DOE/EA-2271

Draft Environmental Assessment

Pacific Northwest National Laboratory Aquatic Research Activities in Sequim Bay and the Strait of Juan de Fuca

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U.S. Department of Energy
Pacific Northwest Site Office
Richland, Washington 99352

SUMMARY

To meet the long-term federal agency mission to enable discovery and advance science, the U.S. Department of Energy (DOE) needs to conduct research activities in and around aquatic environments. This Environmental Assessment (EA) provides information about and analysis of potential DOE research activities associated with the DOE's Pacific Northwest National Laboratory (PNNL)-Sequim campus taking place over the next 20 years in Sequim Bay and the Strait of Juan de Fuca. DOE will use the information contained in this EA to determine whether the Proposed Action represents a major federal action that would significantly affect the quality of the human environment.

Alternatives

Proposed Action. Under the Proposed Action evaluated in this EA, DOE would perform research activities in Sequim Bay and the Strait of Juan de Fuca, including equipment and device installation; vessel and autonomous vehicle use; surveys, sampling, and dye releases; operation of sound, electromagnetic field, and light emitting devices; and marine energy device and tidal turbine installation and operation. DOE has worked in collaboration with National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS) to create an operational framework for activities within the Proposed Action area. This is described in the Programmatic Biological Assessment (Appendix A), which provides a bounding scenario for the research activities that may be performed. Project Design Criteria were agreed on by all three agencies to bound activities, as well as to avoid and minimize effects of the Proposed Action on biological resources. Additionally, DOE, along with NMFS and USFWS, developed mitigation requirements to compensate for effects of the Proposed Action on aquatic species and habitats. The Proposed Action encompasses a suite of potential research activities; the decision to pursue specific research projects would be based on DOE mission need.

No-Action Alternative. Under the No-Action Alternative, DOE would continue to perform research activities with no effect to biological resources listed under the Endangered Species Act (ESA) and no effect to essential fish habitat. Under the No-Action Alternative, PNNL-Sequim campus' marine research capabilities to support the nation's strategic goals would be substantially reduced. These include strategic goals in marine science, national security, renewable energy, and the environment for DOE and other federal sponsors.

Affected Environment. The PNNL-Sequim campus is located on the Strait of Juan de Fuca, to the east of the City of Sequim, at the northern end of Sequim Bay in northeast Clallam County, Washington. Research activities are proposed in Sequim Bay, which is a 2,024-hectare (ha) (5,001-acre [ac]) salt-water body connected to the Strait of Juan de Fuca by a narrow channel. Sequim Bay is bordered by residential properties, the Jamestown S'Klallam Reservation, and a small boat marina. Research activities are also proposed in the adjacent Strait of Juan de Fuca within a 7,250 ha (17,915 ac) area. The Strait of Juan de Fuca research area is bordered by residential properties and USFWS-managed wildlife refuges and includes a portion of the Protection Island Aquatic Reserve. Recreational and commercial vessel traffic is common throughout the Proposed Action area. Within the Proposed Action area, there are multiple species of federally and state listed threatened and endangered species of birds, insects, fish, and mammals. Essential fish habitat, as well as critical habitat for endangered species are present in the Proposed Action area. Cultural and historic resources, such as archeological remains and shipwrecks, have also been identified in the Proposed Action area.

Environmental Impacts of the Proposed Action. Table S.1 summarizes potential impacts associated with the Proposed Action.

Table S.1. Potential Environmental Impacts Associated with Proposed Action and the No-Action Alternative.

Impact Area	Proposed Action	No-Action Alternative
Land Use	No Change	No Change
Air Quality	Minimal increase in greenhouse gas emissions from vessel use.	No Change
Soil and Geological Resources	Land and soil disturbance is limited to shoreline areas and will be temporary, with land returned to original conditions.	No Change
Water Resources	Most activities will have no impact. Best management practices will minimize effects on water quality and assure compliance with Washington State turbidity and mixing zone criteria. Marine energy devices and tidal turbines are expected to have a small impact on water flows.	No Change
Cultural and Historic Resources	No Change	No Change
Aquatic Ecology Resources	During deployment, research activities can cause minor, temporary behavior changes for aquatic species such as avoidance or foraging disruption. Research activities can lead to loss of aquatic habitat for varying amounts of time, but large or systemic loss of habitat is not expected. Acoustic devices, non-eye-safe lasers, marine energy devices, and tidal turbines have the potential to have adverse effects to aquatic resources during operation. DOE has developed measures to avoid or minimize impacts from research activities to aquatic ESA-listed species and habitats, and essential fish habitat. These measures will reduce impacts to fish, birds, mammals, and habitat, reducing the adverse effects of the Proposed Action to both protected and nonprotected resources. Mitigation will be required of certain activities to assure no net-loss of habitat quality.	No Change
Terrestrial Ecology Resources	Research activities can cause minor, temporary behavior changes to terrestrial species that utilize aquatic environments. Acoustic devices, non-eye-safe lasers, marine energy devices, and tidal turbines have the potential to have adverse effects on terrestrial resources during operation. DOE has developed measures to avoid and minimize impacts to protected terrestrial species. These measures will extend to nonprotected species, reducing the adverse effects of the Proposed Action. Impacts to tidal land areas are anticipated to be minimal and temporary, with land returned to original conditions.	No Change
Socioeconomics	No Change	No Change
Environmental Justice	No Change	No Change
Traffic and Transportation	Small increase in vessel traffic due to research activities.	No Change
Human Health and Safety	Negligible changes in estimated injuries per year.	No Change
Visual Resources	Research activities would not likely cause meaningful visual changes.	No Change
Noise and Vibration	Research vessels may temporarily cause noise while performing research or traveling. Noise impacts to ecological resources are evaluated in the aquatic and terrestrial ecology sections.	No Change
Waste Generation and Disposal	No Change	No Change
Intentional Destructive Acts	No Change	No Change
Irreversible and Irretrievable Commitment of Resources	Research vessels would consume diesel or other fuel. Sampling of sediments and eelgrass could occur episodically with controls.	No Change

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FIGURES

TABLES

ACRONYMS AND ABBREVIATIONS

ac	acre(s)
ac-ft/yr	acre-feet per year
ASV	autonomous surface vehicle
AUV	autonomous underwater vehicle
Battelle	Battelle Memorial Institute, Pacific Northwest Division
BLM	Bureau of Land Management
CCDCD	Clallam County Department of Community Development
CE	Common Era
CEQ	Council on Environmental Quality
CFR	*Code of Federal Regulations*
cm	centimeter(s)
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
dBA	A-weighted decibel(s)
DOE	U.S. Department of Energy
EA	environmental assessment
Ecology	Washington State Department of Ecology
EFH	essential fish habitat
EIS	environmental impact statement
EMF	electromagnetic fields
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FEMA	Federal Emergency Management Agency
FR	*Federal Register*
ft	foot/feet
ft^2	square feet
GCRP	U.S. Global Change Research Program
GHG	greenhouse gas
gpm	gallons per minute
ha	hectare(s)
HPA	Hydraulic Project Approval

in	inch(es)
kHz	kilohertz
km	kilometer(s)
km^2	square kilometers
kW	kilowatt(s)
L	liter(s)
LiDAR	Light Detection and Ranging
lpm	liters per minute
m	meter(s)
m^2	square meter(s)
m^3	cubic meter(s)
m/s	meter(s) per second
MHW	mean high water
mi	mile(s)
mi^2	square mile(s)
MLLW	mean lower low water
MMPA	Marine Mammal Protection Act
MMT	million metric ton(s)
MSA	Magnuson-Stevens Fisheries Conservation and Management Act
mt	metric ton(s)
mT	milliTesla(s)
NAAQS	National Ambient Air Quality Standards
NEPA	National Environmental Policy Act of 1969, as amended
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
NRHP	National Register of Historic Places
ORCAA	Olympic Region Clean Air Agency
PBA	programmatic biological and essential fish habitat assessment
PDC	Project Design Criteria
PFFP	portable free fall penetrometers
PNNL	Pacific Northwest National Laboratory
R/V	research vessel
SPI/PV	sediment-profile imaging and plan view imaging

T	Tesla(s)
the Services	NMFS and USFWS
UAS	unmanned aerial systems
UGA	urban growth area
USACE	U.S. Army Corps of Engineers
USC	United States Code
USCB	U.S. Census Bureau
USFWS	U.S. Fish and Wildlife Service
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WDNR	Washington State Department of Natural Resources
WT	water tracing
yd^3	cubic yard(s)
yr	year(s)

1.0 INTRODUCTION AND BACKGROUND

The National Environmental Policy Act of 1969 (NEPA) (42 U.S.C. § 4321 et seq.) requires federal agency officials to consider the environmental consequences of their proposed actions before decisions are made. The U.S. Department of Energy (DOE) adheres to Council on Environmental Quality (CEQ) regulations (Title 40 of the *Code of Federal Regulations* [CFR] Parts 1500–1508 [40 CFR Parts 1500–1508]) and DOE's own NEPA-implementing regulations (10 CFR Part 1021) in pursuit of NEPA compliance. This environmental assessment (EA) provides information about and analyses of DOE research activities, separately and cumulatively, associated with the Pacific Northwest National Laboratory (PNNL)-Sequim campus located in Sequim, Washington, and nearby coastal areas.

PNNL is a DOE Office of Science National Laboratory, and the DOE Pacific Northwest Site Office manages the contract to manage and operate the laboratory. The 47-hectare (ha) (117-acre [ac]) PNNL-Sequim campus is in Clallam County in northwestern Washington State, 74 kilometers (km) (46 miles [mi]) northwest of Seattle, Washington, and 47 km (29 mi) southeast of Victoria, British Columbia (Figure 1.1). The PNNL-Sequim campus is located at the eastern boundary of the City of Sequim, at the mouth of Sequim Bay, on the northern coast of the Olympic Peninsula.

Under the Proposed Action, aquatic research activities would occur in the Proposed Action area over the next 20 years. Research activities would support understanding of renewable energy and its impacts on marine life, development of systems to monitor changes in the marine environment, detection of underwater materials, testing of new or emerging technologies, monitoring marine and coastal resources, environmental chemistry, modeling water resources, ecotoxicology, biotechnology, national security, and other environmental research involving marine resources. Research activities would occur within Sequim Bay and the adjacent portion of the Strait of Juan de Fuca, between Dungeness Spit and Protection Island (Figure 1.2). Future research may include activities such as 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 Light Detection and Ranging (LiDAR); use of autonomous vehicles for sample collection and monitoring; and testing, evaluation, and monitoring of marine energy devices. Types of research activities proposed over the next 20 years are described in detail in Chapter 2.0.

Previously authorized research activities have been individually covered by DOE categorical exclusions, under 10 CFR 1021 Subpart D, specifically B3.16 (small-scale, temporary surveying, site characterization, and research activities in aquatic environments) and B5.25 (small-scale renewable energy research and development projects and small-scale pilot projects located in aquatic environments) (DOE 2024a; DOE 2024b). However, an increase in both the potential scope and frequency of research activities that could occur simultaneously over the foreseeable future has prompted a more comprehensive look at potential research impacts and cumulative impacts as part of the Proposed Action.

DOE will use the information contained in this EA to determine whether the Proposed Action represents a major federal action that would significantly affect the quality of the human environment. If the Proposed Action is determined to be a major action that would have potentially significant environmental impacts, an environmental impact statement (EIS) would be required to proceed with the action. If the Proposed Action is determined to not be a major action that could result in significant environmental impacts, a Finding of No Significant Impact would be issued, and the research activities under the Proposed Action can proceed. In this case, each future research activity will be evaluated prior to the decision to proceed to determine whether the scope and impacts are bounded by this EA.

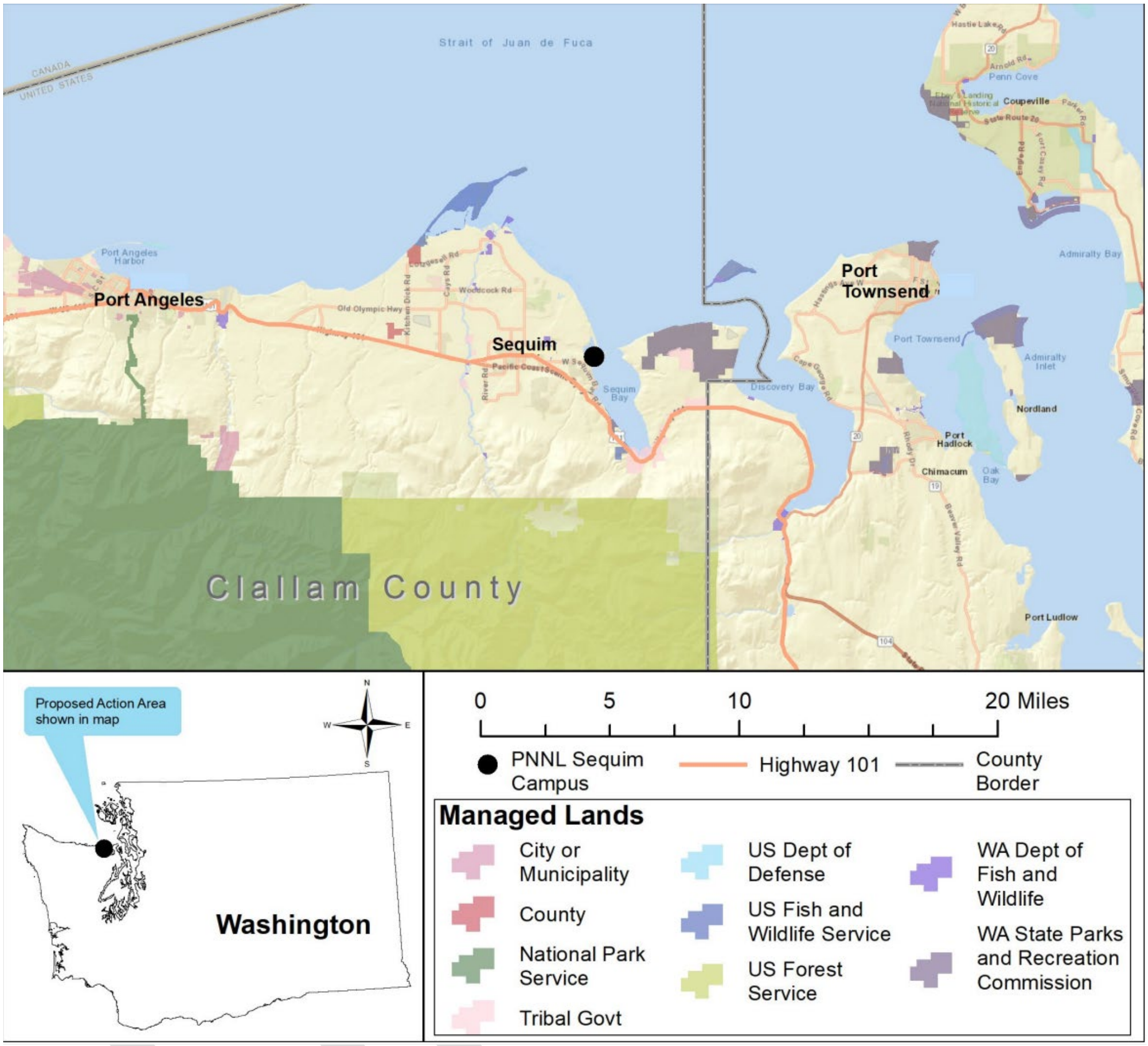

Figure 1.1. Location of PNNL-Sequim Campus in Sequim, Washington.

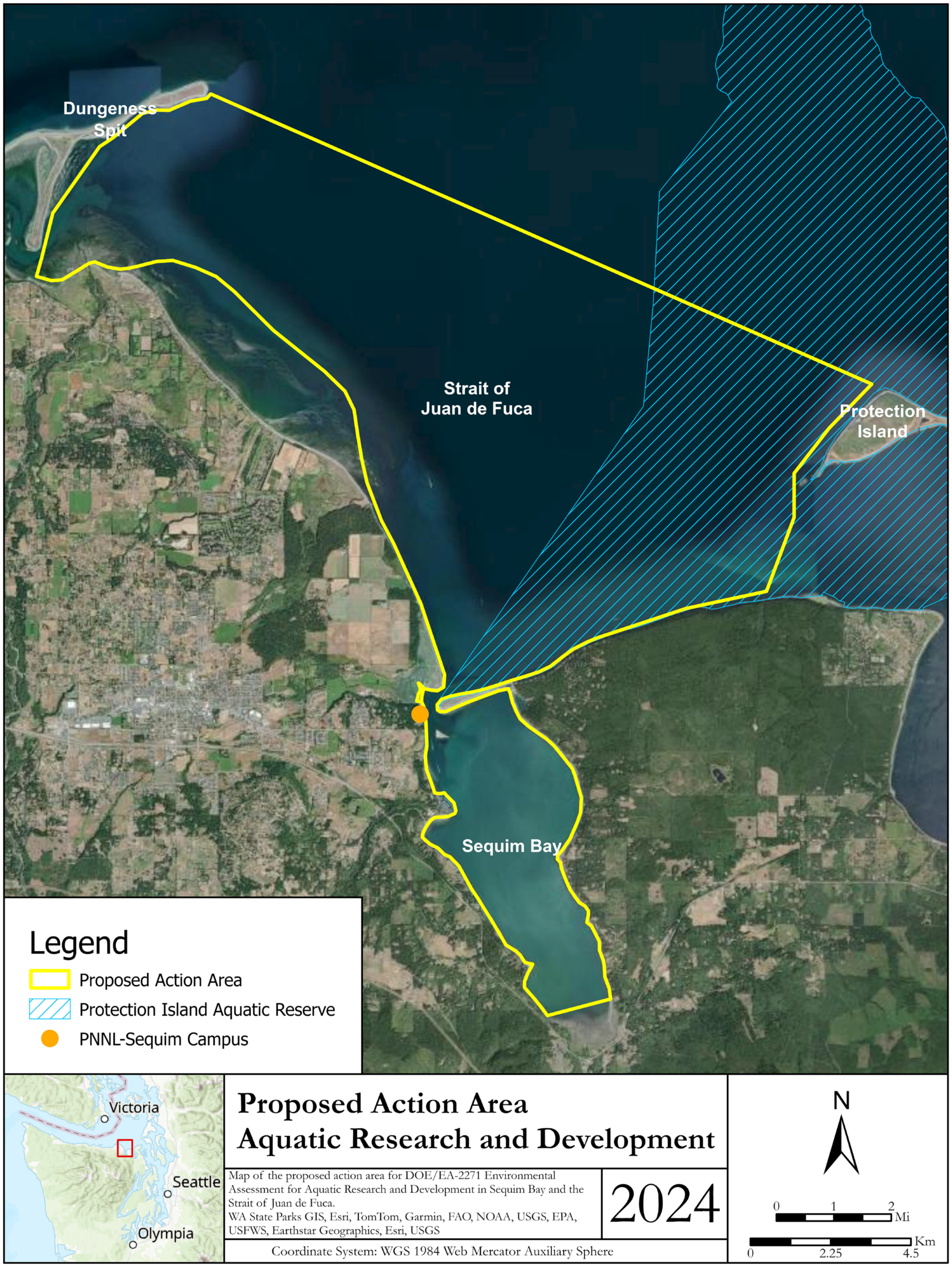

Figure 1.2. Geographic Extent, Including Sequim Bay and the Strait of Juan de Fuca from Sequim Bay North to Dungeness Spit and East to Protection Island.

