, D.A. Carder, and J.J. FinneranRoss, P. S., G.M. Ellis, M.G. Ikonomou, L.G. Barrett-Lennard, and R.F. Addison. 2000. High PCB concentrations in free-ranging Pacific killer whales, Orcinus orca: effects of age, sex, and dietary preference. Marine Pollution Bulletin 40(6):504-515.

Ruckelshaus, M., K. Currens, W. Graeber, R. Fuerstenberg, K. Rawson, N. Sands, and J. Scott. 2002. Planning ranges and preliminary guidelines for the delisting and recovery of the Puget Sound Chinook salmon evolutionarily significant unit. Puget Sound Technical Recovery Team. National Marine Fisheries Service, Northwest Fisheries Science Center. Seattle.

Salo, E. O. 1991. Life history of chum salmon (Oncorhynchus keta). Page 233 in L. Groot and C. Margolis, editors. Pacific salmon life histories. UBC Press, Vancouver, British Columbia, Canada.

Sands, N.J., K. Rawson, K. Currens, B. Graeber, M. Ruckelshaus, B. Fuerstenberg, and J. Scott. 2007. Dawgz 'n the Hood: The Hood Canal Summer Chum Salmon ESU. February 28, 2007 draft document available at: *www.nwfsc.noaa.gov/trt/trt_puget.cfm*.

Sands, N. J., K. Rawson, K. Currens, W. Graeber, M. H. Ruckelshaus, R. Fuerstenberg, J. Scott. 2009. Determination of independent populations and viability criteria for the Hood Canal summer chum salmon evolutionarily significant unit. U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC-101, 58 p.

Sanger, D.M., A.F. Holland, and C. Gainey. 2004. Cumulative impacts of dock shading on Spartina alteniflora in South Carolina estuaries. Environmental Management 33: 741-748

Sequim Gazette. 2015. "'Killer' Photos on Sequim Bay Slideshow." September 10, 2015. Accessed August 4, 2020, at http://www.sequimgazette.com/community/326347391.html

Schaefer, K.M. 1996. Spawn time, frequency, and batch fecundity of yellowfin tuna (Thunnus albacares) near Clipperton Atoll in the eastern Pacific Ocean. Fisheries Bulletin 94: 98-112.

Schindler, D. E., J. B. Armstrong, and T. E. Reed. 2015. The portfolio concept in ecology and evolution. Frontiers in Ecology and the Environment 13:257-263.

Scholik, A. R., and H.Y. Yan. 2002. Effects of boat engine noise on the auditory sensitivity of the fathead minnow, Pimephales promelas. Environmental Biology of Fishes. 63:203-209.

Schwacke, L. H., E. O. Voit, L. J. Hansen, R. S. Wells, G. B. Mitchum, A. A. Hohn, and P.A. Fair. 2002. Probabilistic risk assessment of reproductive effects of polychlorinated biphenyls on bottlenose dolphins (Tursiops truncatus) from the southeast United States coast. Environ. Toxicol. Chem. 21:2752–2764.

Schwacke, L. H., C. R. Smith, F. I. Townsend, R. S. Wells, L. B. Hart, B. C. Balmer, T. K. Collier, S. De Guise, M. M. Fry, L. J. Guillette, Jr., S. V. Lamb, S. M. Lane, W. E. McFee, N. J. Place, M. C. Tumlin, G. M. Ylitalo, E. S. Zolman, and T. K. Rowles. 2013. Health of common bottlenose dolphins (Tursiops truncatus) in Barataria Bay, Louisiana, following the Deepwater Horizon Oil spill. Environ. Sci. Technol. 48:93- 103.

Scordino, J., and B. Pfeifer. 1993. Sea lion/steelhead conflict at the Ballard Locks. A history of control efforts to date and a bibliography of technical reports. Washington Department of Fish and Wildlife Report, 10 p. (Available from Northwest Regional Office, Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE, Seattle, WA 98115.)

Sebastianutto, L., M. Picciulin, M. Costantini, and E.A. Ferrero. 2011. How boat noise affects an ecologically crucial behavior: the case of territoriality in Gobius cruentatus (Gobiidae). Environmental Biology of Fishes. 92:207-215.

Sericano, J. L., T. L. Wade, S. T. Sweet, J. Ramirez, and G. G. Lauenstein. 2014. Temporal trends and spatial distribution of DDT in bivalves from the coastal marine environments of the continental United States, 1986–2009. Mar. Pollut. Bull. 81:303–316. https://www.sciencedirect.com/science/article/abs/pii/S0025326X13007972

Servizi, J.A., and D.W. Martens. 1991. Effect of temperature, season, and fish size on acute lethality of suspended sediments to coho salmon (Oncorhynchus kisutch). Canadian Journal of Fisheries and Aquatic Sciences. 48:493-497.

Shafer, D. J. 1999. The effects of dock shading on the seagrass Halodule wrightii in Perdido Bay, Alabama. Estuaries. 22:936-943.