1.1 Proposed Action Area Description

PNNL-Sequim, historically known as the Marine Sciences Laboratory in Sequim, Washington, is managed and operated by Battelle Memorial Institute, Pacific Northwest Division (Battelle), on behalf of DOE. The site provides capabilities for energy research, climate change effects analyses, wetland and coastal ecosystem restoration, and other environmental research. In-water research projects in and near Sequim and Dungeness Bays, Washington, have supported DOE research needs for national goals related to sustainable energy and environments.

Research projects with specific activities in Sequim Bay are currently covered under National Marine Fisheries Service (NMFS) WCR-2015-3761 (NMFS 2015) and U.S. Fish and Wildlife Service (USFWS) 0IEWFW00-2016-I-0176 (USFWS 2016), including supplements and time extensions. DOE also had two previous consultations with NMFS and USFWS, collectively known as "the Services," for activities near Dungeness Spit, including placement of a LiDAR buoy (WCR-2014-1354; NMFS 2014) (0IEWFW00-2014-I-0672; USFWS 2014); and benthic habitat mapping (WCR-2018-8853; NMFS 2018) (0IEWFW00-2018-I-0911; USFWS 2018). An updated programmatic biological and essential fish habitat assessment (PBA) was prepared to address similar previously consulted activities in Sequim Bay and the Strait of Juan de Fuca, expand activity types and the aquatic environments in which they could occur, and assess effects to ESA-listed species, designated critical habitats, marine mammals, and essential fish habitats (EFH) (DOE 2023). The PBA identifies the potential for research activities to adversely affect protected species and habitats. The PBA defines how DOE will mitigate for potential impacts and streamline consultation with the Services, as required by Section 7 of the ESA and Section 305(b)(2) of the MSA. NMFS issued a Section 7 ESA Biological Opinion and conference opinion, and MSA EFH response on May 3, 2024 (WCRO-2020-02569, NMFS 2024; Appendix B). USFWS issued a Section 7 ESA Biological Opinion on August 21, 2024 (FWS/R1/2024-0008431, USFWS 2024; Appendix C). As detailed within the PBA, DOE will provide yearly reporting to NMFS and USFWS, and DOE, NMFS, and USFWS will meet on a yearly basis to discuss actions that can improve conservation, efficiency, or comprehensiveness under the PBA.

A review of the proposed undertaking was conducted by DOE in accordance with 54 USC § 306108 of the NHPA and implementing regulations 36 CFR 800, including consultation with the Washington State Historic Preservation Office and affected Tribes (Renaud 2021). The consultation resulted in a finding of "No Adverse Effect," as defined in 36 CFR 800.5(d)(1). The NHPA review was amended in 2024 to explicitly include aspects of research scope, as described in the PBA, including sediment sampling and cable installation. The amendment concluded that the scope would not introduce new effects or expand the total potential impacts from what was originally evaluated. DOE determined the amendment maintained the finding of No Adverse Effect (Mendez 2024).

1.1.1 Sequim Bay Research Area

The Sequim Bay research area encompasses the majority of Sequim Bay (Figure 1.3). Sequim Bay is a 2,024 ha (5,001 ac) salt-water body connected to the Strait of Juan de Fuca by a relatively narrow channel (200 meters [m] [656 feet (ft)] wide at mean lower low water [MLLW]) between Travis Spit and the PNNL-Sequim campus dock. The tidal exchange results in moderate tidal currents in this channel (up to 1.5 meters per second [m/s]) with up to a 2.7 m (8.9 ft) tidal exchange at the channel connection with the strait. The bay has a maximum depth of approximately 30.4 m (100 ft) at MLLW. The bay is bordered by residential properties, a small boat marina (John Wayne Marina), and the Jamestown S'Klallam Tribe's Reservation. Recreational and commercial vessel traffic is common throughout the Proposed Action area. Sediments in Sequim Bay can be characterized as mostly mixed-fine sediment or mud with some gravel and cobble in areas with swifter current such as the channel near the PNNL-Sequim campus. Eelgrass beds are patchy and are primarily located in fringe habitat along 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, and fecal coliform (Elwha-Dungeness Planning Unit 2005), all of which limit commercial and recreational shellfish harvest activities. The Proposed Action area includes all of Sequim Bay, from the connection to the Strait of Juan de Fuca to the southern extent designated in Figure 1.3. Shoreline intertidal areas and adjacent land areas are not included in the Proposed Action area except for Battelle or DOE-owned land and tidelands.

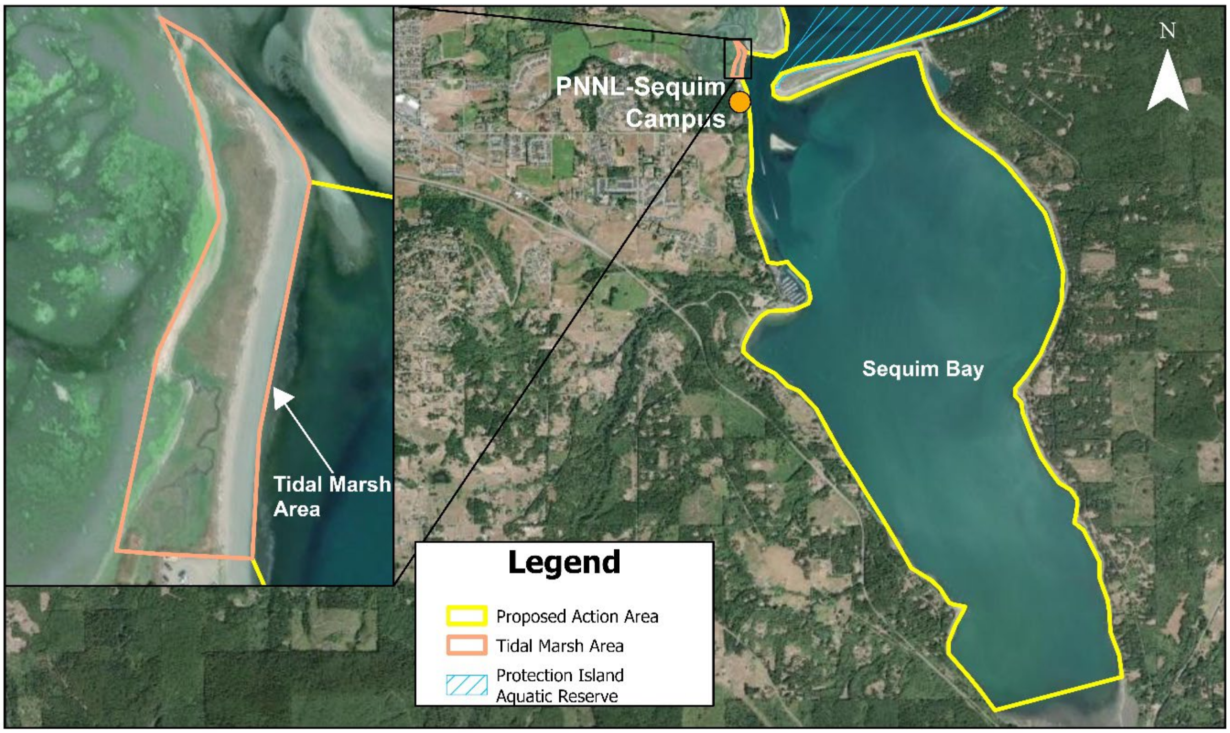

Figure 1.3. Sequim Bay Research Area and Tidal Marsh Area.

1.1.2 Tidal Marsh Area

The tidal marsh area (Figure 1.3) consists of areas below and above mean high water (MHW) along Bugge Spit. Vegetation in the area is consistent with that found in Persistent Emergent Wetlands (Cowardin et al. 1979), such as glasswort (*Sarcocornia pacifica*), saltgrass (*Distichlis spicata*), and tufted hairgrass (*Deschampsia cespitosa*).

1.1.3 Juan de Fuca Research Area

The proposed Juan de Fuca research area is a 7,250 ha (17,915 ac) semi-triangular area, as shown in Figure 1.2. 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. Water depth is generally 10 to 50 m (33 to 164 ft), reaching to > 70 m (> 230 ft) 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 north of Travis Spit is primarily sand and shells with clay and mud components. There are USFWS-managed national wildlife refuges at both Dungeness Spit and Protection Island. Proposed 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 WDNR-managed 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.

1.2 Purpose and Need for Agency Action

To meet the long-term federal agency mission to enable discovery and advance science, DOE needs to conduct research activities in and around aquatic environments. To accomplish agency goals associated with aquatic research, DOE requires access to a marine environment that meets a variety of specific conditions, as well as associated facilities and infrastructure necessary to facilitate marine research.

1.3 Factors Considered for Analysis

This EA evaluates the impacts of research activities within Sequim Bay and the Strait of Juan de Fuca over the next 20 years. The actual number and type of research activities over the next 20 years, on a year-by-year basis or cumulatively at the end of 20 years, is uncertain, but is being bounded by conditions as described under the PBA and additional in water regulations. The CEQ regulations (40 CFR Parts 1500-1508) define the effects that must be addressed and considered by federal agencies in satisfying the requirements of the NEPA process. These include direct, indirect, and cumulative effects.

1.3.1 Direct and Indirect Effects

Direct effects are caused by the action and occur at the same time and place (40 CFR 1508.1). Indirect effects are caused by the action and are later in time or farther removed in distance but are still reasonably foreseeable. Indirect effects may include growth-inducing impacts and other effects related to induced changes in the pattern of land use, population density or growth rate, and related effects on air and water and other natural systems, including ecosystems (40 CFR 1508.1).

1.3.2 Cumulative Effects

Cumulative effects are those effects on the environment that result from the incremental effects of the action when added to the effects of other past, present, and reasonably foreseeable future actions, regardless of what agency (federal or non-federal) or person undertakes such other actions. Cumulative effects can result from actions with individually minor but collectively significant effects taking place over a period of time (40 CFR 1508.1). DOE identified a significant, reasonably foreseeable state development project at Miller Peninsula State Park, which is currently in the project planning stage. Planned project outcomes anticipated in 2025 will include land classifications, a park boundary, a Master Plan, and an EIS under the State Environmental Policy Act. The park property will potentially be developed to be a full-service state park and include overnight accommodations (Washington State Parks and Recreation Commission 2024). Development of water access such as a dock or boat ramp is not planned for Miller Peninsula State Park currently (Washington State Parks and Recreation Commission 2024). Additionally, the Kinder Morgan Trans Mountain Pipeline, a Canadian oil pipeline that began commercial operations in May 2024, will increase transportation of oil through the Strait of Juan de Fuca (Banse 2024).

Smaller-scale projects that were identified include the following:

- the operation and potential expansion of the PNNL-Sequim campus
- expansion of the City of Sequim water system, including to the PNNL-Sequim campus
- a new 500 to 600 home development at John Wayne Marina

- a new psychiatric evaluation and treatment facility near the Jamestown Healing Clinic
- restoration of Sequim Bay shoreline areas to restore salmon habitat and improve water quality
- improvements to fish passage and replacements of culverts throughout Clallam County
- improvements to U.S. Highway 101 east of Sequim, to include a new bypass route for Happy Valley and Palo Alto roads and completion of the Simdars Road intersection
- the Dungeness Off-Channel Reservoir for storing Dungeness River water during winter and spring high-flows for use later in the year
- potential future transfer of ownership of the PNNL-Sequim campus from Battelle to DOE
- potential exclusive use agreement between DOE and Battelle for Battelle-owned land south of the PNNL-Sequim campus.

The mid-level estimate for population growth in Clallam County is approximately 14 percent from 2020 to 2050, and the high estimate is 27 percent (WOFM 2023); these increases correspond to about an additional 10,600 to 21,100 people in Clallam County by 2050. Development and growth in housing, commerce, and support services would be expected to correspond to the population growth.

The cumulative incremental effects of these foreseeable actions are evaluated in each resource area in Section 3.1.

1.3.3 Climate Change

Climate is defined as temporal and spatial patterns of variations in meteorology over a period of several decades (GCRP 2023). In November 2023, the U.S. Global Change Research Program (GCRP) published the Fifth National Climate Assessment: Impacts, Risks, and Adaptation in the United States (GCRP 2023). This report collected, evaluated, and integrated observations and research on climate change in the United States, including assessments of regional climate change in the Pacific Northwest. The GCRP (2023) report predicts that climate change in the Pacific Northwest may noticeably alter the baseline affected environment. Climate change is a global phenomenon that future PNNL-Sequim research activities would not appreciably alter. However, climate change may alter the baseline environment in which the proposed potential future research would occur.

GCRP (2023) identified potential climate changes in the regional environment that are relevant to the assessment of impacts from the Proposed Action, including the following:

- sea level rise
- changes in potential flooding hazards
- changes in precipitation and stream flows
- changes in vegetation, aridity, and potential wildfires
- changes in surface and groundwater availability and water temperature.

Changes in the affected environment and any associated considerations for the assessment of impacts of the Proposed Action are discussed by resource area in Section 3.1 of this EA.

2.0 PROPOSED ACTION AND ALTERNATIVES

2.1 Proposed Action

DOE proposes to perform research activities in Sequim Bay and the Strait of Juan de Fuca to meet its current and anticipated future research needs consistent with the DOE mission. Proposed research activities range from small-scale, temporary surveying, and site characterization activities to tidal turbine research. The decision to pursue specific research projects would be based on DOE mission need.

The Proposed Action encompasses the research activities described in the PBA, bounded by Project Design Criteria (PDC), which include avoidance, minimization, and mitigation to limit adverse effects to biological resources. Additional restrictions to protect biological resources are described in the programmatic biological opinions provided by NMFS and USFWS (Appendix B and Appendix C). As part of yearly collaboration between DOE, NMFS, and USFWS, the PDC may be modified. If modifications to the PDC would result in changed impacts to protected resources, reinitiation of consultation under Section 7 of the ESA and additional NEPA analysis would be required.

Aquatic research activities have previously been categorically excluded from further NEPA review. The PBA includes new activities that require additional analysis to determine potential impacts to the environment. Table 2.1 lists similar research activities that were previously covered under DOE categorical exclusions, and the new activities that are the focus of the PBA. The Proposed Action includes both the previously authorized activities and the newly proposed activities to allow DOE to evaluate potential impacts to the environment from the entire research program.

Table 2.1. Research Activities Previously Authorized and Research Activities that Are Part of the Proposed Action, as Defined in the PBA.

Activity	*Previous Authorizations*	*Proposed Action*
Surface platform/buoy use	✓	✓
Pier and nearshore installations	✓	✓
Seabed installations	✓	✓
Autonomous vehicle surveys	✓	✓
Benthic surveys/sediment sampling	✓	✓
Water, plankton, and invertebrate sampling	✓	✓
Electromagnetic field generation	✓	✓
Light emissions	✓	✓
Acoustic emissions	✓	✓
Community and research scale wave energy converters		✓
Dye and particulate releases		✓
Seagrass, macroalgae, intertidal research		✓
Tidal turbines		✓

The PDC prescribe bounding limitations in aspects such as maximum deployment numbers, deployment length, installation style, and marine mammal observer requirements. The PDC have been developed in collaboration between DOE and the Services, and PDC for each activity are listed in the PBA (Appendix A). PDC include the establishment of tidal work windows, which are the times of year when fish (particularly salmonids) are least likely to be present in the Proposed Action area. Performing in-water activities within tidal work windows minimizes the number of fish exposed to the effects of activities. Performing work outside of the tidal work windows may require additional mitigations, as described in Section 2.1.1–2.1.5 below.

Any activities outside of those described in the PBA would require individual consultation or future modification of the PBA. The PBA allows for adaptive management, and modifications to the PBA and associated conservation measures may occur on an annual basis when DOE, NMFS, and USFWS review monitoring results and impacts of potential modifications to activities. If modifications would result in changed impacts to protected resources, reinitiation of consultation under Section 7 of the ESA and additional NEPA analysis would be required. The research activities described in the PBA are summarized in Section 2.1.1–2.1.5, and include installation, operation, maintenance, and removal.

All activities described below will be subject to the following initial overarching PDC:

1. All devices and associated structures will be removed at the project end.
2. No significant alteration of the shoreline will occur for deployed structures/devices.
3. No deployments will occur in submerged aquatic vegetation, unless for the explicit purpose of submerged aquatic vegetation research.
4. Deployments will anchor in a way to avoid scour (when part of the anchor line rests on the seafloor and is moved by the water, causing scraping and disturbance of the seafloor).
5. Projects requiring anchors will use helical screw anchors when possible.
6. Non-toxic, corrosion resistant materials will be used.
7. Any activities in contact with the seabed surface will move sunflower sea stars by hand if encountered in the area of disturbance.
8. All work will comply with all federal, state, and local regulations.
9. If any project activities result in impacts to an individual of any protected species, the Services will be notified.
10. PNNL will submit a notification or verification email to the Services as required per activity.

2.1.1 Equipment Installation

Equipment, such as floating platforms and buoys, in-water scientific instruments, equipment and support cabling, and seabed installations, will be used for a variety of research activities, including renewable energy development and environmental data collection. Buoys are solid structures that provide buoyancy in water and are typically under 0.7 square meters (m^2) (8 square feet [ft^2]) and can be up to 9.3 m^2 (100 ft^2). Platforms are in-water structures with floats of generally flat, walkable surfaces spanning a larger surface area than buoys. Areas above the buoys and platforms can be solid or grated to allow light to enter the water column. Floating platforms and buoys would generally float at the surface, but devices could be staged at mid-water column with surface markings if needed. In some cases, the platforms, buoys, or other structures may be free floating. Mooring lines may also be used to keep structures in a stable position. Floating platforms or buoys would be temporary and could be deployed for less than 1 day to up to multiple years. All platforms and buoys would be fully removed at the end of the projects. Floating platforms and buoys deployed for greater than 60 days during the period where protected fish are likely to be present (outside of tidal work windows) may require mitigation to compensate for potential impacts to biological resources (see Appendix A). A modified Puget Sound Nearshore Habitat Conservation Calculator is the current mechanism for fulfilling mitigation requirements, which identifies equivalent conservation offsets that can be purchased through regional habitat conservation banks (NOAA 2024a).

Installation of in-water scientific instruments/equipment and support cabling onto or from the PNNL-Sequim dock or pilings may be required for various research activities such as data collection or instrument testing. Research-related equipment installed on or from the PNNL-Sequim dock may be deployed for less than 1 day up to more than a year and equipment would be removed at the end of the project.

Seabed installations are typically used to monitor changes in the marine environment, develop underwater materials detection technology, and support underwater surveys. Installations may include a variety of structures, including equipment and sensors placed on the seabed or installed within the substrate. Seabed installations include, but are not limited to, measurement probes, inert targets, benthic landers, grids and plot frames, housings for equipment arrays, mounts for video equipment, lights, cameras, sensor, or acoustic devices, and autonomous underwater vehicle (AUV) docking systems. Hand tools or water jets are expected to be used to aid with subsurface installation of instruments. Seabed installations will be temporary for the duration of the project and have a limited footprint, as defined by the PBA. Mitigation may be required for equipment and sensor seabed installations deployed for greater than 60 days during the period where protected fish are likely to be present (outside of tidal work windows) to compensate for potential impacts to biological resources.