Shafer, D. J. 2002. Recommendations to minimize potential impacts to seagrasses from single family residential dock structures in the PNW. S.D. Prepared for the U.S. Army Corps of Engineers, editor.

Shaffer, J. A. Doty, D. C., Buckley, R. M., and J. E. West. 1995. Crustacean community composition and trophic use of the drift vegetation habitat by juvenile splitnose rockfish Sebastes diploproa. Marine Ecology Progress Series. Volume 123, pages 13 to 21.

Shared Strategy for Puget Sound (SSPS). 2007. Puget Sound Salmon Recovery Plan – Volume 1. Shared Strategy for Puget Sound, 1411 4th Ave., Ste. 1015, Seattle, WA 98101. Adopted by NMFS January 19, 2007. 503 pp.

Shen, H. G.B. Zydlewski, H.A. Viehman, and G. Staines. 2016. Estimating the Probability of Fish Encountering a Marine Hydrokinetic Device. Renewable Energy 97: 746-756.

Siegle M. R., E.B. Taylor, K.M. Miller, R.E. Withler, and K.L. Yamanaka. 2013. Subtle population genetic structure in yelloweye rockfish (Sebastes ruberrimus) is consistent with a major oceanographic division in British Columbia, Canada. PLoS ONE, 8.

Siegel, J., and L. Crozier. 2019. Impacts of Climate Change on Salmon of the Pacific Northwest. A review of the scientific literature published in 2018. Fish Ecology Division, NWFSC. December 2019.

Siegel, J., and L. Crozier. 2020. Impacts of Climate Change on Salmon of the Pacific Northwest: A review of the scientific literature published in 2019. National Marine Fisheries Service, Northwest Fisheries Science Center, Fish Ecology Division. https://doi.org/10.25923/jke5-c307

Simenstad, C. A., B.S. Miller, C.F. Nyblade, K. Thornburgh, and L.J. Bledsoe. 1979. Food web relationship of northern Puget Sound and the Strait of Juan de Fuca, EPA Interagency Agreemnt No. D6-E693-EN. Office of Environmental Engineering and Technology, US EPA.

Simenstad, C.A. 1988. Summary and Conclusions from Workshop and Working Group Discussions. Pages 144-152 in Proceedings, Workshop on the Effects of Dredging on Anadromous Pacific Coast Fishes, Seattle, Washington, September 8-9, 1988. C.A. Simenstad, ed., Washington Sea Grant Program, University of Washington, Seattle, Washington.

Simenstad, C. A., B. J. Nightingale, R. M. Thom and D. K. Shreffer. 1999. Impacts of ferry terminals on juvenile salmon migrating along Puget Sound shorelines, Phase I: synthesis of state of knowledge. Final Res. Rept., Res. Proj. T9903, Task A2, Wash. State Dept.Transportation, Washington State Trans. Center (TRAC), Seattle, WA. 116 pp + appendices

Simpson, S. D., A.N Radford, S.L. Nedelac, M.C.O. Ferrari, D.P Chivers, M.I. McCormick and M.G. Meekan. 2016. Anthropogenic noise increases fish mortality by predation. Nat. Commun 7, 10544. https://doi.org/10.1038/ncomms10544

Slabbekoorn, H., N. Bouton, I. van Opzeeland, A. Coers, C. ten Cate, A.N. Popper. 2010. A noisy spring: the impact of globally rising underwater sound levels on fish. Volume 25, Issue 7, P419-427

Sobocinski, K. L. 2003. The impact of shoreline armoring on supratidal beach fauna of central Puget Sound. Unpublished Masters Thesis, University of Washington: 83 pp.

Southard, S. L., R.M. Thom, G.D. Williams, T.J. D., C.W. May, G.A. McMichael, J.A. Vucelick, J.T. Newell, and J.A. Southard. 2006. Impacts of Ferry Terminals on Juvenile Salmon Movement along Puget Sound Shorelines. Battelle Memorial Institute, Pacific Northwest Division.

Sparling, C.E., A.C. Seitz, E. Masden, and K. Smith. 2020. “Collision Risk for Animals Around Turbines.” Chapter 3 In A.E. Copping and L.G. Hemery (Eds.), OES-Environmental 2020 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World. Report for Ocean Energy Systems (OES). (pp. 28-65). doi:10.2172/1632881.

Spence, B. C., G.A. Lomnicky, R.M. Hughes, and R.P. Novitzki. 1996. An ecosystem approach to salmonid conservation. ManTech Environmental Research Services, Inc. Corvallis, Oregon. National Marine Fisheries Service, Portland, Oregon.

Sridhar, V., M.M. Billah, J.W. Hildreth. 2018. Coupled Surface and Groundwater Hydrological Modeling in a Changing Climate. Groundwater Vol. 56, Issue 4. https://doi.org/10.1111/gwat.12610

Stachura, M.M., N.J. Mantua, and M.D. Scheuerell. 2014. Oceanographic influences on patterns in North Pacific salmon abundance. Canadian Journal of Fisheries and Aquatic Sciences, 71(2), pp.226-235.

Stadler, J. and Woodbury, D., 2009, August. Assessing the effects to fishes from pile driving: Application of new hydroacoustic criteria. In INTER-NOISE and NOISE-CON Congress and Conference Proceedings (Vol. 2009, No. 2, pp. 4724-4731). Institute of Noise Control Engineering.

Stephens, C. 2015. Summary of West Coast Oil Spill Data: Calendar Year 2015. Pacific States/British Columbia Oil Spill Task Force. June 2015. 26p. Available at: http://oilspilltaskforce.org/wp-content/uploads/2016/07/Oil-Spill-Data-Summary_2015_FINALpdf.pdf

Stephens, C. 2017. Summary of West Coast Oil Spill Data: Calendar Year 2016. Pacific States/British Columbia Oil Spill Task Force. May 2017. 27p. Available at: http://oilspilltaskforce.org/wp-content/uploads/2013/08/summary_2016_DRAFT_16May2017_2.pdf

Struck S. D., C.B. Craft, S.W. Broome, M.D. Sanclements. 2004. Effects of bridge shading on estuarine marsh benthic invertebrate community structure and function. Environmental Management 34(1) 99-111

Sturrock, A.M., S.M. Carlson, J.D. Wikert, T. Heyne, S. Nusslé, J.E. Merz, H.J. Sturrock and R.C. Johnson. 2020. Unnatural selection of salmon life histories in a modified riverscape. Global Change Biology, 26(3), pp.1235-1247.

Stutes, A.L., Cebrian, J. and Corcoran, A.A., 2006. Effects of nutrient enrichment and shading on sediment primary production and metabolism in eutrophic estuaries. Marine Ecology Progress Series, 312, pp.29-43.

Subramanian, A., S. Tanabe, R. Tatsukawa, S. Saito, and N. Miyazaki. 1987. Reduction in the testosterone levels by PCBs and DDE in Dall’s porpoises of Northwestern North Pacific. Mar. Pollut. Bull. 18:643–646.

Sundermeyer, M.A., E.A. Terray, J.R. Ledwell, A.G. Cunningham, P.E. LaRocque, J. Banic, and W.J. Lillycrop. 2007. Three -dimensional Mapping of Fluorescent Dye using a Scanning, Depth resolving Airborne LiDAR.” Journal of Atmospheric and Ocean Technology 24:1050–1065.

Tabor, R.A., A.T.C. Bell, D.W. Lantz, C.N. Gregersen, H.B. Berge, D.K. Hawkins. 2017. Phototaxic Behavior of Subyearling Salmonids in the Nearshore Area of Two Urban Lakes in Western Washington State. American Fisheries Society 2017ISSN: 0002-8487 print / 1548-8659 onlineDOI: https://doi.org/10.1080/00028487.2017.1305988

Tagal, M., K.C. Massee, N. Ashton, R. Campbell, P. Pleasha, and M.B. Rust. 2002. Larval development of yelloweye rockfish, Sebastes ruberrimus. N, Northwest Fisheries Science Center.

Taylor, M.F.J., Suckling, K.F., Rachlinski, J.J. 2005. The effectiveness of the Endangered Species Act: A quantitative analysis. BioScience 55(4): 360-367. Available at: http://www.biologicaldiversity.org/publications/papers/bioscience2005.p df

Teachout, E. 2012. Evaluating the Effects of Underwater Sound from Pile Driving on the Marbled Murrelet and the Bull Trout. Washington Fish and Wildlife Office, Lacey, Washington.

Thom, R. M., and D. K. Shreffler. 1996. Eelgrass meadows near ferry terminals in Puget Sound. Characterization of assemblages and mitigation impacts. Battelle Mar. Sci. Lab., Sequim, WA.

Thom, R. M., Southard, S.L., Borde, A.B. et al. 2008. Light Requirements for Growth and Survival of Eelgrass (Zostera marina L.) in Pacific Northwest (USA) Estuaries. Estuaries and Coasts 31, 969–980. https://doi.org/10.1007/s12237-008-9082-3

Thorne, K., G. MacDonald, G. Guntenspergen, R. Ambrose, K. Buffington, B. Dugger, C. Freeman, C. Janousek, L. Brown, J. Rosencranz, J. Holmquist, J. Smol, K. Hargan, and J. Takekawa. 2018. U.S. Pacific coastal wetland resilience and vulnerability to sea-level rise. Science Advances 4(2). DOI: 10.1126/sciadv.aao3270

Toft, J. D., J.R. Cordell, C.A. Simenstad, and L.A. Stamatiou. 2007. Fish distribution, abundance, and behavior along city shoreline types in Puget Sound. North American Journal of Fisheries Management. 27, 465-480.