2.1.2 Vessel and Autonomous Vehicle Use

Research vessels are typically used for transportation, drifting or towing instrumentation, survey and monitoring, equipment deployment, and environmental sampling. Vessels may range from kayaks to research ships.

AUVs, which include remotely operated as well as fully autonomous vehicles, and autonomous surface vehicles (ASVs) may be deployed within the research areas. Research activities may utilize AUVs or ASVs for surveying and mapping, component delivery, or other environmental monitoring tasks. AUVs and ASVs are mobile platforms that can carry instruments. AUVs can travel over a range of different depths, while ASVs typically remain at the surface. AUV docking and device charging systems may be installed within the Proposed Action area. Docking systems may include other equipment related to AUV or ASV operation. Power sources for docking stations could include cabling to shore, marine energy devices, solar panels, or batteries. Unmanned aerial systems (UAS) may also be used to deploy sensors such as LiDAR for terrain measurements, video, photography, and to support other research activities. NMFS guidance for marine wildlife and flight restrictions for Protection Island and Dungeness Spit will be followed.

2.1.3 Surveys, Sampling, and Dye Releases

Surveys and sampling activities are used to inform research such as renewable energy development and impacts on marine life, environmental chemistry, ecotoxicology, and for detecting changes in the marine environment. Activities such as benthic surveys, water column sampling, dye and particulate releases, and surveys of submerged aquatic vegetation all support the DOE mission.

Surveys and sampling include but are not limited to diver surveys, underwater video, sonar, water and sediment collection, and benthic characterization surveys. Sediment sampling includes the collection of substrates using equipment such as a hand trowel, grab sampling, or coring device. Most sampling devices would be deployed from a research vessel or research platform. Benthic characterization could utilize sediment-profile imaging and plan view (SPI/PV) imaging systems or portable free fall penetrometers (PFFP) to assess sediment composition and behavior. SPI/PV imaging systems and PFFPs include ground disturbance, typically less than 1 m (3 ft) deep. Benthic characterization could also be performed using crawlers that can tow cameras or sleds that detect objects on the seabed.

Water column sampling supports research related to water resources monitoring, ecotoxicology, and marine environmental monitoring. Within the water column, sampling can have targets such as nutrients, minerals, plankton, invertebrates, marine microbes, and abiotic substances. Sampling methods include hand collection, sampling devices, and gear with mesh sizes designed for the collection target. Water column sampling can be deployed by research vessel, platform, buoy, AUV, or previously installed research equipment.

Research and survey activities in and around submerged aquatic vegetation are performed to determine biogeochemical and ecosystem processes, and to facilitate testing of technologies under diverse habitat conditions. Submerged aquatic vegetation can include seagrasses, kelp, and other macroalgae. Divers perform underwater experiments on eelgrass and macroalgae, the surrounding water column, and substrates. Examples of potential research activities include transplanting of eelgrass shoots and rhizomes; installation of equipment and sensors; sampling specimens, water, and sediment; and deployment of equipment to collect habitat data. Installation of scientific equipment within intertidal and periodically inundated areas may include instruments to measure greenhouse gas flux, light, sediment accretion, hydrology, and photosynthetic response. Instruments such as polyvinyl chloride collars and push point samplers could be utilized. Sediment cores (typically 0.06 cubic meters [m^3] [2 cubic ft] in volume) could be collected, and groundwater wells could be inserted within the cores and fitted with sensors to collect data.

Dye and particulate releases help characterize the marine environment. They are typically used for spatial data analysis or to study dispersion. Measurements are obtained by releasing a dye and using instruments such as a turbidity sensor or light detector to detect changes. The hardware may be mounted on a vessel, float, AUV, equipment, or the substrate.

2.1.4 Operation of Emitting Devices

Devices that emit light, acoustics, and electromagnetic fields (EMF) are used to support research activities such as device deployment, biofouling prevention, habitat assessment, bathymetry mapping, renewable energy development, detection capability development, and monitoring of marine resources.

Light-emitting devices employed in research activities range from devices supporting photography and video to LiDAR systems and associated lasers. Underwater photography may require illumination from an artificial source such as flood lights or strobes. Light is typically intermittent, but continuous light for research such as biofouling prevention may be used. LiDAR systems may be used for activities such as marine resource monitoring in the vicinity of marine energy devices, tidal turbines, or other equipment, for bathymetry studies, and for surface applications such as wind measurements and habitat assessments. Underwater LiDAR detection systems may use either a red laser, green laser, or both. Red lasers are eye-safe for humans and marine animals. Green lasers are not eye-safe for humans or marine animals at near distances. Some deployments of green lasers are able to detect animals approaching a system and automatically turn off. LiDAR systems can be deployed underwater or above water using manned or autonomous vehicles and systems can be multidirectional.

Sound-generating (acoustic) devices are used in research related to marine renewable energy development, marine resource monitoring, object detection, navigation, and communications. Target or equipment simulation may be necessary to test detection by different acoustic devices. Simulated sounds could include mimicking those made by marine animals or underwater infrastructure such as rotating underwater turbines. Equipment such as echosounders and sub-bottom profilers are used for detection of 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. Other equipment such as sonars and acoustic cameras could be used. Sound emission devices may be deployed on the PNNL dock, installed on the substrate, moored in the water column, bundled with other instrumentation, towed, carried by divers, or on buoys. The PBA provides examples of the range of sound-emitting devices that could be used for research that are both outside of and within hearing range of marine mammals or fish. The PBA also provides the physical parameters of the generated sounds.

Devices and cables that may emit EMF support power, data transfer, device and cable testing, and other research activities. EMF devices would 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 Neodynium magnet. Deployed cables operate with fields typically up to 5 milliTesla (mT), which is about the strength of a common refrigerator magnet and similar to the field generated by an electric motor. Devices that generate EMF could include either alternating current or direct current configurations. Research-related cables and devices generating EMF may be buried, rest on the seabed, be suspended in the water column, or float at the surface. Anchoring devices, such as helical anchors, may be needed to avoid scour by the cable along the seabed. If projects require several cables or repeated cable installation in the same area, a conduit may be installed to allow installation and removal of cables in a way that avoids repeated disturbance of the substrate.

2.1.5 Marine Energy Device Installation and Operation

Marine energy devices are structures that can harness energy from the marine environment. Research activities are generally focused on understanding marine energy device design and performance. Research activities can also focus on the interaction of devices and example models with the environment. Tidal turbine research is designed to support future marine energy development and would involve activities that test turbine concepts, microgrid research, and marine resource monitoring.

2.1.5.1 Community and Research Scale Marine Energy Devices (Excluding Tidal Turbines)

Community and research scale marine energy devices can harness energy from ocean waves, currents, tides, salinity gradients, and temperature changes. Marine energy devices are characterized as designs without exposed blades. The power produced by community and research scale devices would not be delivered to the U.S. power grid and would be limited to up to hundreds of kilowatts (kW) of power generation.

Marine energy devices can include devices such as point absorbers, wave overtopping reservoirs, attenuators, oscillating water columns, and inverted pendulums. Some devices capture kinetic energy by moving with wave action. Point absorbers convert the movement of a buoyant structure into power. Wave overtopping reservoirs rely on the movement of water through the center of the storage reservoir to move a turbine. An attenuator uses the motion generated from waves to capture energy. Oscillating water columns rely on the pressure difference between the rising and falling water within the headspace of the device to move an internal turbine. Inverted pendulums act as paddles and rely on the horizontal movement of waves to push a paddle-type structure. Figure 2.1 shows examples of marine energy device designs. Part of the PDC, as described in the PBA, includes mitigation for marine energy devices deployed for greater than 60 days during the period where protected fish are likely to be present (outside of tidal work windows) to compensate for potential impacts to biological resources.

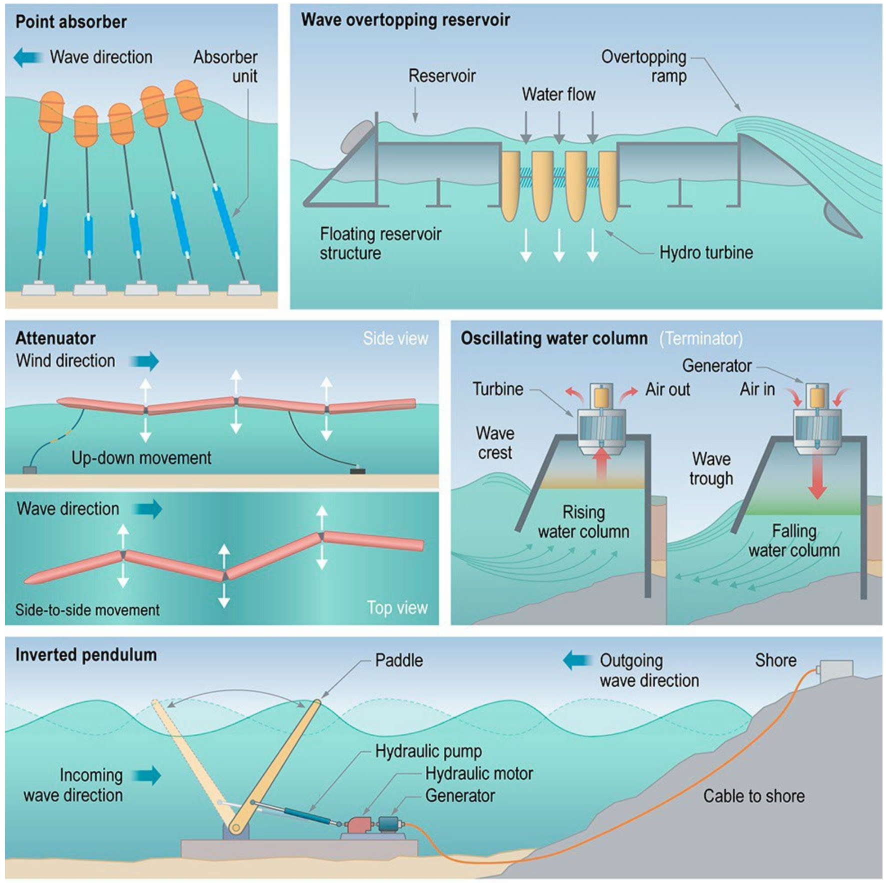

Figure 2.1. Examples of Types of Marine Energy Devices and Movement Style (from Augustine et al. 2012).

2.1.5.2 Tidal Turbines

Tidal turbines are devices that convert tidal energy into power, typically through the rotation of a turbine. The depth, flow speeds, size, and proximity to shoreside infrastructure make the inlet to Sequim Bay an ideal location for testing small to medium-scale tidal turbines. Tidal turbine research could involve deployment of various turbine types, including novel designs, under various operational scenarios, depending on emerging market and research needs. Types of turbines that may be deployed include but are not limited to axial-flow or horizontal axis turbines, crossflow turbines, oscillating hydrofoil turbines, venturi effect turbines, Archimedes screws, and tidal kites. Figure 2.2 shows examples of tidal turbines that could be deployed under the Proposed Action. As described in the PBA, initial research on tidal turbines will include monitoring methods for marine resources and information exchange with NMFS and USFWS. This information can help inform potential future commercial turbine use.

Tidal turbine rotation is dictated by current flow, and turbine blades will typically not always operate during a 24-hour cycle. Research will include optimizing energy production and studying real-world deployment scenarios. To support this, turbines may operate over a range of speeds to determine peak operating efficiency. Within the first year of the PBA, only one turbine can be deployed in the Proposed Action area at any given time. The number of total tidal turbines deployed as part of the PBA may increase over time, dependent on adaptive management and collaboration with the Services. DOE is taking a conservative approach by initially only deploying one tidal turbine, analyzing the monitoring results and impacts, and collaborating with the Services to determine a path forward. Mitigation for tidal turbines deployed for greater than 60 days during the period where protected fish are likely to be present (outside of tidal work windows) is required as a PDC within the PBA to compensate for potential impacts to biological resources.

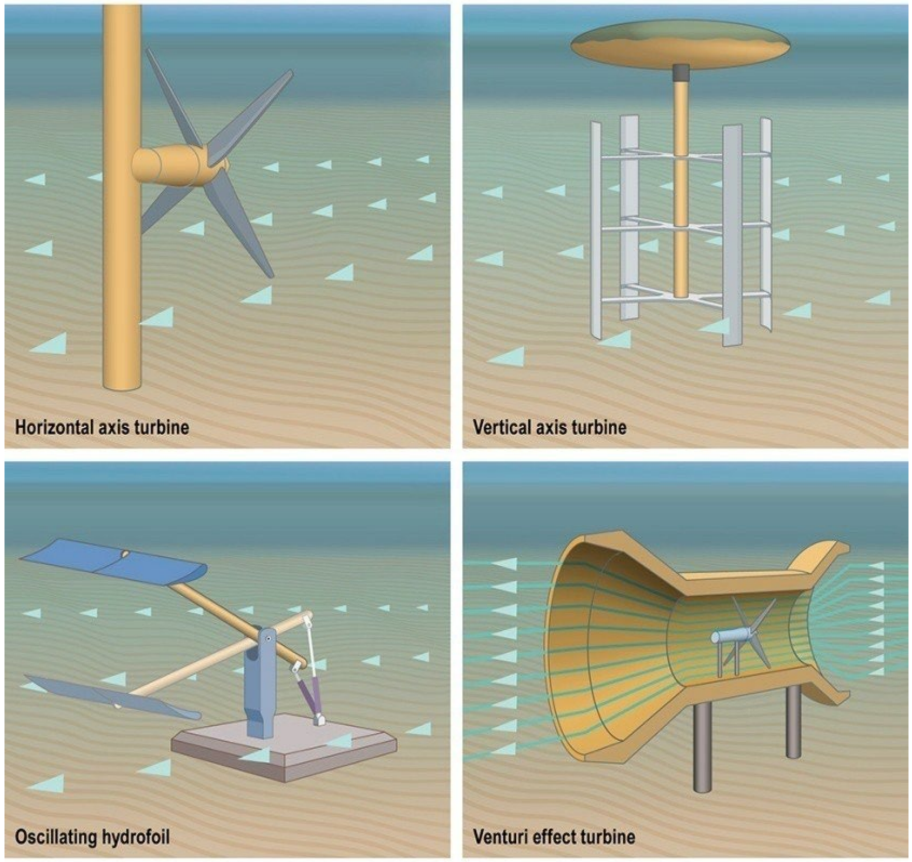

Figure 2.2. Tidal Turbine Examples (from Augustine et al. 2012).

2.2 No-Action Alternative

Under the No-Action Alternative, DOE would continue to perform the previously authorized scope of research activities in Sequim Bay and the Strait of Juan de Fuca until existing authorizations expire in the winter of 2025 (USFWS 2023, USACE 2023). After the expiration of authorizations, DOE would no longer be able to perform research activities in Sequim Bay and in the Strait of Juan de Fuca with the potential to affect ESA-listed resources and EFH. Without the expansion of authorized research, as described in the Proposed Action, DOE would be unable to perform the scientific research required to meet future mission needs.

2.3 Alternatives Evaluated but Dismissed from Detailed Analysis

To meet the long-term federal agency mission to enable discovery and advance science, DOE conducts research activities in and around aquatic environments and requires access to a marine environment that meets a variety of specific conditions. As part of its evaluation process, DOE evaluated performing research activities at other locations within Puget Sound. An alternate research area would require additional lease or access agreements, resulting in uncertainty for funding and access to water and tideland habitats over the desired 20-year period. This would not meet the DOE need for access to a marine environment to perform aquatic research. The current project area is adjacent to the PNNL-

Sequim campus, which has existing infrastructure that supports research capabilities. Renovations may be required in alternate project areas to accommodate research and convert leased areas to meet DOE mission needs. DOE investment on these improvements would be lost upon expiration of the lease. This option does not meet the DOE need to utilize facilities and infrastructure to enable research capabilities, such as the infrastructure that exists at the PNNL-Sequim campus. In addition, the use of infrastructure outside of DOE ownership could result in public access to research equipment that may have safety risks. An alternative location would not result in the efficient utilization of existing DOE capabilities.

3.0 AFFECTED ENVIRONMENT AND ENVIRONMENTAL CONSEQUENCES

3.1 Affected Environment and Impacts of the Proposed Action

A general description of the Proposed Action area was provided in Section 1.1. Resources with the potential to be affected, along with the effects, are discussed further in this section. The affected environment and the impacts of the Proposed Action are described in Section 3.1, irreversible and irretrievable commitment of resources are described in Section 3.2, the impacts of the No-Action Alternative are described in Section 3.3, and the comparison of the Proposed and No-Action Alternatives are described in Section 3.4.

Research activities (Table 2.1) under the Proposed Action would occur within the geographical boundaries depicted in Figure 1.2. Aspects of the research locations and the environments that might be affected by the research activities over the next 20 years are described in this section.

3.1.1 Land Use

3.1.1.1 Affected Environment

Shoreline intertidal areas and adjacent land areas are not included in the Proposed Action area except for Battelle or DOE-owned land and tidelands, which occur on and adjacent to the PNNL-Sequim campus. The PNNL-Sequim campus includes developed industrial areas and vacant undeveloped land in addition to Sequim Bay shoreline areas and tidelands associated with the campus shoreline (including Bugge Spit), the Middle Ground, and Travis Spit (Figure 3.1). The lands surrounding the PNNL-Sequim campus are generally devoted to agricultural and residential uses.

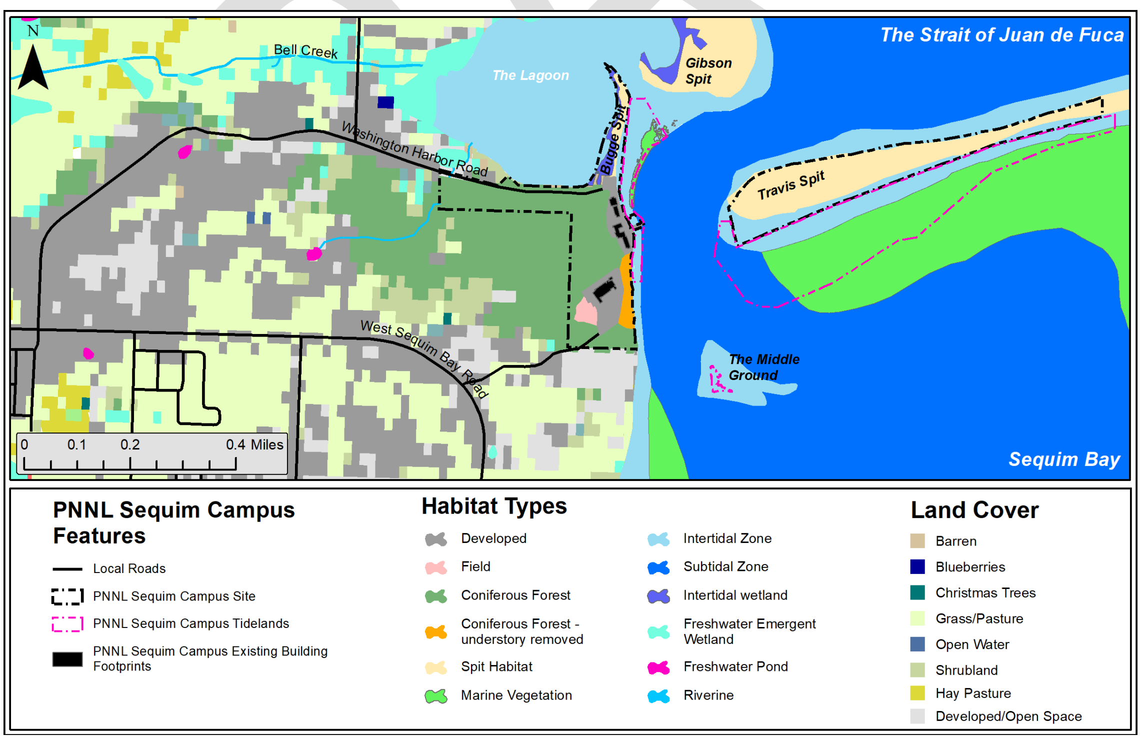

Figure 3.1. Current Land Cover on the PNNL-Sequim Campus and Surrounding Area.