Toft, J. D., A.S. Ogston, S.M. Heerhartz, J.R. Cordell, and E.E. Flemer. 2013. Ecological response and physical stability of habitat enhancements along an urban armored shoreline. Ecological Engineering. 57:97-108.

Tolimieri, N., and P. S. Levin. 2005. The roles of fishing and climate in the population dynamics of bocaccio rockfish. Ecological Applications, 15(2):459-468.

Tonnes, D. M., M. Bhuthimethee, J. Sawchuk, N. Tolimieri, K. Andrews, and K. Nichols. 2016. Yelloweye rockfish (Sebastes ruberrimus), canary rockfish (Sebastes pinniger), and bocaccio (Sebastes paucispinis) of the Puget Sound/Georgia Basin. 5-Year Review. National Marine Fisheries Service. Seattle, WA.

Trites, A. W. and C.P. Donnelly. 2003. The decline of Steller sea lions Eumetopias jubatus in Alaska: a review of the nutritional stress hypothesis. Mammal Rev. 33(1): 3-28.

Trites, A. W. and D. A. S. Rosen (eds). 2018. Availability of Prey for Southern Resident Killer Whales. Technical Workshop Proceedings. November 15–17, 2017. Marine Mammal Research Unit, Institute for the Oceans and Fisheries, University of British Columbia, Vancouver, B.C., 64 p.

Turnpenny, A. W. H., K.P Thatcher, and J.R. Nedwell. 1994. The effects on fish and other marine animals of high-level underwater sound. Fawley Aquatic Research Laboratory, Ltd., Report FRR 127/94, United Kingdom. 79 p.

Turnpenny, A., and J. Newell. 1994. The effects on marine fish, diving mammals, and birds of underwater sound generated by seismic surveys. Fawley Aquatic Research Laboratories Limited, Marine and Freshwater Biology Unit, Southampton, Hampshire, UK. 48 p.

Tyack, P.L., and C.W. Clark. 1998. Quick-look report: Playback of low-frequency sound to gray whales migrating past the central California coast. Unpublished.

USDC. 2009. Endangered and threatened wildlife and plants: Final rulemaking to designate critical habitat for the threatened southern distinct population segment of North American green sturgeon. U.S. Department of Commerce, National Marine Fisheries Service. Federal Register 74(195):52300-52351.

USDC. 2010. Endangered and threatened wildlife and plants, final rulemaking to establish take prohibitions for the threatened southern distinct population segment of North American green sturgeon. U.S. Department of Commerce, National Marine Fisheries Service. Federal Register 75(105):30714-30728.

USDC. 2013. Endangered and Threatened Species, proposed rule for designation of critical habitat for Lower Columbia River coho salmon and Puget Sound steelhead. Federal Register, Vol. 78, No. 9. January 14, 2013.

USDC. 2014. Endangered and threatened wildlife; Final rule to revise the Code of Federal Regulations for species under the jurisdiction of the National Marine Fisheries Service. U.S Department of Commerce. Federal Register 79(71):20802-20817.

van der Knaap, I., E. Ashe, D. Hannay, A. Ghoul Bergman, K.A. Nielsen, C.F. Lo, R. Williams. 2022. Behavioural responses of wild Pacific salmon and herring to boat noise. Marine Pollution Bulletin, Volume 174, https://doi.org/10.1016/j.marpolbul.2021.113257.

Veilleux, H.D., Donelson, J.M. and Munday, P.L., 2018. Reproductive gene expression in a coral reef fish exposed to increasing temperature across generations. Conservation physiology, 6(1), p.cox077.

Veldhoen, N., M.G. Ikonomou, C. Dubetz, N. MacPherson, T. Sampson, B.C. Kelly, and C.C. Helbing. 2010. Gene expression profiling and environmental contaminant assessment of migrating Pacific salmon in the Fraser River watershed of British Columbia. Aquatic Toxicology 97(3):212-225.

Vélez-Espino, Luis A., John Kenneth Baker Ford, H. A. Araujo, G. Ellis, C. K. Parken, and K. C. Balcomb. Comparative demography and viability of northeastern Pacific resident killer whale populations at risk. Fisheries and Oceans Canada= Pêches et océans Canada, 2014.

Venn-Watson, S., Colegrove KM, Litz J, Kinsel M, Terio K, Saliki J, et al. 2015. Adrenal Gland and Lung Lesions in Gulf of Mexico Common Bottlenose Dolphins (Tursiops truncatus) Found Dead following the Deepwater Horizon Oil Spill. PLoS ONE 10(5): e0126538. doi:10.1371/journal. pone.0126538

Viberg, H., A. Fredriksson, and P. Eriksson. 2003. Neonatal exposure to polybrominated diphenyl ether (PBDE-153) disrupts spontaneous behaviour, impairs learning and memory, and decreases hippocampal cholinergic receptors in adult mice. Toxicol. Appl. Pharmacol. 192:95–106.