Land uses on the campus and in nearby areas (within 1 mi [1.6 km] of PNNL) include the following:

- Existing PNNL-Sequim campus facilities, including research laboratories and support buildings.
- The City of Sequim Water Reclamation Facility.
- Sequim Bay, located due east, which supports a mix of commercial, recreational, and cultural uses
- Several small farming and livestock operations; much of the area is designated as prime farmland.
- Marlyn Nelson County Park at Port Williams, and Gibson Spit.
- Residential subdivisions, mobile home parks, and scattered residences.
- Travis Spit, Bugge Spit, and The Middle Ground shoal are undeveloped portions of the PNNL-Sequim campus. The Jamestown S'Klallam Tribe is authorized to harvest resources from Travis Spit, per an agreement with DOE.

Clallam County currently zones the PNNL-Sequim campus as "Research and Development Park" (Clallam County 2021a). Development in this area is governed by the Sequim-Dungeness Regional Plan (Clallam County 2021a). However, specific development actions on the marine shorelines of the county are permitted by the county (Clallam County 2021b). Additionally, research activities within the Proposed Action area may require evaluation under the Clallam County Shoreline Master Program (Clallam County 2021b). If the PNNL-Sequim campus is annexed to the City of Sequim, future land use along the Sequim Bay shoreline areas may be governed by the City of Sequim Shoreline Master Program (City of Sequim 2019).

3.1.1.2 Environmental Consequences

In water, tidal lands, and shoreline Proposed Action research activities within the defined geographical boundary locations are not expected to change or alter land zone or shoreline designations. Any research equipment or infrastructure installations would be temporary in nature and the land or benthos returned to original conditions. Proposed Action research activities would not affect the ability of the Jamestown S'Klallam Tribe to harvest resources from Travis Spit.

3.1.1.3 Cumulative Effects

The anticipated land-use impacts of the Proposed Action were evaluated in the context of the reasonably foreseeable future actions identified in Section 1.3.2, including climate change. Taken together, those actions and the Proposed Action do not result in cumulative land-use effects on the local area. Minor effects to shoreline and tidelands resulting from storms and sea level rise may occur over the next 20 years but are not incrementally affected by the Proposed Action.

3.1.2 Air Quality

3.1.2.1 Affected Environment

The Clean Air Act (42 U.S.C. § 7401 et seq.), as amended in 1990, requires the U.S. Environmental Protection Agency (EPA) to set National Ambient Air Quality Standards (NAAQSs) (40 CFR Part 50) for pollutants considered harmful to public health and the environment. The EPA has set NAAQSs for six "criteria" pollutants, including carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO_2), ozone (O_3), particulate matter (PM), and sulfur dioxide (SO_2). The Proposed Action area is in Clallam and Jefferson Counties, which are part of the Olympic-Northwest Washington Intrastate Air Quality Control Region (40 CFR Part 81). An Air Quality Control Region is an area designated by the EPA for the attainment and maintenance of the NAAQSs. All counties within this Air Quality Control Region are listed as "unclassifiable/attainment" or "better than national standards" for all criteria air pollutants (40 CFR Part 81). Section 112 of the Clean Air Act addresses emissions of hazardous air pollutants for specific source categories. EPA regulations established under Section 112 are known as National Emission Standards for Hazardous Air Pollutants.

3.1.2.2 Environmental Consequences

Use of marine vessels during research activities under the Proposed Action could add hydrocarbon emissions to the environment within the Proposed Action area. Greenhouse gas (GHG) emissions resulting from the use of marine vessels in the Proposed Action were calculated by estimating future usage of marine vessels currently utilized for PNNL research activities in Sequim Bay. Under the Proposed Action, GHG emissions are estimated to increase, when compared to emissions from current research activities, by 28.7 metric tons (mt) of carbon dioxide (CO_2), 0.00125 mt methane (CH_4), and 0.00025 mt nitrous oxide (N_2O) per year over the course of 20 years. Carbon dioxide equivalent (CO_2e) is used to convert GHG emissions from other greenhouse gases into the amount of carbon dioxide with the same global warming potential. Estimated GHG emissions from current research activities are 62.8 mt CO_2e per year (using global warming potentials from 40 CFR 98). Annual increases in GHG emissions because of the Proposed Action are estimated to be 28.8 mt CO_2e, for a total estimated annual GHG emissions of 91.6 mt CO_2e under the Proposed Action. Total GHG emissions in Washington State in 2019 were 102.1 million metric tons (MMT) CO_2e, with 40.3 MMT CO_2e resulting from transportation activities and 16.7 MMT CO_2e resulting from non-highway vehicles (Ecology 2022). Estimated increases in GHG emissions from the Proposed Action would constitute an approximate 0.00003 percent increase in total state annual CO_2e emissions, and a 0.0002 percent increase in emissions from non-highway vehicle use. Estimated annual GHG emissions from current research activities are equivalent to GHG emissions from one gasoline-powered passenger vehicle driven 161,000 miles (EPA 2024a). The annual increased GHG emissions resulting from the Proposed Action are equivalent to emissions from one gasoline-powered passenger vehicle driven 74,000 miles (EPA 2024a). Therefore, the total annual amount of estimated GHG emissions resulting from the Proposed Action is equivalent to the emissions from one gasoline-powered passenger vehicle driven 235,000 miles (EPA 2024a). DOE recently obtained a new hybrid research vessel (R/V), the R/V Resilience, which would minimize air emissions.

The social cost of greenhouse gases is a tool used to better understand and communicate the net harm to society from increased emissions. This tool considers the value of climate change impacts such as changes in natural disasters, human health effects, and the value of ecosystem services (IWG SC-GHG 2021). DOE uses the EPA social cost of greenhouse gases calculator in NEPA reviews (EPA 2024b). Considering GHG emissions resulting from the Proposed Action, as described above, over a 20-year period from 2025 to 2045, the Proposed Action is calculated to result in total social cost of greenhouse gases equal to $440,000 (in 2023 dollars), using the 2.0 percent discount rate.

3.1.2.3 Cumulative Effects

The nearby PNNL-Sequim campus generates air emissions that are regulated through the Olympic Region Clean Air Agency (ORCAA) to enforce EPA chemical air requirements (ORCAA 2023). Two 600 kW emergency diesel generators are staged at the PNNL-Sequim campus. Criteria and hazardous air pollutant emissions are permitted under ORCAA Approval Order 13NOI968. The approval order includes certain operating, fuel sulfur content, opacity, monitoring, record, and maintenance requirements. Because the potential-to-emit is minor for all pollutants, the PNNL-Sequim campus is considered a "Minor" source.

Because of the location of marine resources and recreational marinas near the project areas, it is expected that boat traffic in the area may be frequent and add diesel emissions in the region from recreational or commercial use, as well as official use by local law enforcement and the U.S. Coast Guard. While the Proposed Action will contribute emissions from vessel activity associated with the Proposed Action, the incremental impacts to air quality are expected to be negligible.

3.1.3 Soils and Geological Resources

3.1.3.1 Affected Environment

As work may occur within Battelle or DOE-owned tidal lands, soils and geological resources are evaluated for the PNNL-Sequim campus. Ground surface elevations at the PNNL-Sequim campus range from about 46 m (150 ft) in the upland area to sea level in the shoreline area. The periphery of the upland area slopes steeply to the north and east, and a near-vertical bluff separates the developed uplands area from Sequim Bay. The PNNL-Sequim campus vicinity is underlain by Quaternary-age unconsolidated glacial and interglacial deposits to a depth greater than 366 m (1,200 ft) (Thomas et al. 1999). Surficial deposits on the upland portion of the PNNL-Sequim campus site are glacial till 14,500 to 17,500 years old, described as unstratified, poorly sorted, clayey, sandy silt up to 46 m (150 ft) thick, with an average thickness of 9 m (30 ft) throughout the greater region (Schasse and Logan 1998). These surficial deposits are underlain by undifferentiated deposits from older glacial events and interglacial periods. Water-bearing units of coarse-grained sands and gravels are found in the unconsolidated deposits throughout the region, including in the vicinity of the PNNL-Sequim campus (Thomas et al. 1999). Tertiary-age sedimentary (primarily siltstone, sandstone, and mudstone) and volcanic (primarily basalt and basalt breccia) rocks underlie the unconsolidated deposits (Schasse and Logan 1998).

Several recorded earthquakes and seismically active faults are located within 8 km (5 mi) of the PNNL-Sequim campus, and the nearest fault trace is about 3.2 km (2 mi) to the southwest (WDNR 2024a). The region is subject to significant seismic hazards, as evidenced by the estimated peak ground acceleration of about 0.85 grams for 2 percent probability of exceedance in 50 years (USGS 2024a; Peterson et al. 2024). Very strong shaking (Modified Mercalli Intensity VII) in the PNNL-Sequim campus region is predicted for several of the earthquake scenarios evaluated by Washington State (e.g., the Cascadia Subduction Zone earthquake scenario) (WDNR 2013, WDNR 2024a). Susceptibility to liquefaction is rated as very low or low for both the uplands and shoreline areas of the PNNL-Sequim campus, except for Travis Spit and Bugge Spit, which are rated as moderate to high for liquefaction susceptibility (WDNR 2024a). The shoreline area of the PNNL-Sequim campus and Travis Spit are subject to tsunami hazard (inundation) for the Cascadia Subduction Zone scenario (WDNR 2024a). Although the glacial deposits at the PNNL-Sequim campus support the near-vertical slopes along the bluff at the site, recent landslides and widespread areas of landslide susceptibility have been mapped in the Puget Sound region (WDNR 2024a). No volcanic hazard has been identified in the PNNL-Sequim campus region (WDNR 2024a).

Soils present on the PNNL-Sequim campus site include moderately well-drained gravelly loam soils, 50 to 100 centimeters (cm) (20 to 40 inches [in]) deep, that are present on most of the undeveloped upland area (NRCS 2019); these soils are classified as prime farmland. Shallower, gravelly sandy loam soils make up the remaining upland areas that are not steeply sloped. These soils are not prime farmland. The steeper soils above Washington Harbor Road are excessively drained, gravelly loamy sands that are not prime farmland. These steeper soils are identified as an erosion and landslide hazard (City of Sequim 2023). The shoreline area has no formal soil classification.

No commercial mineral resources are known to be present on the PNNL-Sequim campus. Sand and gravel have been widely mined from the glacial outwash deposits found throughout the region, and the bedrock has been mined for stone (USGS 2024b; WDNR 2024).

3.1.3.2 Environmental Consequences

The in-water, tidal lands, and shoreline activities of the Proposed Action would only result in minimal impacts on soils and geological resources. Any land and soil disturbance that may occur is expected to be limited to shoreline areas and would be temporary, with the land returned to original conditions. The Proposed Action would not impact any prime farmland areas.

3.1.3.3 Cumulative Effects

Some of the future actions identified in Section 1.3.2, including climate change, would affect soil and geological resources in the PNNL-Sequim campus and surrounding region. However, because the Proposed Action would have minimal or no long-term impacts, the incremental contribution to cumulative effects in the region would be minimal. No additional cumulative effects on soils or geological resources would occur.

3.1.4 Water Resources

3.1.4.1 Affected Environment

The PNNL-Sequim campus is situated in the Sequim Bay watershed, near the inlet to Sequim Bay from the Strait of Juan de Fuca. The nearest fish bearing stream to the action area is Bell Creek, located north of Washington Harbor Road, which drains an area of about 19.7 square kilometers (km^2) (7.6 square miles [mi^2]) (USGS 2024c) and discharges to a tidal lagoon connected to the Sequim Bay inlet. The tidal marsh area is part of this tidal lagoon. Bell Creek is part of the Sequim Bay watershed, which covers an area of 145 km^2 (56 mi^2) surrounding the bay (Elwha-Dungeness Planning Unit 2005). The Dungeness River, located about 8 km (5 mi) west of the PNNL-Sequim campus, is the primary surface source of freshwater in the region and is used for irrigation throughout the lower Dungeness River basin (Ecology 2010). The Dungeness River drains an area of about 520 km^2 (200 mi^2) (USGS 2024d) and discharges into the eastern end of the Juan de Fuca research area. Water resources in the Dungeness River and Sequim Bay watersheds (including groundwater) are managed to satisfy present and future human needs and to protect instream values and resources (WAC 173-518; Clallam County 2005). There are no wild and scenic rivers, as designated in 16 USC 1274, in the Proposed Action area. There are Federal Emergency Management Agency (FEMA)-designated floodplains within the Proposed Action area (FEMA 1989).

Groundwater in the region between the Dungeness River and the Strait of Juan de Fuca/Sequim Bay occurs within the unconsolidated deposits that extend from the ground surface to the underlying bedrock. These deposits reach a maximum thickness of more than 610 m (2,000 ft) to the north of Sequim Bay (Thomas et al. 1999). The regional groundwater system consists of three aquifers (shallow, middle, and lower) with intervening low permeability confining units (Thomas et al. 1999). Groundwater generally flows from recharge areas in the south to discharge areas in the north that include springs, streams, Sequim Bay, and the Strait of Juan de Fuca. Groundwater is the primary source of drinking water and other non-irrigation water uses in Clallam County. Groundwater use has increased over time (Ecology 2010, Thomas et al. 1999). Most wells in the region are constructed at depths less than 90 m (300 ft) below ground surface, likely in the shallow and middle aquifers (Thomas et al. 1999).

Seawater is withdrawn from Sequim Bay for use in research and development operations at the PNNL-Sequim campus via an offshore intake located on the floor of Sequim Bay north of the campus. Pumping capacity is 760 liters per minute (lpm) (200 gallons per minute [gpm]). No water right is required for the withdrawal of seawater (Ecology 1994). No freshwater use at the PNNL-Sequim campus is from a surface water source. The PNNL-Sequim campus obtains fresh groundwater from a well screened in the lower aquifer at an elevation of about -120 m (-400 ft) (National Geodetic Vertical Datum of 1929) located in the shoreline area near the base of the bluff (Ecology 1981). Well water is used for drinking and sanitary needs, and as a freshwater source for research and development operations. Combined water rights of 25 acre-feet per year (ac-ft/yr) (31,000 m^3/yr) (with a peak flow of up to 380 lpm [100 gpm]) are held by the property owner for groundwater withdrawal (Tilden 2016). An application for an additional water right to accommodate an increase in freshwater needs for research was filed with the state for 250 ac-ft/yr (308,000 m^3/yr), with a peak withdrawal rate of 760 lpm (200 gpm); it is currently pending (Tilden 2016). Connection of the PNNL-Sequim campus to the City of Sequim water system is currently planned (City of Sequim 2022). If connected, the City of Sequim would provide drinking water to the PNNL-Sequim campus and well water would continue to be used for research needs.

Water quality use designations for Sequim Bay and the Strait of Juan de Fuca are extraordinary quality aquatic life use, primary contact recreational use, all harvest uses, and all miscellaneous uses (aesthetics, boating, commerce/navigation, and wildlife habitat) (WAC 173-201A-612). The extraordinary quality aquatic life use classification requires that water quality "markedly and uniformly exceed the requirements for all uses including, but not limited to, salmonid migration and rearing; other fish migration, rearing, and spawning; clam, oyster, and mussel rearing and spawning; crustaceans and other shellfish (crabs, shrimp, crayfish, scallops, etc.) rearing and spawning" (WAC 173-201A-210). Sequim Bay near Goose Point is listed as impaired for the designated aquatic life use because of low dissolved oxygen (Ecology 2024a; Listing ID 10296). The tidal lagoon and mouth of Sequim Bay north of the PNNL-Sequim campus are listed as impaired for aquatic life due to algae growth arising from human causes (Ecology 2024a; Listing ID 21727). No impairments for aquatic life use are listed for the Strait of Juan de Fuca research area. Impairments for recreation and harvesting uses are listed for locations on the western shore of Sequim Bay and the coast of the Strait of Juan de Fuca due to bacterial contamination (Ecology 2024a; Listing IDs 40364, 40402, 84254, and 9933). Two locations in the strait southwest of Dungeness Spit are listed as impaired for harvesting uses due to harmful chemicals in tissue samples (Ecology 2024a; Listing IDs 64471, 64477, 64540, and 64526). Several streams discharging into the Proposed Action area are currently impaired for exceedance of one or more water-quality standards, including dissolved oxygen, bacteria, turbidity, temperature, and biological integrity (Ecology 2024a).

Groundwater quality in the region is generally good, as evidenced by its extensive use for drinking water and by recent monitoring in the Sequim area (Soule 2013). However, the shallow aquifer in most areas is vulnerable to contamination from septic systems and fertilizer (Soule 2013). The City of Sequim public water supply system is required to complete regular monitoring of water quality. This drinking water source met all water-quality requirements in 2023 (City of Sequim 2023). Groundwater from the PNNL-Sequim campus well is monitored regularly for potentially harmful substances. No exceedances have been observed in the last 10 years. The presence of bacteria (as total coliform or *E. coli*) has been observed in the distribution system during monthly sampling but has not been detected in the groundwater source. [1]

Discharges to Sequim Bay from the PNNL-Sequim campus are permitted at two outfalls (Ecology 2017). Monitoring of treated wastewater discharge flow and water quality are required. No permit violations have been reported since 2017. Sanitary wastewater from the shoreline and uplands buildings are discharged to a septic system located in the uplands area. No other discharges to ground occur on the PNNL-Sequim campus.

[1] Sample results and exceedances results were reviewed 8/28/2024 at https://fortress.wa.gov/doh/eh/portal/odw/si/SingleSystemViews/GenInfoSingleSys.aspx?OrgNum=10351&OrgName=BATTELLE+NORTHWEST+MARINE+LAB&xid=55591.

3.1.4.2 Environmental Consequences

There are FEMA-designated floodplains within the Proposed Action area. However, the Proposed Action is made up of environmental research activities that do not involve building structures or any activities that will result in long-term change to ecosystems. Additionally, the Proposed Action will not involve draining, dredging, channelizing, filling, diking, impounding, or related activities in floodplains. Therefore, DOE has determined that a formal floodplain assessment as described in 10 CFR Part 1022 is not required for the Proposed Action (10 CFR Part 1022).