Viberg, H., N. Johansson, A. Fredriksson, J. Eriksson, G. Marsh, and P. Eriksson. 2006. Neonatal exposure to higher brominated diphenyl ethers, hepta-, octa-, or nonabromodiphenyl ether, impairs spontaneous behavior and learning and memory functions of adult mice. Toxicol. Sci. 92:211–218.

Voellmy, I.K., J. Purser, D Flynn, P. Kennedy, S.D. Simpson, A.N. Radford. 2014. Acoustic Noise reduces foraging success in two sympatric fish species. Animal Behavior 89, 191-198.

Wade, P. R. 2021. Estimates of abundance and migratory destination for North Pacific humpback whales in both summer feeding areas and winter mating and calving areas. Paper SC/68c/IA03 submitted to the Scientific Committee of the International Whaling Commission

Wainwright, T. C. and L. A. Weitkamp. 2013. Effects of climate change on Oregon Coast coho salmon: habitat and life-cycle interactions. Northwest Science 87(3): 219-242.

Wait, M., J. Fletcher, and A. Tuohy. 2018. Nearshore habitat use by Hood Canal Summer run chum salmon in Hood Canal and the Strait of Juan de Fuca. Presented at Salish Sea Ecosystem Conference, Seattle. WA. https://cedar.wwu.edu/ssec/2018ssec/allsessions/464

Waggitt, J.M., A.M.C. Robbins, H.M. Wade, E.A. Masden, R.W. Furness, A.C. Jackson, and B.E. Scott. 2017. Comparative Studies Reveal Variability in the Use of Tidal Stream Environments by Seabirds. Marine Policy 81: 143-152.

Ward, E. J., M.J. Ford, R.G. Kope, J.K.B. Ford, L.A. Velez-Espino, C.K. Parken, L.W. LaVoy, M.B. Hanson, and K.C. Balcomb. 2013. Estimating the impacts of Chinook salmon abundance and prey removal by ocean fishing on Southern Resident killer whale population dynamics. U.S. Dept. Commer., NOAA Tech. Memo. NMFS- NWFSC-123.

Ward, E.J., J.H. Anderson, T.J. Beechie, G.R. Pess, M.J. Ford. 2015. Increasing hydrologic variability threatens depleted anadromous fish populations. Glob Chang Biol. 21(7):2500–9. Epub 2015/02/04. pmid:25644185.

Wartzok, D. and D.R. Ketten. 1999. "Marine Mammal Sensory Systems." In Biology of Marine Mammals, J. Reynolds and S. Rommel (eds.), Smithsonian Institution Press, pp. 117-175, Washington, D.C.

Washington State Department of Ecology (WDOE). 2017. Spill Prevention, Preparedness, and Response Program. 2017-2019 Program Plan. Publication 17-08-018. 29p.

Washington, P. 1977. Recreationally important marine fishes of Puget Sound, Washington. National Oceanic and Atmospheric Administration, Northwest and Alaska Fisheries Center. 122 pages.

Washington, P. M., R. Gowan, and D.H. Ito. 1978. A biological report on eight species of rockfish (Sebastes spp.) from Puget Sound, Washington. NOAA National Marine Fisheries Service Northwest and Alaska Fisheries Science Center Processed Report, 50 p.

Wasser, S. K., J. I. Lundin, K. Ayers, E. Seely, D. Giles, K. Balcomb, J. Hempelmann, K. Parsons, R. Booth. 2017. Population growth is limited by nutritional impacts on pregnancy success in endangered Southern Resident killer whales (Orcinus orca). PLoS ONE 12(6): e0179824. https://doi.org/10.1371/journal. pone.0179824.

Watkins, W.A. 1986. Whale reactions to human activities in Cape Cod waters. Marine Mammal Science 2:251-262.

WDFW and ODFW. 2001. Joint state eulachon management plan. Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife.

WDFW. 2009. The Biology and Assessment of Rockfishes in Puget Sound. Sept 2009. Palsson, Tsou, Bargmann, Buckley, West, Mills, Cheng, and Pacunski. FPT 09-04. Accessed via. https://www.researchgate.net/profile/Wayne-Palsson/publication/324833293_The_Biology_and_Assessment_of_Rockfishes_in_Puget_Sound/links/604a98b4299bf1f5d840d93b/The-Biology-and-Assessment-of-Rockfishes-in-Puget-Sound.pdf

WDFW (Washington Department of Fish and Wildlife). 2013. Threatened and Endangered Wildlife in Washington: 2012 Annual Report. Listing and Recovery Section, Wildlife Program, Olympia, Washington..

Washington Department of Natural Resources (WDNR). 2017. Puget Sound Seagrass Monitoring Report, Monitoring Year 2015. https://www.dnr.wa.gov/publications/aqr_nrsh_psseagrass_report_2017_2015.pdfWeis, J. and P. Weis. 2004. Effects of CCA wood on non-target aquatic biota. Pages 32- 44 in Pre-Conference Proceedings, Environmental Impacts of Preservative- Treated Wood. Florida Center for Solid and Hazardous Waste Management, Gainesville, FL. Available at: http://www.ccaresearch.org/Pre- Conference/#release

Weis, J. S., P. Weis and T. Proctor. 1998. The Extent of benthic impacts of CCA-treated wood structures in Atlantic Coast estuaries. Archives Environmental Contamination and Toxicology 34:313-322

Weitkamp, D.E. 1991. Epibenthic zooplankton production and fish distribution at selected pier apron and adjacent non-apron sites in Commencement Bay, WA, Report to Port of Tacoma. Parametrix, Seattle, WA.

Whitcraft, C.R., and L.A. Levin. 2007. Regulation of benthic algal and animal communities by salt marsh plants: impact of shading. Ecology 88: 904-917

Whitfield, A.K., and A. Becker. 2014. Impacts of recreational motorboats on fishes: A review. Marine Pollution Bulletin 83, 24-31.

Whitney, D. E. and Darley, W.M., 1983. Effect of light intensity upon salt marsh benthic microalgal photosynthesis. Marine Biology, 75(2), pp.249-252.

Wiles, G. J. 2004. Washington State Status Report for the Killer Whale. March 2004. WDFW, Olympia, Washington. 120p.Willette, T.M. 2001. Foraging behaviour of juvenile pink salmon (Oncorhynchus gorbuscha) and size-dependent predation risk. Fisheries Oceanography. 10:110-131.

Willette, T. M. 2001. Foraging behaviour of juvenile pink salmon (Oncorhynchus gorbuscha) and size-dependent predation risk. Fisheries Oceanography. https://onlinelibrary.wiley.com/doi/full/10.1046/j.1054-6006.2001.00042.

Williams, R., D. Lusseau and P. S. Hammond. 2006. Estimating relative energetic costs of human disturbance to killer whales (Orcinus orca). Biol. Cons. 133:301–311.

Williams, R., E. Ashe, and D. Lusseau. 2010. Killer whale activity budgets under no-boat, kayak-only and power-boat conditions. Contract via Herrera Consulting, Seattle, Washington. 29 pp.

Williams, T.H., B.C. Spence, D.A. Boughton, R.C. Johnson, L.G. Crozier, N.J. Mantua, M.R. O'Farrell, and S.T. Lindley. 2016. Viability assessment for Pacific salmon and steelhead listed under the Endangered Species Act: Southwest. NOAA Fisheries Southwest Fisheries Science Center, Santa Cruz, CA: U.S. Dep Commerce NOAA Tech Memo NMFS SWFSC 564.

Wyman, M.T., Kavet, R., Battleson, R.D. 2023. Assessment of potential impact of magnetic fields from a subsea high-voltage DC power cable on migrating green sturgeon, Acipenser medirostris. Mar Biol 170, 164. https://doi.org/10.1007/s00227-023-04302-4

Xie, Y. B., Michielsens, C.G.J., Gray, A.P., Martens, F.J. & Boffey, J.L. 2008. Observations of avoidance reactions of migrating salmon to a mobile survey vessel in a riverine environment. Canadian Journal of Fisheries and Aquatic Sciences, 65, 2178-2190.

Yan, H., N. Sun, A. Fullerton, and M. Baerwalde. 2021. Greater vulnerability of snowmelt-fed river thermal regimes to a warming climate. Environmental Research Letters 16(5). https://doi.org/10.1088/1748-9326/abf393

Ylitalo, G. M., J. E. Stein, T. Horn, L. L. Johnson, K. L. Tilbury, A. J. Hall, T. Rowles, D. Greig, L. J. Lowenstine, and F. M. Gulland. 2005. The role of organochlorines in cancer-associated mortality in California sea lions (Zalophus californianus). Mar. Pollut. Bull. 50:30–39.

Zerbini, A., J. Waite, J. Laake, and P. Wade. 2006a. Abundance, trends and distribution of baleen whales off Western Alaska and the central Aleutian Islands. Deep Sea Research Part I: Oceanographic Research Papers 53(11):1772-1790.

Zamon, J. E., T.J. Guy, K. Balcomb, and D. Ellifrit. 2007. Winter Observations of Southern Resident Killer Whales (Orcinus orca) near the Columbia River Plume during the 2005 Spring Chinook Salmon (Oncorhynchus tshawytscha) Spawning Migration. Northwestern Naturalist 88(3):193-198.

Zhang, J., Kitazawa, D., Taya, S. *et al.* Impact assessment of marine current turbines on fish behavior using an experimental approach based on the similarity law. *J Mar Sci Technol* **22**, 219–230 (2017). https://doi.org/10.1007/s00773-016-0405-y

Ziccardi, M. H., S.M.Wilkin, T.K. Rowles, and S. Johnson. 2015. Pinniped and Cetacean Oil Spill Response Guidelines. U.S. Dept. of Commer., NOAA. NOAA Technical Memorandum NMFS-OPR-52, 138p.