The Proposed Action does not involve use of freshwater or seawater beyond water sampling, which would have negligible impacts. The potential impacts to water resources are evaluated below for the Proposed Action's effects on water quality. Proposed Action activities would mitigate potential impacts on water quality by following, at minimum, the below:

- Removal of all devices and structures at the project end, which will avoid the long-term corrosion of equipment and release of contaminants.
- No significant alteration of the shoreline, which will avoid local alteration of currents and shoreline erosion.
- Use of anchoring methods that avoid scour and use of helical screw anchors, when possible, which will minimize local increases in turbidity.
- Use of non-toxic, corrosion resistant materials, which will minimize the short-term release of contaminants from degraded equipment.
- Compliance with applicable water quality regulations, which are intended to protect the designated uses of waters in the Proposed Action area. The applicable water quality criteria include: toxic, radioactive, or harmful material concentration limits (WAC 173-201A-260); no impairment of aesthetic values by the presence of materials or their effects (WAC 173-201A-260); bacterial limits (WAC 173-201A-210); and aquatic life criteria for temperature (13 °C, 55.4 °F), dissolved oxygen (7.0 mg/L), turbidity (5 Nephelometric Turbidity Units or 10 percent over background), pH (human-caused variation less than 0.2 units) (WAC 173-201A-210).

The Proposed Action's effects on water quality are evaluated below.

Equipment Installation

Equipment attached to the existing PNNL-Sequim campus dock would be limited in surface area and quantity. Floating platforms and buoys would be bounded by dimensions in the PBA, constructed of non-toxic and corrosion-resistant materials, and would be anchored using materials and methods that minimize seabed disturbance and scouring. Subsurface probes and other devices would be installed at depths up to 2.1 m (7 ft) and would be buried by hand or using a water jet. Some temporary and localized increase in turbidity is expected during anchoring and device burial. The water quality criteria for turbidity during and immediately after in-water construction activities are applicable outside a mixing zone at a radius of 45.7 m (150 ft) from the area of disturbance (WAC 173-201A-210). Authorized mixing zones must be minimized in size (and pollutant concentration) and require supporting information indicating no significant impacts to habitat, water uses, or ecosystem damage (WAC 173-201A-400). PDCs applicable to equipment installation activities minimize the effects on water quality from equipment degradation and assure compliance with the applicable turbidity criteria.

Vessel and Autonomous Vehicle Use

Vessel use under the Proposed Action would conform to procedures currently followed for existing vessel use under PNNL-Sequim campus operations (e.g., spill prevention and control). Autonomous vehicles would be constructed for marine use and deployed for limited durations. No water quality impacts are anticipated for these activities.

Surveys, Sampling, and Dye Releases

Benthic surveys using a penetrometer would disturb sediments over a diameter of 8 cm (3 in) to a depth up to 1 m (3.3 ft) for each drop, with drops spaced 24.4 m (80 ft) apart. Sediment sampling surveys would be limited in number, duration, and total volume sampled (0.8 m^3 [1 cubic yard (yd^3)] per survey and 23 m^3 [30 yd^3] per year) across the Proposed Action area. The largest samples would be 10 cm (3.9 in) samples cored to a depth of 3 m (10 ft). Benthic sample collection would result in temporary and localized turbidity increase that is expected to be bounded by the turbidity increase expected from equipment installation. Groundwater wells may be installed after sediments are cored. These wells would be used for monitoring only and would have no effect on groundwater quality. Water column sampling would have no effect on water quality. Dye and particulate releases would use non-toxic materials at minimum concentrations needed for the application.

Operation of Emitting Devices

Light-/EMF-emitting and acoustic devices are expected to be constructed for marine use to minimize potential corrosion that may locally affect water quality. No water quality impacts are anticipated for activities deploying these devices.

Marine Energy Device Installation and Operation

Installation of marine energy devices and tidal turbines is expected to produce a localized and temporary increase in turbidity for devices that are anchored to the seabed. Similar to the discussion of equipment installation, the materials and methods used would minimize seabed disturbance, scouring, and equipment corrosion. Potential effects on water quality from marine energy device and tidal turbine operation[1] are posited to arise from changes in water flows induced by the presence of devices (Whiting and Chang 2020), from the release of contaminants from device materials (similar to what has been studied for wind turbines; Ebeling et al. 2023) and from inadvertent spills of contaminants (Lazuga 2024). Potential effects are expected to be larger for commercial-scale facilities and for installations in smaller, shallower water bodies (e.g., estuaries). The Proposed Action marine energy device and tidal turbine installations would be on a smaller, community/research scale and would, therefore, be expected to have a proportionally small impact on water flows. An expressed goal of the Proposed Action is to develop approaches for understanding the interaction of marine energy devices and tidal turbines with the environment and, thus, better understanding their potential water quality (and other) impacts.

3.1.4.3 Cumulative Effects

Continued population growth and development in Clallam County and future climate change are expected to put additional pressure on the freshwater resources (surface and groundwater) of the region. Although annual average precipitation is projected to slightly increase with climate change, the number of days with temperatures below freezing is projected to decrease significantly. This is expected to reduce snowpack and alter runoff patterns, thereby affecting water availability during some times of the year. Identified

[1] See the database of studies at https://tethys.pnnl.gov/receptor/water-quality.

projects in the region that alter land use may have localized effects on water quality in the Proposed Action area. Cumulative water quality effects from these projects and from climate change are expected to be most impactful for the tidal marsh area, Sequim Bay nearshore areas, and near the mouth of the Dungeness River. When considered with the cumulative effects, the temporary, incremental effects of the Proposed Action research activities are expected to be negligible.

3.1.5 Cultural Resources and Historic Properties

The term cultural resources includes, but is not limited to, archaeological material (artifacts) and sites that date to the prehistoric, historic, and ethnohistoric periods and that are currently located on the ground surface or buried beneath it; standing structures and their component parts that are over 50 years of age and represent a major historical theme or era and structures that have an important technological, architectural, or local significance; cultural and natural places, select natural resources, and sacred objects that have importance for American Indians; and American folklife traditions and arts. Historic property means any prehistoric or historic district, site, building, structure, or object included or eligible for inclusion in the National Register of Historic Places (NRHP) maintained by the Secretary of the Interior. This term includes artifacts, records, and remains that are related to and located within such properties. The term includes properties of traditional religious and cultural importance to an Indian Tribe or Native Hawaiian organization and that meet the NRHP criteria. Historic properties may include a diverse range of resources depending on the project location and type of undertaking. Section 106 of the NHPA requires federal agencies to consider the effects of their undertakings on historic properties included or eligible for inclusion on the NRHP (36 CFR Part 800). The NRHP is the nation’s official list recognizing buildings, structures, objects, sites, and districts of national, state, or local places that are historically significant and worthy of preservation. The criteria for eligibility are listed in 36 CFR 60.4, *Criteria for Evaluation*.

The current Proposed Action was reviewed under the NHPA in 2021 in support of the initial issuance of the research permit (Renaud 2021). In Washington State, archaeological reports are considered current if they have been completed within the last decade. Because the original archaeological review was completed within that time frame, it is still considered current. An addendum report to Renaud (2021) was conducted by Mendez (2024) to provide additional details on scope that had not been explicitly described in the original review. The section below considers information from both reports.

3.1.5.1 Affected Environment

Contemporary research suggests that there may be submerged resources within the proposed project action area. Research by Collins (2005) indicates that the Dungeness River occupied several valleys, called paleochannels, at different times during the Holocene period. Following or resulting from de-glaciation about 12,000 years ago, the paleo-Dungeness River carved into glacial and glaciomarine deposits, which created three paleochannels at present day locations: Cassalery Creek (southwest of Jamestown), Bell Creek (east of Sequim leading into Washington Harbor), and Gierin Creek (north of Bell Creek). The three paleochannels have milder land gradients, supporting the theory that the movement of the paleo-Dungeness River resulted in the creation of four distinct river landscapes (the three paleochannels and the paleo-Dungeness River). As the Holocene sea levels rose, the paleo-Dungeness River deposited sediments in each of the three paleochannels, creating higher sea level surfaces. Linden and Schurer (1988) estimate that sea levels in Victoria, BC, and surrounding areas may have been as much as 50 m (164 ft) lower 11,000 to 9,000 years ago than today. Between 9,000 and 5,000 years ago, it was at least 11 m (36 ft) lower than present day levels (Collins 2005).

Evidence suggests that the Dungeness River has been building its current delta for possibly the last few hundred years prior to the 1855 mapping of the Dungeness River Delta by the U.S. Coast and Geodetic Survey. This is reinforced by the distinctness of the Meadowbrook Creek Dungeness River paleochannel, a former channel similar in size to the modern Dungeness River that diverged from the river around present-day river mile 2.5. The morphology of the modern Dungeness River area implies that this diversion from its historic location is a newer phenomenon. The early 1800s location of the Dungeness River is where the Meadowbrook Creek channel is today. The evidence of paleochannels supports the possibility that activities of early populations may exist around the paleochannels. Therefore, there may be submerged coastal sites present offshore within the Proposed Action area.

To understand the cultural resources in the study area, one must refer to the overall history of the region. This section documents the precontact, ethnographic, and historic chronology of the Salish Sea with an emphasis on the Olympic Peninsula region. Cultural sequences in this section follow those proposed by Hutchings and Williams (2020), who combine western archaeological timeframes with Indigenous history of the Salish Sea, known as Xwullemy. Brief descriptions of each time period and associated sites are described below.

Salish Sea I (17,000 to 13,000 years ago)

Puget Sound was deglaciated around 16,000 years ago. There are well-dated archaeological sites in the Pacific Northwest that demonstrate human activity about 2,000 years after deglaciation (e.g., Paisley Caves in Oregon [Gilbert et al. 2008], Cooper's Ferry in Idaho [Davis et al. 2019]). However, archaeologists frequently associate the Clovis culture as the predominant Paleoindian culture from this era, despite Clovis-era sites dating thousands of years later. Clovis sites are characterized by the large, fluted eponymous projectile point, which is unique to the period.

The earliest recorded emergence of human activity in the Salish Sea is contributed to the Manis site on the Olympic Peninsula. The Manis site, located approximately 5 km (3 mi) west of Sequim Bay, contains the 12,800-year-old remains of a mastodon (*Mammut americanum*) with a possible bone point lodged in one of its ribs (Gustafson et al. 1979; Carlson 1990; Ames and Maschner 1999). Other archaeological evidence within the region comes mostly from Clovis-era sites, although there are a few Clovis and pre-Clovis sites along the northwest coast dating between 13,000 to approximately 12,000 years ago (Dixon 2013; Hutchings and Williams 2020).

Salish Sea II (13,000 to 10,000 years ago)

There are few archaeological sites that date to the Salish Sea II period. Lack of archaeological sites dating to this period may be more a result of rising sea levels and submerging shorelines rather than the absence of human activity. The DeStaffany site on San Juan Island, north of the Proposed Action area, dates to the Salish Sea II period. The site consists of a lithic scatter located on a 25 m (82 ft) high bedrock outcrop (Kenady et al. 2002, 2008). Artifacts recorded from the site resemble those of the Western Stemmed Tradition, dated in other pre-Clovis sites between 13,000 years and as late as 8,500 years ago.

Salish Sea III (10,000 to 5,000 years ago)

This period is characterized by extensive environmental changes and the development of early subsistence economies that preceded the rise of permanent settlements, resource intensification, and complex social organizations. Subsistence strategies concentrated on large animal hunting and plant food gathering. Some of the first house pits in the Pacific Northwest date to this period.

Sites from this era were located on bluffs near marine, riverine, or estuary resources. Leaf-shaped projectile points known as Cascade or Olcott were common in the archaeological record. Other cultural material from this period includes lithic procurement tools, debitage, midden, and floral and faunal remains. The Van O's site in Port Angeles is reported to be a late Olcott campsite dating to this period.

Excavations revealed that the site contained at least 15 leaf-shaped basalt projectile points, cobble choppers, unifacial scrapers, modified flakes, cobble spall tools, flake-gravers, evidence of worked bone, food processing, and small sandstone abrading slabs. Olcott-like projectile points have also been observed at Ahlstrom's Prairie near Lake Ozette and Tongue Point, west of Port Angeles (Bergland 1983).

Salish Sea IV (5,000 years ago to 1775 Common Era [CE])

This period represents a continuation of adaptive strategies developed in earlier times, with increasing technologies and specialization (Bergland 1983). This phase is characterized by winter villages made of large plank houses, storage use, seasonal use of specialized resource locations, small, notched projectile points indicative of bow-and-arrow technology, and sophisticated art (Ames and Maschner 1999). Cultural continuity became more evident during the Salish IV period. Important food resources during this time include shellfish and fish, followed by elk, deer, and sea mammals (Matson and Coupland 1995). Bone, antler, and ground stone tools first appear between 4,500 and 3,500 years ago. Large shell midden sites also emerge during this time (Ames and Maschner 1999). Shell middens within the Salish Sea represent a variety of activities, including temporary, seasonal procurement and processing camps to semi-permanent villages (Hutchings and Williams 2020).

Village houses are perhaps the most definitive feature of this period. Village houses were multipurpose and served as winter dwellings and were the location of public ceremonies (Suttles and Lane 1991). Village sites were connected mainly through familial ties and were divided by winter villages and summer camps. Winter was considered the season of ceremonies, feasting, and strengthening of family and kin bonds. Winter villages were fairly permanent and contained between 100 to 500 people (or, such as Dungeness, nearly 1,000). Villages consisted of one or more longhouse structures with outlying cabins and huts for lower class and slaves (Gunther 1927). Occupation was from the late fall through mid-spring. In contrast, summer camps were occupied seasonally, ranging from a few days to an entire summer. Summer camps were focused on resource procurement sites, such as the mouths of rivers and estuaries, plant gathering areas, or near marine resources like fishing banks or whale lookouts. Seasonal camps were constructed of tents or huts made of cedar or rush mats layered over a wooden frame.

On the Olympic Peninsula, understanding of this time is based on the archaeological record from the Ozette Village, near the Makah reservation. While the site's cultural deposits span a time period of about 2,000 years, only the last 450 years have been extensively investigated (Bergland 1983; Daugherty 1970; Mauger 1978; Gleeson and Grosso 1975; Gleeson 1970, 1980; Samuels 1983, 1991; Huelsbeck 1981, 1989). Significant preservation at Ozette has helped scholars learn more about house assemblage distributions, the relationship of space use between structures and within structures (Mauger 1978; Huelsbeck 1989; Samuels 1983, 1992).

In addition to Ozette, sxʷčkʷíyəŋ (pronounced "soo-ch-kwee-ing") on Washington Harbor, within the PNNL-Sequim campus, exemplifies the above-mentioned characteristics in one locale. Sxʷčkʷíyəŋ was a large village site with an associated shell midden that controlled the mouth of Sequim Bay (Smith 1907; Gunther 1927; Blukis-Onat and Larson 1984; Renaud and Perrin 2019). The village was located under the bluff and was surrounded by a palisade wall. Radiocarbon dating indicates that the site was occupied for at least 600 years (Blukis-Onat and Larson 1984).

Salish Sea V (1775 to 1900)

This time period marks the early modern period, where Europeans began exploring the region and encountering the S'Klallam and other Tribes across the Olympic Peninsula. Before European contact, over thirty S'Klallam villages were spread along the shores of the Peninsula, including Sequim Bay. Five traditional languages were spoken throughout the area: Squamish, Halkomelem, Nooksack, Northern

Straits, and Klallam (Suttles and Lane 1991). Speakers of the Klallam language are native to the northern Olympic Peninsula, between the Hoko River and Port Discovery Bay. Most travel in the region was by way of the canoe. Coast Salish groups manufactured different styles of dugout canoes for various purposes, including saltwater fishing, freshwater fishing, transportation, and war (Suttles and Lane 1991).

Fishing for salmon and other anadromous fish was a major component of the subsistence pattern within the Salish Sea. Anadromous species included five species of salmon (i.e., Chinook [*Oncorhynchus tshawytscha*], coho [*Oncorhynchus kisutch*], sockeye [*Oncorhynchus nerka*], chum [*Oncorhynchus keta*], and pink [*Oncorhynchus gorbuscha*]) and three species of trout (i.e., steelhead [*Oncorhynchus mykiss*], cutthroat [*Oncorhynchus clarkia*], and Dolly Varden [*Salvelinus malma*]) (Schalk 1988). Herring (*Clupea pallasii*) was taken from Washington Harbor, as well as around Dungeness, while smelt (*Osmeridae* sp.) and eulachon (*Thaleichthys pacificus*) were caught on the spits and beaches. Humpback salmon (*Oncorhynchus gorbuscha*) were found in the Dungeness River (Gunther 1927). Shellfish were gathered on rocks east of Washington Harbor, while flounder (*Paralichthys* sp.) and sea mammals were available in the saltwater.

European explorers, fur traders, and missionaries began arriving in the Northwest around the late 1700s. Spanish explorer Juan Perez explored the region in the 1770s and the Quimper and Eliza expeditions passed through in 1790 and 1791, naming all the major landforms and waterways. Few names were retained after Capt. George Vancouver's explorations in 1792, when most places were renamed for British personages or crew members.

The first Euromerican settlers came to the Sequim area by 1851 (Langness 1992) and Dungeness between 1851 and 1852 (Keeting 1976; Langness 1992). Before the arrival of Europeans, approximately 200,000 Indigenous people lived on the Northwest Coast. The smallpox epidemic decimated at least one-third of the population at the time (Hutchings and Williams 2020). European contact impacted subsistence, spiritual, and other aspects of Indigenous culture. Sequim Prairie in particular was directly affected by the settlers' arrival as they used the open prairies for settlement and agriculture (Gorsline 1992; Lane 1972; Norton 1979).

The S'Klallam, along with the Chemakum and Skokomish Tribes, signed the Point No Point Treaty of 1855. The treaty allowed the Tribes to retain usual fishing places and techniques and temporary housing, but they could not take shellfish from settler-staked land (Gates 1955; Lane 1975). Few other than the Skokomish moved to the reservation, mainly because there was little cleared space and few dwellings. By 1874, under the leadership of James Balch, some S'Klallam families (mainly Dungeness S'Klallams) joined together to purchase 210 acres of land, which they named Jamestown. Each contributor, including some from Sequim Bay, Discovery Bay, and Port Townsend, received an amount of land proportional to their contribution (Eells 1985; Gunther 1927; Taylor 1976).

Salish Sea VI (1900 to present)

In 1913, the town of Sequim was platted (Robinson 2005). The name Sequim derives from the Klallam word *Suxtcikwin* (Gunther 1927), meaning "quiet water," and is applied to the village at Washington Harbor (Fish 1983). The establishment of the rail line between Port Angeles and Port Townsend in 1914 provided mail, passenger, and freight service to the surrounding area (Keeting 1976). With the railroad, Sequim was transformed from a country village to a small city with direct transportation connections via rail and water with Seattle and distant markets connected with Puget Sound. The line was eventually sold to the Chicago, Milwaukee, St. Paul, and Pacific (CMSP&P) railroad in 1918. CMSP&P ended operations on the line in 1967 and abandoned all lines west of Miles City, Montana, in 1980 (Nerbovig 1976). The Port Angeles-Port Townsend line was put up for bid and purchased by the Seattle and North Coast

Railroad, which began providing service in 1980 (Fish 1983). Seattle and North Coast ceased operations in 1984 and the tracks have since been dismantled and removed.