APPENDIX A: PNNL HABITAT CONSERVATION CALCULATOR

The PNNL Habitat Conservation Calculator is an abbreviated version of the Nearshore Habitat Conservation Calculator (NHCC). As needed, the NHCC is updated annually with the latest science. If the PNNL Habitat Conservation Calculator is currently only using two of the seven available tabs. If updates to the NHCC occur in the two common tabs the PNNL calculator will be updated too.

The NHCC accounts for a 40 year life span of a structure. The PNNL calculator has been adjusted down to a two year life span, to account for the short term projects.

As mentioned in the Opinion, the calculators design and values were derived from scientific literature and best available information, as required by ESA. The Calculator underwent and independent peer review in 2023. The independent peer review found that the Nearshore Calculator is well-founded and analytically sound, and based on best available science. Results of that peer review can be found on NOAA's webpage titled "Independent Peer Review of NOAA Fisheries' Puget Sound Nearshore Calculator".

This appendix includes the NMFS' Puget Sound Nearshore Habitat Conservation Calculator User Guide. Users of this guide should annually (February of each year) check for updated versions at: https://www.fisheries.noaa.gov/resource/tool-app/puget-sound-nearshore-conservation-calculator.

APPENDIX B: MARINE MAMMAL MONITORING PLAN

MMMPs are needed for Activities 9B, 10B, and 13

Light Monitoring Protocol:

• Non-eye safe laser (e.g., green laser) operation will use Protected Species Observers (PSOs).
• Discontinuation of operation of non-eye-safe lasers if a protected marine mammals is within 50 m for in-water work.
• Non-eye safe devices with automated shutdown capability would also have that capability enabled during deployment.
• Additionally, the PSO will scan areas prior to and during use of aerial LiDAR if non-eye-safe and discontinue operations if pinnipeds or marbled murrelet are in the survey area.
• The PSO will report observed effects on protected species (i.e. fish/marine mammals).

Sound Monitoring Protocol:

• Sound and pressure levels above thresholds emitted by instruments operating at frequencies within the hearing range of protected species will be mapped as effect isopleths.

• PNNL determines effect isopleths (distance from the sound source to where the sound pressure level attenuates to below the reference effect threshold) for sound emissions by using an Acoustic Effects Calculator (AEC).

• Time limits for use of sound sources with injury isopleths greater than 20 m or behavioral isopleths greater than 50 m:

− 8 hour/day (a day is 12:00:00 to 11:59:59)

− 5 day/week (a week is Monday to Sunday)

− 2 week/month (a month is any calendar month)

− 6 month/year (max consecutive months of activity is 4) (a year is Jan 1 to Dec 31)

− Total allowable hours of sound emission activity per year is 480 or 5.5% of a year.

Verification of the implementation would become invalid if the proposed time limits for injury isopleths greater than 20 m or behavioral isopleths greater than 50 m are exceeded.

For potential marine mammal injury and behavioral effects, PSOs and vessel staff will be employed to survey affected areas based on distance, as outlined below.

Use of PSOs for Injury (Level A harassment) effect isopleths for marine mammals:

- 0-25 m- vessel staff are observers
- 25-100 m- 1 designated PSO

- 100-500 m- 2 designated PSOs; one with binoculars
- >500 m - individual consultation required

Use of PSOs for Behavior (Level B harassment) effect isopleths for marine mammals:
- 0-5 m – No observing necessary
- 5-50 m – Vessel staff are observers
- 50-500 m – 1 designated PSO
- 500-1000 m – 2 designated PSOs; one with binoculars
- >1000 m – 3 designated PSOs; two with binoculars.

Tidal work windows will be followed to the maximum extent possible for devices operating at frequencies within the hearing range of fish and at sound pressure levels that exceed fish injury thresholds.

Tidal Turbine Monitoring Protocol:

Turbine Installation Activities/Marine Energy Devices BMP:
- A PSO will be used during installation and decommissioning activities.
- If protected species are seen within 50 m of the device, stop work and continue operation 30 minutes after the protected species have left the project vicinity

Turbine Monitoring priorities include:

- Monitoring nearfield underwater interactions with and behaviors of marine species in response to deployed devices, including avoidance and evasion behaviors, and possibly displacement.
- Monitoring nearfield marine species underwater habitat use, in relation to hydrodynamic features, to improve the understanding of how seabirds use high-flow environments.
- Detecting collisions.

Tidal Turbine Monitoring:

- PNNL will deploy, at a minimum, an integrated monitoring system for the duration of tidal turbine deployments.
- At the first detection of a target of interest (e.g., seabirds, marine mammals and fish) within a 1 m radius of a turbine, USFWS and NMFS will be notified.
- Subsequent monitoring may attempt a machine vision (unmanned) video camera to facilitate potential species identification (which will be limited by light/water clarity conditions).
- Artificial illumination will only be required if species events are observed with the multibeam sonar at night or if it is determined that artificial illumination will aid in species identification due to clarity conditions.
- The first target interaction observed that is designated as a blade strike will be reported to the Services and the turbine shut down until further consultation.

- PNNL, on behalf of DOE, will conduct near-field underwater monitoring during each week of any given year while a turbine is deployed in order to cover possible seasonal variation in near-field underwater habitat use.

APPENDIX C: NOTIFICATION/VERIFICATION TEMPLATE

PACIFIC NORTHWEST NATIONAL LABORATORY
RESEARCH ACTIVITIES PROGRAMMATIC (RAP) IMPLEMENTAITON FORM

Notification/Verification Form

Notification: ☐ Verification: ☐ Does Not Meet Requirements: ☐

<table>
<tr><td colspan="5">To be filled out by PNNL:</td></tr>
<tr><td>Date:</td><td colspan="4">Responsible PM/Task Lead:</td></tr>
<tr><td>PNNL Reference #:</td><td colspan="4"></td></tr>
<tr><td>Project Title:</td><td colspan="4"></td></tr>
<tr><td colspan="5">To be filled out by Services:</td></tr>
<tr><td colspan="2">NMFS: WCRO-2020-02569-</td><td colspan="3">FWS:</td></tr>
<tr><td>Biologist:</td><td></td><td colspan="3">Approved date:</td></tr>
<tr><td colspan="5">Project Information:</td></tr>
<tr><td rowspan="4">Activity:

Check <u>all</u> that apply</td><td>** 1a☐ b☐ c☐</td><td>2 ☐</td><td>** 3a☐ b ☐</td><td>4a☐ b ☐</td></tr>
<tr><td>*5a☐ b☐ c☐</td><td>6 ☐</td><td>7 ☐</td><td>*8 ☐</td></tr>
<tr><td>*9a☐ b☐</td><td>*10a☐ b☐</td><td>11a☐ b☐</td><td>** 12a☐ b☐</td></tr>
<tr><td>*** 13 ☐</td><td>Lat:</td><td colspan="2">Long:</td></tr>
<tr><td>Any Overarching Criteria Not Met?</td><td colspan="4"></td></tr>
<tr><td>General Construction Measures Taken:</td><td colspan="4">1 ☐ 2 ☐ 3 ☐ 4 ☐ 5</td></tr>
<tr><td>EFH CR's:</td><td colspan="4">1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐</td></tr>
<tr><td>If NOT following EFH CR, why?</td><td colspan="4"></td></tr>
<tr><td>Project Start Date and Duration:
(See calculator summary page)</td><td colspan="4">Start;
End:
Days:
Days outside work window:</td></tr>
<tr><td><u>Offsets</u>

*Potentially required for Activities 1, 3, 12, & 13</td><td colspan="4">Final Calculator date: ______________

Balance: _______________

☐ Submit documentation that all required credits/offsets were purchased prior to the impacting project's construction start date</td></tr>
<tr><td><u>Monitoring Plans</u>

*Required for Activities 9, 10, & 13</td><td colspan="4">The following reports are required:

☐ Marine Mammal Monitoring Plan

☐ MAMU Monitoring Plan</td></tr>
</table>

Brief Project Description:	
Square footage of coverage or sample size *Required for Activities 1, 3, 5, 8, 12, & 13	
If Near Protection Island - Describe Coordination with WDNR:	
Any Additional Information:	

APPENDIX D: REPORT FORM

Annual Consultation Summary Report
Pacific Northwest National Laboratory Programmatic – Sequim Bay
Year:

General

Project Name:	
Reporting Agency:	Pacific Northwest National Laboratory (on behalf of DOE – Pacific Northwest Site Office)
Contact Person:	*PNNL Contact*
Date of Report:	
Time Period for anticipated activities:	

Permits

Projects

Table 1. *Year* Summary.

Project	Equipment Deployed	Date Installed	Date Removed	Location

Table 2. Activities by Deployment Type

Activity Type	Amount Deployed (per year)	Sequim Bay Total	Strait of Juan de Fuca	Total
Surface Platforms and Buoys				
Sequim Dock Installations (in Water)				
Seabed Installations				
Vessel Use				

Activity Type	Amount Deployed (per year)	Sequim Bay Total	Strait of Juan de Fuca	Total
Autonomous Aquatic Vehicles				
Unmanned Aerial Systems				
Benthic Surveys				
Water Column Sampling: Plankton, Invertebrates and Scientific Parameters				
Dye and Particulate Releases				
Seagrass, Macroalgae and Intertidal Research				
Light Emitting Devices				
Acoustic Devices and Noise				
Electromagnetic Field Operations				
Community and Research Scale Marine Energy Devices				
Tidal Turbine Research (adaptive)				

Table 3. *Year* Anticipated Activities

Project	Equipment Deployed	Date Installed	Date Removed	Location