In the 1930s, expansion of regional road systems, including the opening of U.S. 101, known as the Olympic Loop Highway, drastically improved vehicle access to the Olympic Peninsula. Between 1936 and 1938, the Lower Elwha Tribe and the Port Gamble S'Klallam Tribes established their reservations (Lower Elwha Klallam Tribe 2022; Port Gamble S'Klallam 2024). The establishment of Olympic National Park in 1938 further increased the attractiveness of the Peninsula as a destination for travel and recreation (Fish 1983). Tourism developments in the area include the establishment of Sequim Bay State Park, John Wayne Marina, and the Olympic Discovery Trail. The main industries in the area have remained logging and farming.

Cultural Resources Within the Project Area

To identify historic properties within the project area, a literature search was conducted using the Washington State Department of Archaeology and Historic Preservation Washington Information System for Architectural and Archeological Records Data database, the DOE cultural resources program geodatabase managed by PNNL, and the National Oceanic and Atmospheric Administration (NOAA) Wrecks and Obstruction Database for shipwrecks. A one-mile radius was incorporated in the search to identify resources that may be affected by the undertaking. Renaud (2021) has a comprehensive analysis of the previously recorded sites and surveys within the Proposed Action area. Updated inventory results are briefly described below.

A total of 23 sites are within one mile of the Proposed Action area. Of those, seven sites are recorded as historic, 15 are precontact, and one site is multicomponent. Eight of the 23 sites are eligible for the NRHP, two sites are not eligible, and the remainder are unevaluated. Major sites near Sequim Bay include the sxʷčkʷíyəŋ village site and Protection Island. Protection Island is part of the USFWS' National Wildlife Refuge. The island was a practice artillery range during World War II (USFWS website). Minor archaeological work conducted on the island has uncovered mastodon bones, teeth, and tusks around the high bluffs. Graveyard Spit, south of Dungeness Spit, marks the location of the 1868 Tsimshian Indian massacre site where ten Tsimshian men, seven women, and one child were murdered while camping on the spit (Harper 1969). The site is listed on the Washington Heritage Register. One shipwreck is recorded within the Proposed Action area, south of Travis Spit in the north end of Sequim Bay (NOAA 2024). Although the location is recorded, no details about the wreck are included in the description except that the wreck is visible.

A total of 68 cultural surveys have been done within one mile of the project area. Since the publication of the Renaud (2021) report, four additional surveys have been completed. The reviews covered projects including proposed fish passages at five locations in Clallam County (Durkin and Adams 2021), emergency septic system replacement for the Clallam Conservation District (Koehnen 2022), acquisition of six Clallam County parcels adjacent to Miller Peninsula State Park (Hibdon and Walton 2022), and an archaeological review for Washington State Parks and Recreation Commission's master planning for Miller Peninsula State Park (Kopperl et al. 2024). None of the reviews intersect the Proposed Action area.

The Lummi Nation has identified the Salish Sea, Xwullemy, as a Traditional Cultural Property. The Lummi Nation consider Xwullemy eligible for the NRHP, eligible for listing as a National Historic Landmark, and eligible for inclusion in the World Heritage List for its association with the culture, traditions, and history of the Lummi (Lummi Indian Business Council 2018).

3.1.5.2 Environmental Consequences

The presence of paleochannels in the western shoreline boundaries of the Proposed Action area suggests the likelihood of submerged resources within the area. Multiple locations across the North Olympic shoreline, including Dungeness Bay, are important culturally for the S'Klallam, and continue to be traditional use areas for the Tribes today. There are previously recorded archaeological sites and historic properties within proximity to Proposed Action area, including one submerged resource near Sequim Bay. The research activities would avoid or minimize actions within those areas as much as reasonably possible to minimize potential impacts to known historic properties or sensitive areas. Activities would be limited to the duration of each project and all equipment would be removed after the conclusion of activities. Visual and auditory impacts would not be expected from the Proposed Action.

DOE determined in 2021 that the project would result in No Adverse Effect to historic properties, as defined by 36 CFR 800.5(b). Mendez (2024) conducted an addendum review to clarify details on the benthic sediment sampling and cable use to determine if the original determination of No Adverse Effect was still an appropriate finding. The assessment concluded that the revised activities would not introduce new effects or expand the total potential impacts from what was originally evaluated in 2021. The additional description of the benthic sampling volumes and clarification of the cable use were within the types of impacts considered during the evaluation of effects in the 2021 report. The scale and scope of the proposed activity combined with the unlikely possibility of inundated precontact archaeological sites indicated the unlikelihood that historic properties may be present. As such, DOE determined that the finding of No Adverse Effect remained appropriate.

Activities such as sediment sampling may potentially impact submerged resources near the paleochannels. However, the scope and scale of the proposed activities combined with the effort to reduce actions within known sensitive areas would most likely not adversely impact any potential submerged resources or historic properties present in those areas.

3.1.5.3 Cumulative Effects

Urbanization and development can be detrimental to cultural resources, which are non-renewable resources. Potential impacts to cultural resources in the larger regional context may be small to moderate depending on the activity. Foreseeable activities described in Section 1.3.2 have the potential to introduce physical, visual, or auditory impacts to cultural resources depending on the location of development, design of facilities and use areas, vertical and horizontal depth of planned disturbances, and similar associated activities. Engagement with local and state agencies and Tribes should occur to take into account any potential historic properties and Traditional Cultural Properties that may be in the area to avoid or minimize impacts to resources. Natural and cultural resources surveys should also occur before development to determine the presence or absence of resources in planned development areas.

DOE identified the state development project at Miller Peninsula State Park as a reasonably foreseeable activity. Development associated with the state park may introduce visual, auditory, and physical impacts to known historic properties in the area. Archaeological investigations in support of that undertaking occurred in 2024 and recorded cultural material (Kopperl et al. 2024). If development were to occur outside of areas initially identified as potential development, surveys should occur prior to determine if historic properties are present and determine the effect of the undertaking on those resources.

As described in Mendez (2024), no new effects or impacts are anticipated from the revised benthic sampling and cable installation scope. Therefore, cumulative impacts to historic and cultural resources from these activities are not anticipated.

3.1.6 Aquatic Ecology Resources

DOE prepared a PBA to analyze the effects of the Proposed Action to federally protected species and habitats within the Proposed Action area (Appendix A). When considered together, the research activities under the Proposed Action have the potential to affect aquatic resources. The PBA describes these effects along with proposed avoidance, minimization, and mitigation actions to reduce the potential impacts of the Proposed Action. On May 3, 2024, and August 21, 2024, NMFS and USFWS, respectively, issued programmatic biological opinions with performance criteria described as PDC to use as performance limits and measures to minimize or mitigate impacts to protected species and designated critical habitats, as well as EFH (Appendix B, Appendix C). Through the use of PDC, adaptive management, and coordination with NMFS and USFWS throughout the 20-year life of the Proposed Action, NMFS and USFWS found the Proposed Action is not likely to jeopardize the continued existence of federally protected aquatic resources and will not result in the destruction or adverse modification of federally protected habitats. Discussion of Proposed Action effects to federally protected species and habitats, including EFH, will not be included throughout the remainder of this section and can be found in the PBA (Appendix A) and the above-mentioned programmatic biological opinions (Appendix B and Appendix C). The PBA analyses were used to conservatively infer the potential for impacts to all non-protected aquatic resources and the following subsections summarize these impacts and potential for cumulative effects.

3.1.6.1 Affected Environment

For Sequim Bay and waters within the action area of the Strait of Juan de Fuca, the aquatic assemblages are similar to those found in the Dungeness National Wildlife Refuge and include habitats such as beaches, lagoons, mudflats, eelgrass beds, and salt marshes (USFWS 2013). Sequim Bay provides habitat to many marine animals, including commercially valuable species (Pacific herring and surf smelt [*Hypomesus pretiosus*]), anadromous and resident fishes, otters, macroinvertebrates, seals, and shellfish (e.g., crab, clams, mussels, oysters, scallops, snails) (Lefebvre et al. 2008; Dungeness River Nature Center 2024; Elwha-Dungeness Planning Unit 2005; USFWS 2013). Common aquatic species that occur in the area include fish species such as sole, sculpin, Pacific tomcod (*Microgadus proximus*), striped perch (*Embiotoca lateralis*), Pacific herring, sand lance (*Ammodytes hexapterus*), and spiny dogfish (*Squalus acanthias*) (Miller et al. 1980). Beaches provide habitat for marine mammals, including harbor seals (*Phoca vitulina*) and occasionally northern elephant seals (*Mirounga angustirostris*), while lagoons and mudflats provide food resources for crab and anadromous and forage fish (USFWS 2013). Several species of cetaceans migrate and forage in the waters of the Strait of Juan de Fuca and, on rare occasions, may be seen in Sequim Bay. These include killer whales (*Orcinus orca*), humpback whales (*Megaptera novaeangliae*), gray whales (*Eschrichtius robustus*), minke whales (*Balaenoptera acutorostrata*), Dall's porpoise (*Phocoenoides dalli*), and harbor porpoise (*Phocoena phocoena*) (DOE 2023). Eelgrass beds are essential for many species because they provide forage and habitat. Birds, snails, and crab species rely on eelgrass as forage, and bacteria in the sediment of eelgrass beds provide food for invertebrates (e.g., crab larvae). Some fish species use eelgrass for spawning habitat, and other anadromous and forage fish use eelgrass beds for cover or to find food (e.g., oysters) in the water column surrounding the eelgrass beds (USFWS 2013). Salt marshes are extremely productive ecosystems. They provide habitat for phytoplankton, a species at the base of many general aquatic assemblages and consumed by many other species (e.g., zooplankton, anadromous and forage fishes, invertebrates; USFWS 2013).

The Proposed Action area includes a portion of the Protection Island Aquatic Reserve, as shown in Figure 3.2. This 9,623 ha (23,778 ac) reserve, designated in 2010, consists of tidelands and bedlands managed by the WDNR. The reserve includes all waters between the island and both Quimper and Miller Peninsulas, including Travis Spit extending outward to the 61 m (200 ft) bathymetry contour. The reserve was created, in part, to protect the valuable resources and habitats it provides to numerous aquatic and terrestrial species.

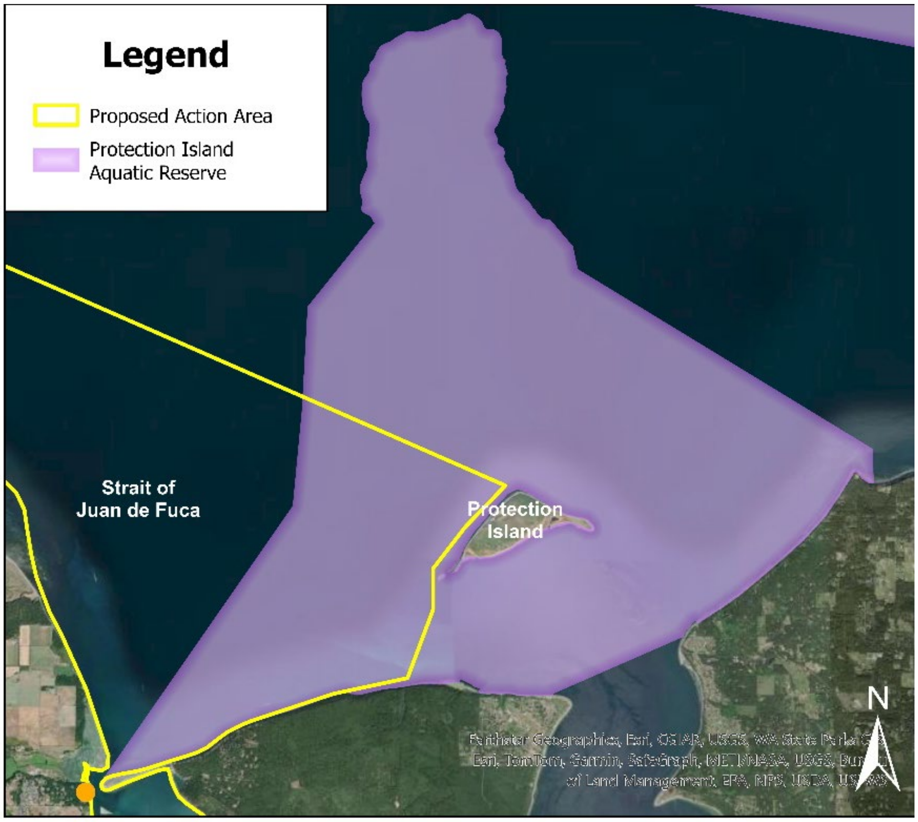

Figure 3.2. The Extent of Protection Island Aquatic Reserve and the Proposed Action Area.

3.1.6.2 Environmental Consequences

Environmental consequences to aquatic resources are analyzed below by activity. The PDC and corresponding mitigation requirements were developed to avoid net loss of habitat quality as a result of the Proposed Action. As described in the NMFS programmatic biological opinion, "The location of projects covered under [the PBA] will be spread across Sequim Bay and a portion of the Strait of 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 [the PBA], we expected no-net loss of nearshore habitat or critical habitat conservation value over time" (NMFS 2024). Some proposed activities may affect aquatic resources or habitats of the Protection Island Aquatic Reserve. Any activities within the reserve would be consistent with the management goals of the reserve and conducted with approval from and in coordination with the WDNR Protection Island Aquatic Reserve managers. Impacts as described below would apply to the Protection Island Aquatic Reserve for activities approved within that area.

Equipment Installation

Impacts from deployment and operation of surface platforms and buoys or attaching equipment to the PNNL-Sequim dock are expected to be minor, with temporary avoidance of the area by aquatic species during installation and removal and minor impacts associated with the potential for entanglement with mooring lines. The PDC for mooring lines requires adding mid-line floats when necessary to prevent entanglement. Any shading of benthic substrate and the water column by the installation of platforms would have minimal impact on habitat and would be temporary. As described in the NMFS programmatic biological opinion, "Most of the project approved through the [PBA] are of a very short-term nature and will have little, to no, effect on migration and prey" (NMFS 2024). A summary of the potential for impacts is provided in Table 3.1.

Species that forage in Sequim Bay may be temporarily affected by seabed installation activities through disruption of access to habitat near the in-water work. The footprint of individual projects would be small relative to the overall expanse of Sequim Bay and the Strait of Juan de Fuca, thus, nearby, unaffected foraging habitat would occur in abundance adjacent to the specific project areas, and any effects during installation would be considered negligible. Installation impacts to habitats may have minor effects to those resources that utilize those areas by temporarily changing habitat. The PDC for anchoring of instruments and equipment to the seabed (including cables running from the PNNL-Sequim campus shoreline to instruments in Sequim Bay channel) will require a method that minimizes seabed disturbance and avoids areas with macroalgae or other submerged aquatic vegetation unless the specific focus of the research is on such areas.

Table 3.1. Likelihood of Impact between Aquatic Species and Habitats with Installation and Operation of Equipment in Project Areas.

Species or Habitat	Surface Platforms (Grated and Solid) and Buoys	PNNL-Sequim Dock Equipment	Seabed Equipment
Aquatic Species			
Fish	Minor, temporary avoidance impact during installation and removal.	Minor, temporary avoidance impact during installation and removal.	Minor, temporary avoidance impact during installation and removal.
Cetaceans	Minor, temporary avoidance impact during installation and removal; minor for entanglement with mooring lines.	No Impacts.	Minor, temporary avoidance impact during installation and removal.
Pinnipeds	Minor, temporary avoidance impact during installation and removal; minor for entanglement with mooring lines.	Negligible.	Minor, temporary avoidance impact during installation and removal.
Benthic Species	Minor, temporary avoidance impact during mooring attachment.	Negligible.	Minor, temporary avoidance impact during installation and removal.
Habitats			
Benthic and Pelagic Habitats	Minor, temporary impact during installation, operation, and removal.	Minor, temporary impact during installation and operation.	Minor, temporary impact during installation, operation, and removal.

Vessels and Autonomous Vehicles

Use of vessels, autonomous vehicles, and UAS in Sequim Bay and the Strait of Juan de Fuca research areas is not expected to have more than a minor and temporary effect on aquatic resources and habitats. The Marine Mammal Protection Act (MMPA) provides restrictions on UAS operation near marine mammals; all MMPA restrictions will be followed to reduce potential impacts such as harassment of marine mammals. Effects from light and sound that may be emitted from these vehicles are analyzed in the relevant sections below. Such effects are expected to be minimal for pelagic species, as such disturbance would not likely be greater than that caused by typical vessel traffic. Effects to benthic species would be minor, as benthic substrate may be temporarily disturbed during anchoring.

Surveys, Sampling, and Dye Releases

Neither benthic habitat and species characterization nor sediment collection is expected to have more than a minor and temporary effect on foraging opportunities for species in the area. Pelagic species that forage in Sequim Bay and the Strait of Juan de Fuca may be temporarily affected by characterization and collection activities. A summary of the potential for impacts is provided in Table 3.2.

Pelagic species that forage in Sequim Bay or the Strait of Juan de Fuca may be temporarily affected by sampling, through disruption of access to habitat and disturbance during foraging near the sampling locations. Because nearby, unaffected foraging habitat occurs within and surrounding the project areas, any effects of water column sampling would be considered negligible, as affected species could move to nearby areas.

Most research activities will be required to carefully avoid impacts to sensitive habitats such as eelgrass beds, submerged aquatic vegetation, and intertidal areas. However, some research focused specifically on understanding these areas may be performed for the explicit purpose of submerged aquatic vegetation research. Research projects would not meaningfully alter the habitats that are being researched, given the limit of no more than a total of 20 m^2 (215 ft^2) of disturbance (including submerged aquatic vegetation collection) in any given area in any given year. Additionally, the dispersed manner of collection (no more than 10 percent of the eelgrass in any given collection area) would reduce the impact at any given point within a collection area and, thus, speed natural recovery through vegetative growth. Impacts to aquatic species may be minor for temporary disruption of foraging in the area. A summary of the potential for impacts is provided in Table 3.2.

Fluorescent dyes are commonly used for hydrological and circulation studies, and they are non-toxic to humans and sea life at low concentrations. All usage will require following manufacturers guidelines or label requirements, and releases will use minimum concentrations necessary to accomplish desired research objectives. Species could experience a temporary reduction in water visibility and, thus, a small disturbance to foraging habitat. This impact is expected to be minor. Instruments used to detect the presence of the dyes or tracers would be suspended in the water, installed on the seabed or a floating platform, or deployed on a surface vessel or AUV; impacts of these various equipment installations are discussed elsewhere. The presence of the dyes or tracers in the water column would be short-term, and they would be quickly diluted; thus, impacts to habitats would be negligible. A summary of the potential for impacts is provided in Table 3.2.

Table 3.2. Likelihood of Impact Between Aquatic Species and Habitats with Survey, Sampling, and Dye Releases in Project Areas.

Species or Habitat	**Benthic Surveys, Seagrass, Macroalgae, and Intertidal Research**	**Water Column Sampling**	**Dye and Particulate Releases**
Aquatic Species			
Fish	Minor, temporary avoidance and foraging disruption during research activities.	Minor, temporary avoidance impact during research activities. Some juveniles susceptible to capture.	Minor, temporary foraging disturbance during research activities.

Species or Habitat	Benthic Surveys, Seagrass, Macroalgae, and Intertidal Research	Water Column Sampling	Dye and Particulate Releases
Cetaceans	Minor, temporary avoidance and foraging disruption during research activities.	Minor, temporary avoidance impact during research activities.	Minor, temporary foraging disturbance during research activities.
Pinnipeds	Minor, temporary avoidance and foraging disruption during research activities.	Minor, temporary avoidance impact during research activities.	Minor, temporary foraging disturbance during research activities.
Benthic Species	Minor effects during sediment collection or other research activities.	No impacts	Minor, temporary foraging disturbance during research activities.
Habitats			
Benthic and Pelagic Habitats	Minor, temporary disturbance during research activities.	Minor, temporary disturbance during research activities.	Minor, temporary disturbance during research activities.

Emitting Devices

Use of emitting devices includes introduction of light, sound, and EMF.

Light Emissions

Operation of light sources, as described, is not expected to affect large portions of aquatic habitats, as the operation would be restricted to a small portion of the project areas, given size restrictions of devices within PDC. Temporary use of light sources during operation could temporarily affect the water column and may discourage use of habitat in the area. However, the small relative area and temporary operations are not expected to result in more than minor effects to protected and non-protected species, as nearby unaffected habitat could be used for foraging or migration. 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]). To avoid and minimize impacts from non-eye-safe lasers, Protected Species Observers will be used, so that operation of the laser can be discontinued if a protected aquatic species is within 50 m (164 ft) of the laser. In addition, devices with automated shutdown capability, which discontinue use of the laser if an animal is near the source, would have that capability enabled during deployment. PNNL will implement the above practices to any configuration of one or more non-eye-safe green laser light-emitting instruments, including any associated with marine renewable energy research (e.g., tidal turbines).

Operation of light sources, as described, is not expected to affect habitats, as the operation would be restricted to the project areas. Operation could temporarily affect use of habitat resources for migration or foraging; however, the small relative area and temporary operations are expected to have minimal effects on use of habitats in the project areas as nearby unaffected habitat could be used for foraging or migration. A summary of the potential for impacts is provided in Table 3.3.

Table 3.3. Likelihood of Impact Between Aquatic Species and Habitats with Light Emissions in the Project Areas.

Species or Habitat	Light Emissions
Aquatic Species	
Fish	Minor, behavioral disruption for all light sources and potential for ocular injury from non-eye-safe lasers.
Cetaceans	Minor, behavioral disruption for all light sources and potential for ocular injury from non-eye-safe lasers.
Pinnipeds	Minor, behavioral disruption for all light sources and potential for ocular injury from non-eye-safe lasers.
Benthic Species	Minor, potential for behavioral disruption for all light sources during operation.
Habitats	
Benthic and Pelagic Habitats	No impacts to habitats.

Sound Emissions

The acoustic-emitting equipment and instruments proposed and described in the PBA are considered non-impulsive, which is less harmful to marine species than impulsive sound. Though when used without mitigation, non-impulsive sound sources still have the potential to adversely affect aquatic species, including marine mammals. Operation of acoustic-emitting 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. Mitigation actions, such as using Protected Species Observers to shut down operation of acoustic devices when marine mammals could be affected, limiting duration times, and following tidal work windows to minimize impacts on fish, are all expected to reduce the impacts of acoustic devices. The operation of devices would be for limited periods of time, including daily, weekly, monthly, and yearly limits. With the PDC, as described in the PBA, noise emitting-devices are expected to have an overall minor impact on aquatic species and habitats. A summary of the potential for impacts from the Proposed Action is provided in Table 3.4.

Table 3.4. Likelihood of Impact Between Aquatic Species and Habitats with Acoustic Emissions in Project Areas.

Species or Habitat	Impact of Acoustic Operations
Aquatic Species	
Fish	Minor, potential for injury, but most of the likely sound sources are outside of hearing range. Some sounds may cause temporary behavioral disruption.
Cetaceans	Minor to adverse, potential for injury for all cetaceans, may be classed as adverse impacts to high-frequency cetacean species (i.e., porpoises), other cetaceans have a moderate potential for auditory injury. Behavioral disruption may affect large areas for sources with high sound pressure level. Protected Species Observers will be used to minimize the potential for adverse effects.
Pinnipeds	Minor to moderate, potential for injury from some sound sources, but sensitivity is much less than high-frequency cetaceans. Behavioral disruption may affect large areas for sources with high sound pressure level. Protected Species Observers will be used to minimize the potential for moderate effects.
Benthic Species	Indeterminable, hearing ability unknown.
Habitats	
Benthic and Pelagic Habitats	No impact to habitats.

Electromagnetic Fields

Generation of EMF would likely occur with marine energy device operations and 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 by electrified devices and cables during operation and could temporarily affect the associated benthic species 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. A summary of the potential for EMF to affect aquatic species and habitats is provided in Table 3.5.

Table 3.5. Likelihood of Impact Between Aquatic Species and Habitats with EMF Devices and Cables, Marine Energy Devices, and Tidal Turbine Research.

Species or Habitat	EMF Devices & Cables	Marine Energy Devices	Tidal Turbine Research
Aquatic Species			
Fish	Minor, temporary avoidance impact during installation, operation, and removal.	Minor, temporary avoidance impact during installation and removal. Minor to moderate effects during operation.	Minor, temporary avoidance impact during installation and removal. Minor to adverse effects during operation.
Cetaceans	Minor, temporary avoidance impact during installation, operation, and removal.	Minor, temporary avoidance impact during installation and removal. Minor to moderate effects during operation.	Minor, temporary avoidance impact during installation and removal. Minor to adverse effects during operation.
Pinnipeds	Minor, temporary avoidance impact during installation, operation, and removal.	Minor, temporary avoidance impact during installation and removal. Minor to moderate effects during operation.	Minor, temporary avoidance impact during installation and removal. Minor to adverse effects during operation.
Benthic Species	Minor, temporary avoidance impact during installation, operation, and removal.	Minor, temporary avoidance impact during installation and removal of seabed-installed devices.	Minor, temporary avoidance impact during installation and removal of seabed-installed devices. No effects during operation.
Habitats			
Benthic and Pelagic Habitats	Minor, temporary impact during installation and removal. No effects during operation.	Minor, temporary impact during installation and removal. No effects during operation.	Minor, temporary impact during installation and removal. No effects during operation.

Marine Energy Devices

Marine energy devices tend to have fewer moving parts that could interact with marine life than tidal turbines. Installation and operation of marine energy devices may affect aquatic species and habitats because of the potential for collision with or entrainment within moving parts of the device, though there is a lack of documentation showing an increase in fish or marine mammal collision from marine energy devices, as described in Copping and Hemery (2020). PDC, as described in the PBA, will be utilized to minimize collision and entrainment potential for protected species, and these protections are expected to extend to nonprotected species. Effects from noise and EMF generated from operation are discussed above as separate research components, and this activity provides an example of multiple research activities or phenomena operating concurrently. Habitats may be temporarily affected by deployment of marine energy devices. However, the footprint of such installations is expected to be minor compared to nearby unaffected habitats.

Cetaceans, pinnipeds, and fish may swim away from operating marine energy 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), recent field studies around operating marine energy devices indicate that marine mammals can detect the devices acoustically and use avoidance behaviors to avoid coming near devices. Operation of marine energy devices with higher approach velocities may entrain forage species. However, the footprint of such installations is expected to be minor with regard to nearby unaffected habitats. A summary of the potential for marine energy devices to affect aquatic species and habitats is provided in Table 3.5.

Tidal Turbine Research

Installation and removal of tidal turbines may affect habitats. Operation of tidal turbines may affect aquatic resources due to potential collision with parts (e.g., blades, rotors) of the device when the turbine is moving (tidal turbines do not operate under all flow conditions). Collision risk between a device and marine animal has been a significant barrier in the permitting process for such devices (Horne et al. 2022); however, there is a lack of documentation showing an increase in fish or marine mammal or diving seabird collision with blades (da Silva et al. 2022).

Given the lack of documentation showing an increase in aquatic resource 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). Consequently, DOE chooses to take a conservative approach regarding the potential impacts of tidal turbines and their consequences. Therefore, the risk of collision to species will be minimized based on adaptive future tidal turbine deployments and information obtained from marine resource monitoring. The monitoring protocols described in Section 5.3 of the PBA (DOE 2023) were developed in coordination with NMFS and USFWS in response to perceived collision risk to marine mammals, seabirds, and fish. DOE will use the best available technologies to monitor nearfield underwater interactions with and behaviors of marine species in response to deployed devices, habitat use near the tidal turbine, and to detect collisions. PDCs include notification to the Services if a seabird, marine mammal, or fish is detected within 1 m (3 ft) of the tidal turbine and shutdown of the tidal turbine until further consultation in the event of a blade strike of a target. Within the first year of the PBA, one turbine can be deployed in the action area at any given time. The number of total allowed deployments tidal turbines deployed as part of the PBA may increase over time, dependent on adaptive management and collaboration with the Services. A summary of the potential for marine energy devices to affect aquatic species and habitats is provided in Table 3.5.

3.1.6.3 Cumulative Effects

Sequim Bay has been influenced by changes in tributary watersheds that affect the Sequim Bay nearshore water quality. Activities that affect water quality include timber harvest (Weston 2006), land conversions, growth-related commercial and residential development, and agriculture. As discussed in NMFS (2016), human population growth would be the main cause of most of the future negative impacts on marine species and their habitat, including ESA-listed species and critical habitat (NMFS 2022). Expansion of the Kinder Morgan Trans Mountain Pipeline in Canada will increase the amount of oil transported through the Strait of Juan de Fuca, increasing risk of a catastrophic oil spill that could drastically impact the aquatic resources and habitats of the Salish Sea. The proposed development of Miller Peninsula State Park may increase recreational use of the area. The PNNL-Sequim campus development plan (DOE 2022) may involve marine research facility improvements in the nearshore areas of the PNNL-Sequim facilities and dock. However, research activities under the Proposed Action are expected to have only incremental impacts that would not affect the cumulative effects of other activities in the region.

3.1.7 Terrestrial Ecology Resources

Because proposed research activities mainly occur in the water and, to a lesser extent, in the nearshore areas, potential to affect terrestrial resources is limited to terrestrial species that also depend on aquatic and nearshore habitats. As discussed in Section 3.1.6, DOE prepared a PBA to analyze the effects of the Proposed Action to federally protected species and habitats within the defined geographic area. The PBA describes these effects, along with proposed avoidance, minimization, and mitigation actions to reduce the potential impacts of the Proposed Action. Through the use of PDC, adaptive management, and coordination with the Services throughout the 20-year life of the Proposed Action, USFWS found the Proposed Action is not likely to jeopardize the continued existence of federally protected terrestrial resources (USFWS 2024). Discussion of Proposed Action effects to federally protected species and habitats will not be included throughout the remainder of this section and can be found in the PBA (Appendix A) and the associated USFWS programmatic biological opinion (Appendix C). The PBA analyses were used to conservatively infer the potential for impacts to all non-protected terrestrial resources, and the following subsections summarize these impacts and potential for cumulative impacts.

3.1.7.1 Affected Environment

The Proposed Action area abuts the PNNL-Sequim campus in Sequim Bay along with Protection Island and Dungeness Spit within the Strait of Juan de Fuca. The PNNL-Sequim campus includes upland and lowland habitats. Undeveloped uplands consist of a bluff that overlooks Sequim Bay and the sloping terrain that rises approximately 46 m (150 ft) above sea level. Coniferous forest habitat begins above the ordinary high-water mark of Sequim Bay, extending west to the campus boundary (PNNL 2020). Most of the forest is mature, naturally regenerated second growth estimated to be 100 to 160 years old (Becker 2019). The dominant and subdominant canopy species are Douglas fir (*Pseudotsuga menziesii*) and western red cedar (*Thuja plicata*), respectively. The mature coniferous forest on the PNNL-Sequim campus is part of a somewhat larger, mature coniferous forest complex that includes private property west of the PNNL-Sequim campus. The forest provides habitat for common forest mammals, including black-tailed deer (*Odocoileus hemionus*), coyote (*Canis latrans*), and Douglas squirrel (*Tamiasciurus douglasii*). Western toads (*Anaxyrus boreas*), northern red-legged frogs (*Rana aurora*), and rough-skinned newts (*Taricha granulosa*) have also been observed. Bats and numerous bird species are known to utilize the forest during all seasons.

The shoreline and beach at the foot of the bluff that parallels the Sequim Bay shoreline, Travis Spit, and The Middle Ground make up lowlands undeveloped because of potential impacts on natural and cultural resources, recommended setbacks, and physical access. Much of the beach area near the PNNL-Sequim campus dock has been developed and contains research facilities and supporting infrastructure. The proposed project area includes intertidal wetlands, such as Bugge Spit, with vegetation consistent with Persistent Emergent Wetlands (Cowardin et al. 1979). Vegetation found on Bugge Spit consists of glasswort mixed with saltgrass and, as elevation increases, transitions to tufted hairgrass. 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*). Bugge Spit and the adjacent estuarine wetland west of Bugge Spit (which is outside of the Proposed Action area) are recognized as priority waterfowl and shorebird concentration habitats utilized heavily during fall-spring by American wigeon (*Mareca americana*) and other duck species.

Protection Island lies approximately 1.5 mi (2.4 km) north of Diamond Point and just over 5.5 mi (8.8 km) east-northeast of the PNNL-Sequim campus. The island is undeveloped and provides nesting habitat for burrow-nesting seabirds in the Salish Sea. Most of the island within the Protection Island National Wildlife Refuge is managed by the USFWS to provide habitat for rhinoceros auklets (*Cerorhinca monocerata*), tufted puffins (*Fratercula cirrhata*), pigeon guillemots (*Cepphus columba*), pelagic cormorants (*Phalacrocorax pelagicus*), and bald eagles (*Haliaeetus leucocephalus*). Harbor seals also haul out, and northern elephant seals have birthed young on the beaches. It is closed to visitation, and visitors are required to approach no closer than 183 m (200 yards [yd]) to limit wildlife disturbance when traveling nearby. The west end of the island is land managed as a seabird sanctuary by the Washington Department of Fish and Wildlife (WDFW). The feeder bluffs and sandy spits of the island feed nearby mixed kelp beds. Protection Island is surrounded by the much larger Protection Island Aquatic Reserve, as described in Section 3.1.6. The reserve was created in part to protect the valuable resources and habitats it provides to numerous aquatic and terrestrial species.

The action area is bounded to the west by the Dungeness National Wildlife Refuge. The sand spit and tidelands provide important bird habitat for many species, most prominently for shorebirds and waterfowl. Dunlins (*Calidris alpina)*, sanderlings (*Calidris alba*), and black oystercatchers (*Haematopus bachmani*) are common seasonally, and large numbers of brant (*Branta bernicla*) stage at the refuge during migration and winter. Harbor seals are frequently observed here rearing pups. The refuge is managed by the USFWS and is open to the public with restrictions to protect sensitive wildlife resources.

3.1.7.2 Environmental Consequences

The Proposed Action will occur in the waters of Sequim Bay and the Strait of Juan de Fuca, including the WDNR Protection Island Aquatic Reserve. The Proposed Action would occur offshore and limited activities would occur within Battelle or DOE-owned land adjacent to the shoreline and tidelands. There are wetlands within the Proposed Action area. However, the Proposed Action is made up of environmental research activities that do not involve building structures or any activities that will result in long-term change to the ecosystem. Additionally, the Proposed Action will not involve draining, dredging, channelizing, filling, diking, impounding, or related activities in wetlands. Therefore, DOE has determined that a wetland assessment, as described in 10 CFR Part 1022, is not required for the Proposed Action (10 CFR Part 1022).

The nature of the activities generally limits the potential for impacts to most terrestrial wildlife and habitats. However, aquatic bird groups (e.g., seabirds, waterfowl, etc.) are highly mobile; commonly utilize shoreline, nearshore, and offshore habitats; and may be adversely affected. Birds common to the Salish Sea and the proposed project area include those listed above as nesting nearby, along with other puffin, cormorant, and auklet species; loons; grebes; murrelets; scoters and other sea ducks; and diving ducks (e.g., scaup, redhead, mergansers, etc.). Additional bird groups that forage on or just under the water surface include gulls, terns, phalaropes, and dabbling ducks (Gaydos and Pearson 2011). These birds are less at risk than those that dive simply because they spend much less time underwater, thus limiting potential exposure. Although bats are not easily observed, they are also highly mobile, known to occur in the vicinity, have been observed in offshore environments (Pelletier et al. 2013; True et al. 2021), and some proposed activities also have the potential to affect this wildlife group. Though the Proposed Action area is not within the boundaries of Protection Island National Wildlife Refuge or Dungeness National Wildlife Refuge, birds, bats, and other terrestrial ecological resources that may depend on those areas may be impacted by the Proposed Action. Table 3.6 summarizes anticipated project impacts to terrestrial species groups and habitats.

Equipment Installation

Deployment, operation, and decommissioning of scientific instrumentation and equipment on floating platforms and buoys may temporarily alter habitat for terrestrial species by creating perch or rest sites in open water foraging habitats. Attraction of prey (i.e., small fish, insects) may increase foraging near surface devices (buoys, platforms) by both bats and piscivorous birds. Both phenomena may increase general bird and bat entanglement risk with lines, ropes, and cabling present on the structures. However, implementation of best management practices, including use of tensile materials or midline floats to minimize mooring slack and best management practices, will minimize any entanglement risk to both taxa. Some bird species may temporarily avoid foraging in areas where devices are deployed. Avoidance is expected to be temporary as individuals habituate to the presence of a device or shift use to other nearby areas. Bird and bat interactions with surface devices are expected to be limited and impacts to be minor based on the number and types of equipment proposed to be deployed, the nature of interactions, and project controls designed to limit risk to wildlife.

Surface devices (buoys, platforms) may temporarily deter some wildlife from using nearby habitats while also creating resting (bird foraging/loafing perches, harbor seal haul out) habitat for other species in open waters. Neither avoidance nor attraction are expected to appreciably alter use of these resources by terrestrial wildlife.

Vessels and Autonomous Vehicles

Surface vessel operations may temporarily displace seabirds in the vicinity of operations. This disturbance would be minor and is not expected to alter foraging patterns, effectiveness, or habitat use. The Proposed Action area is open to public boat access. Vessel and vehicle operations are expected to follow seasonal and area access restrictions within protected areas unless otherwise permitted. Vessels can disturb wildlife due to noise emissions. Access is restricted within 183 m (200 yd) of Protection Island with the purpose of protecting seabird nest sites, and this access restriction will preclude Proposed Action disturbance to seabird nest sites from vessel noise and research activities. Limited vessel and vehicle operations are not expected to noticeably increase vessel occurrence in the project area.

UAS use can affect some bird species. Most waterbirds are usually not affected to even relatively close UAS approaches (Lyons et al. 2018; Vas et al. 2015), but some raptors are sensitive to and will act aggressively toward airborne objects in their nesting territory, including drones (Junda et al. 2016). Bald eagles (*Haliaeetus leucocephalus*) are known to nest annually within or near the PNNL-Sequim campus, and other raptors (hawks, eagles, owls) likely nest elsewhere in the action area. Peregrine falcons (*Falco peregrinus*) may also occur during spring and fall migratory seasons. Some birds may be temporarily displaced during UAS operations. Institutional controls, including UAS flight observers, bald eagle nest and bird accumulation area (Bugge Spit) buffers, and UAS flight curtailment policies when raptors are present, minimize risk to birds from UAS operations.

Surveys, Sampling, and Dye Releases

Benthic and water column surveys and sampling activities may displace individual birds. Dyes are commonly used and non-toxic to wildlife when deployed. Effects of these activities are expected to be minor, of very short duration, and have negligible effect on any birds or bats. Removal of minor amounts of water and biological material from or release of dye and particulates in the Protection Island Aquatic Reserve would not be noticeable beyond a very localized area and for a short duration. None of these activities are expected to noticeably degrade habitats or reduce their value to terrestrial wildlife.

Emitting Devices

Emission of energy (i.e., light, sound, EMF) into the environment, if it occurs at harmful levels, has the potential to injure both seabirds and could reduce habitat quality and use.

Light Emissions

Higher energy, non-eye-safe lasers, such as green lasers, can cause ocular injury. Proposed use of lasers for research would occur by directing them into or through waters of the study area. This creates the potential for eye injury to bird species that forage underwater. Characteristics of seawater (e.g., density, turbidity, entrained debris, etc.) serve to reduce energy levels over much shorter distances than in air, such that even relatively strong green lasers would not be harmful at distances approaching 30 m (100 ft). Eyes of birds under the water surface that encounter research laser lights within this distance may be injured. Because lasers would be oriented toward the sea floor during normal operations, birds that routinely feed nearer to the surface (e.g., gulls, terns, phalaropes, dabbling ducks) would be less susceptible to injury, while those that often forage at or near the bottom (e.g., sea ducks and others) would be at greater risk for injury. Non-eye-safe lasers may also be used where the laser travels through the air. This has the potential for eye injury to bird species flying within the airspace of the study area.

To reduce the risk of non-eye-safe lasers to terrestrial species, including birds, Protected Species Observers will be deployed during use of potentially harmful lasers, and lasers will be powered off if/when protected species are observed near enough to the laser device to be injured. Protected terrestrial species include species listed under the ESA, birds protected by the Migratory Bird Treaty Act, and state-listed species. Additionally, some devices can automatically detect nearby objects and turn off harmful lasers. Implementation of project controls including use of Protected Species Observers and object detection/automatic shut off capabilities will limit, but not eliminate, the potential for injury to birds.

Light energy below levels known to be injurious may attract prey (i.e., small fish, insects) and their predators (i.e., seabirds, bats). However, like attraction to buoys and platforms, limited and temporary artificial light in the environment will not meaningly alter behavior or habitat use and effects would be negligible. Limited and temporary effects of artificial light in the environment will not affect terrestrial resources in or the value of the Protection Island Aquatic Reserve.

Sound Emissions

Devices that emit sound into the water are proposed for research uses, including fish tags, buoys, acoustic pingers, bottom profilers, echosounders, sonar, transducers, and acoustic cameras. Most broadcast sound intermittently, while others broadcast continuously during use. Sounds produced will vary by frequency and pressure level (loudness). Avian hearing is recognized to be most sensitive at 1–4 kilohertz (kHz) frequency and insensitive to sounds > 20 kHz (Beason 2004). Although some uncertainty exists within the scientific community about the importance of bird hearing underwater, generally, it is accepted that a diving birds' ability to hear underwater is important (Dooling and Therrien 2012; Larsen et al. 2020; Zeyl et al. 2022). Devices may emit sound that impact bird behavior; in these cases, birds are expected to leave the impacted area and resume typical behaviors outside of the impacted area. Proposed use of devices emitting sound at frequencies with the potential to be heard by diving birds and at injurious levels could result in temporary or permanent hearing loss, potentially limiting their ability to survive or thrive. The majority of anticipated sound-emitting activities that can cause injury require the bird to be less than 1 m (< 3 ft) from the emitting device (DOE 2023). Sound sources with injury distances greater than 20 m (66 ft) will have usage limitations, as described in the PBA. Use of devices emitting sound outside the hearing range of birds, both frequency and volume, would have no effect. Underwater sound emissions are not expected to affect bats.

Electromagnetic Fields

The emission of electromagnetic energy is expected to occur at or near the sea floor and would approximate the strength of a commercially available Neodymium magnet (1.25 T) at the source. Although diving birds may encounter magnetic fields from research equipment at the sea floor, the strength would not affect birds.

Marine Energy Devices

Generally, tidal devices, including turbines and kites, have larger, more exposed moving parts. Other marine energy devices harness more vertical water movements and, generally, are more self-contained, with smaller, fewer moving parts. Both types have the potential to affect diving birds directly from collision and indirectly through disturbance and habitat loss.

Tidal Turbine Research

Scientific data and evidence to evaluate risks posed to wildlife from the deployment and operation of tidal energy devices is limited because it is still an emerging energy technology (McCluskie et al. 2012). Injury or mortality from collision with underwater moving parts is believed to be the greatest risk to bird populations from tidal turbines. Risk factors may include foraging habits, such as preference for foraging locations of high tidal flow and at depths turbines would be deployed, as species that share these characteristics are more likely to encounter a turbine (Furness et al. 2012). Those that forage near the seafloor may also be at higher risk. Guillemots, cormorants, loons, puffins, and auks may be at greater risk from tidal turbines than others (Furness et al. 2012; McCluskie et al. 2012).

Tidal turbines will not always operate and will have variable rotation speed, minimizing collision risk to species. The risk of collision will be further minimized based on adaptive future tidal turbine deployments and information obtained from marine resource monitoring. The monitoring protocols described in Section 5.3 of the PBA (DOE 2023) were developed in coordination with NMFS and USFWS in response to perceived collision risk to marine mammals, seabirds, and fish. DOE will use the best available technologies to monitor nearfield underwater interactions with and behaviors of marine species in response to deployed devices, habitat use near the tidal turbine, and detected collisions. PDCs include notification to the Services if a seabird, marine mammal, or fish is detected within 1 m (3 ft) of the tidal turbine and shutdown of the tidal turbine until further consultation in the event of a blade strike of a target. Additionally, only one tidal turbine will be allowed to be deployed at a time in the first year of research activities to allow for data collection from monitoring and adaptive management and collaboration with the Services.

Other Marine Energy Devices

The state of knowledge about effects of other marine energy devices to bird populations is similarly sparse for the same reasons as tidal turbines. In addition to risks described for tidal turbines, marine energy devices that convert action of the water surface to energy may pose a collision risk to low-flying and aerial diving birds and could also pose entrapment risks depending on the design. Marine energy device presence may deter birds from using nearby habitats. However, the nature of existing designs and methods of operation results in less or slower moving parts underwater. This implies these devices pose less risk of injury and mortality to birds than tidal devices, and tidal devices themselves have not been shown to increase diving seabird collision with blades (Sparling et al. 2020; da Silva et al. 2022). Additionally, marine energy devices would not be placed in high tidal exchange areas, further decreasing apparent risks to birds underwater. Furness et al. (2012) surmised loons to be at moderate risk of detrimental impacts from wave energy converters, followed, to a lesser extent, by scoters, guillemots, cormorants, diving ducks, and others (Furness et al. 2012; McCluskie et al. 2012). Alternatively, marine energy device presence could benefit individuals of some species by providing roost or loaf habitat otherwise unavailable and attracting forage fish, thereby extending foraging area, time, or efficiency (Furness et al. 2012). Conversely, some devices could create entanglement and entrapment risks to some bird species.

Table 3.6. Environmental Consequence of Proposed Research Activities to Terrestrial Species and Resources.

Activity		Marine Birds	Bats	Intertidal Wetlands
Equipment Installation	Buoys and Floats	Minor, temporary avoidance or attraction during operation, minor entanglement risk.	Minor, temporary avoidance or attraction during operation.	No Impacts.
	Subsurface/Mid-water Devices	Minor, temporary avoidance impact during operation; minor for entanglement.	No Impacts.	No Impacts.
	Seabed Devices	Minor, temporary avoidance impact during operation; minor for entanglement.	No Impacts.	No Impacts.
Vessels and Autonomous Vehicles		Minor, temporary avoidance, temporary nest defense/disturbance.	Negligible.	No Impacts.
Surveys, Sampling, and Dye Releases	Benthic Surveys, Seagrass, Macroalgae, and Intertidal Research	Minor, temporary avoidance and foraging disruption during research activities.	Minor, temporary avoidance and foraging disruption during research activities.	Minor, temporary disturbance during research activities.
	Water Column Sampling	Minor, temporary avoidance and foraging disruption during research activities.	Minor, temporary avoidance and foraging disruption during research activities.	No Impacts.
	Dye and Particulate Releases	Minor, temporary avoidance and foraging disruption during research activities.	Negligible.	No Impacts.

Activity		Marine Birds	Bats	Intertidal Wetlands
Energy Emissions	Light	Minor, behavioral disruption for all light sources and potential for ocular injury from non-eye-safe lasers.	Minor, behavioral disruption for all light sources.	No Impacts.
	Sound	Minor, potential for injury, but most of the likely sound sources are outside of hearing range. Some sounds may cause temporary behavioral disruption.	No Impacts.	No Impacts.
	Electromagnetic	Negligible.	No Impacts.	No Impacts.
Marine Energy Devices	Tidal Turbines	Minor, temporary avoidance impact during installation and removal. Minor to adverse effects during operation.	Minor, temporary avoidance impact during installation and removal. No effects during operation.	No Impacts.
	Marine Energy Devices (Excluding Tidal Turbines)	Minor, temporary avoidance impact during installation and removal. Minor to moderate effects during operation.	Minor, temporary avoidance impact during installation and removal. Negligible effects during operation.	No Impacts.

3.1.7.3 Cumulative Effects

As described in Section 1.3.2, cumulative effect sources are diverse. Sequim Bay intertidal wetlands have been influenced by shoreline residential and commercial development (e.g., John Wayne Marina, private and public overwater structures). Land use around Sequim Bay, the watersheds that feed it, and Puget Sound and the Olympic Peninsula continues to grow as the human population expands, resulting in a general degradation of the environment. Urbanization, transportation, and resource extraction have adversely affected terrestrial wildlife that require relatively undisturbed habitats, such as intact mature coniferous forest or nearshore bluffs. Shoreline armoring and river impoundment have altered regional feeder bluff formation and sediment transportation, which has impacted the creation of beaches and other nearshore habitats many terrestrial species require. Development has ultimately led to degradation of water quality, and since terrestrial ecology is intertwined with aquatic ecology, terrestrial wildlife has been affected. Expansion of the Kinder Morgan Trans Mountain Pipeline in Canada will increase the amount of oil transported through the Strait of Juan de Fuca, increasing risk of a catastrophic oil spill that could drastically impact shorelines, beaches, and the bird populations that depend on the Salish Sea. Proposed development of Miller Peninsula State Park could decrease the suitability of nearby forest habitat to bats and other wildlife. These cumulative effects are likely to depress local bird populations, thereby increasing the value of remaining intact habitats of the Protection Island National Wildlife Refuge, Protection Island Aquatic Reserve, and Dungeness National Wildlife Refuge. The Proposed

Action is not expected to noticeably degrade nearby intact terrestrial habitats or affect their value to terrestrial species. Therefore, additional cumulative effects from the proposed action would be negligible with respect to those of other activities.

3.1.8 Socioeconomics

3.1.8.1 Affected Environment

This section describes the baseline socioeconomic characteristics of Clallam County, which makes up the majority of the Proposed Action area and is where the PNNL-Sequim campus is located. This section describes the population demographics and the economy of the region.

Table 3.7 shows population projections and percent growth from 2000 to 2050 for Clallam County and Washington State. According to the 2020 Census, an estimated 77,155 people live in Clallam County. During the last two decades, the population in Clallam County grew at a slower rate than Washington State. Based on population projections, the populations in both Clallam County and Washington State are expected to continue to grow through 2050 if current rates of fertility, mortality, and migration remain unchanged.

Table 3.7. Population Projections and Percent Growth from 2000 to 2050 for Clallam County and Washington State.

Metric	Year	Clallam County Population	Clallam County Percent Change	Washington State Population	Washington State Percent Change
Recorded	2000	64,525	-	5,894,121	-
Recorded	2010	71,404	10.7%	6,724,540	14.1%
Recorded	2020	77,155	8.1%	7,705,281	14.6%
Projected	2030	81,791	6.0%	8,502,764	10.3%
Projected	2040	85,374	4.4%	9,248,473	8.8%
Projected	2050	87,800	2.8%	9,937,575	7.5%

"-" denotes no entry in table cell.

Sources: 2000 data from USCB 2001 Table DP01 (USCB 2000), 2010 data from USCB 2011 Table P2 (USCB 2010), 2020 data from USCB 2021 Table P2 (USCB 2020), 2030–2050 projected data from WOFM (2023)

According to the U.S. Census Bureau's (USCB) 2018–2022 American Community Survey 5-Year Estimates, the educational services and healthcare and social assistance industry represented the largest employment section in Clallam County, followed by retail trade (USCB 2022 [Table DP03]). The civilian labor force in Clallam County was 31,956 persons and the number of individuals employed was 30,216 (USCB 2023 [Table DP03]). Estimated income information for the socioeconomic region of influence is presented in Table 3.8 below. As shown in Table 3.8, both the median household income and per capita income in Clallam County were lower than the state average. Additionally, the percentages of both families and individuals living below the poverty level in Clallam County were higher than the state average.

Table 3.8. Estimated Income Information for Clallam County and Washington State (2018–2022, 5-Year Estimates).

Metric	Clallam County	Washington State
Median household income (dollars)[a]	66,108	90,325
Per capita income (dollars)[a]	38,181	48,685
Families living below the poverty level (percent)	6.6	6.3
People living below the poverty level (percent)	10.9	9.9

(a) In 2022 inflation-adjusted dollars.
Source: USCB 2022 [Table DP03]

According to the USCB 2018–2022 American Community Survey 5 Year Estimates, the unemployment rate in Clallam County was 5.4 percent. Comparatively, the unemployment rate in Washington State during the same period was 5.0 percent (USCB 2022 [Table DP03]). Washington State defines counties where the three-year unemployment rate is at least 20 percent higher than the statewide average as distressed areas (WESD 2023). As of 2023, Clallam County was considered a distressed economy in Washington (WESD 2023).

Currently, PNNL employs around 80 staff at the PNNL-Sequim campus, most of whom reside in Clallam County. The campus consists of land parcels owned by Battelle, which contributed approximately $117,000 in property taxes to Clallam County in 2024. At the current staffing levels, the annual payroll is estimated at $5 million. Additionally, PNNL's local purchases of goods and services in Clallam County total approximately $1.8 million per year, based on current operations (DOE 2022). The current operations of the PNNL-Sequim campus have a minor economic impact on Clallam County's broader economy. The 80 jobs at the campus account for less than 0.2 percent of the county's total employment (USCB 2022 [Table DP03]). The $5 million annual payroll is a small fraction of Clallam County's total payroll, which exceeds $1 billion (WESD 2022). Likewise, the local spending by the PNNL-Sequim campus and the property tax revenue it generates contribute only minimally to the county's overall economic activity.

3.1.8.2 Environmental Consequences

PNNL-Sequim campus growth is projected to accommodate up to 60 additional staff, bringing the total to approximately 135 staff members over the next 20 years (DOE 2022). The expected increase in payroll, from $5 million to approximately $10 million, would have minor positive socioeconomic impacts. Minimal effects on community services and infrastructure, such as housing and schools, are anticipated. This growth is associated with development of the PNNL-Sequim campus, analyzed as a separate activity under NEPA (DOE 2022). The Proposed Action in this assessment is limited to temporary research activities and is unlikely to necessitate further staff increases beyond what was accounted for in DOE 2022, resulting in only a minimal boost to local employment. Therefore, the overall socioeconomic impacts within the broader economy would be minimal.

3.1.8.3 Cumulative Effects

The anticipated socioeconomic impacts of the Proposed Action were evaluated in the context of the reasonably foreseeable future actions identified in Section 1.3.2. The reasonably foreseeable future actions are likely to result in cumulative socioeconomic impacts such as increased economic activity, employment, traffic, and increased demand on community infrastructure and services. However, the

Proposed Action will only result in minimal socioeconomic impacts that would be negligible with respect to those other activities.

DOE is pursuing, as a separate NEPA activity, the potential transfer of ownership of the PNNL-Sequim campus from Battelle to DOE. If this transfer takes place, Clallam County may lose approximately $117,000 annually in property taxes currently paid by Battelle, as DOE would be exempt from property taxes. Although this loss in revenue is possible, it would represent a minor fraction of Clallam County's annual revenue of nearly $126 million (Clallam County 2023). The transfer would likely compensate for the loss in property tax revenue by leading to increased DOE investments in the PNNL-Sequim campus. These investments would boost local staffing and payroll taxes, bring in more visiting scientists, support new facility construction, and increase community spending, all of which are expected to positively impact the local economy. While the campus would continue operating without the property transfer, DOE is more likely to make substantial investments if the transfer occurs. The transfer may occur during the 20-year period of the Proposed Action.

3.1.9 Environmental Justice

3.1.9.1 Affected Environment

Executive Order 12898, "Federal Action to Address Environmental Justice in Minority and Low-Income Populations," directs federal agencies to identify and address the human health or environmental impacts of federal actions, which might have disproportionately high and adverse impacts on minority populations and low-income populations (59 FR 7629). U.S. Census Bureau data were used to identify minority populations including Black or African American, American Indian and Alaska Native, Asian, Native Hawaiian and other Pacific Islander, other races, two or more races, and Hispanic or Latino. Census data also are used to identify the proportion of the population residing below the federal poverty level.

This section describes the affected environment of Clallam County, which makes up the majority of the Proposed Action area and is where the PNNL-Sequim campus is located. According to the U.S. Census Bureau 2018-2022 5-year American Community Survey (USCB 2023) population data, the population of Clallam County is over 77,000 and includes approximately 21 percent minority persons (Nonwhite Hispanic and Latino, Asian, Native American, African American, and persons of multiple races). The Hispanic, Native American, and two or more races populations make up the principal racial and ethnic minorities in Clallam County. The population of Clallam County includes 11 percent low-income residents (USCB 2023). Table 3.9 illustrates the county and state minority and low-income populations. Figures 3.3 and 3.4 show the distribution of minority and low-income census block groups in eastern Clallam County that exceed the state average percentages for minority or low-income.

Table 3.9. 2018–2022 5-Year Estimates of Minority and Low-Income Populations in Clallam County and the State of Washington.

Demographic	Clallam County	Percent	Washington	Percent
White	61,164	79.3%	4,918,820	63.8%
Black or African American	571	0.7%	296,170	3.8%
American Indian and Alaska Native	3,931	5.1%	91,191	1.2%
Asian	1,234	1.6%	723,062	9.4%
Native Hawaiian and Other Pacific Islander	113	0.1%	62,490	0.8%
Some other race	432	0.6%	43,221	0.6%
Two or more races	4,978	6.5%	511,114	6.6%

Demographic	Clallam County	Percent	Washington	Percent
Non-Hispanic	72,423	93.9%	6,646,068	86.3%
Hispanic/Latino[(a)]	4,732	6.1%	1,059,213	13.7%
Total population	77,155	100.0%	7,705,281	100.0%
Aggregate minority	15,991	20.7%	2,786,461	36.2%
Low-income	8,410	10.9%	762,823	9.9%

(1) Of any race, counted separately from the racial categories.
Source: USCB 2023

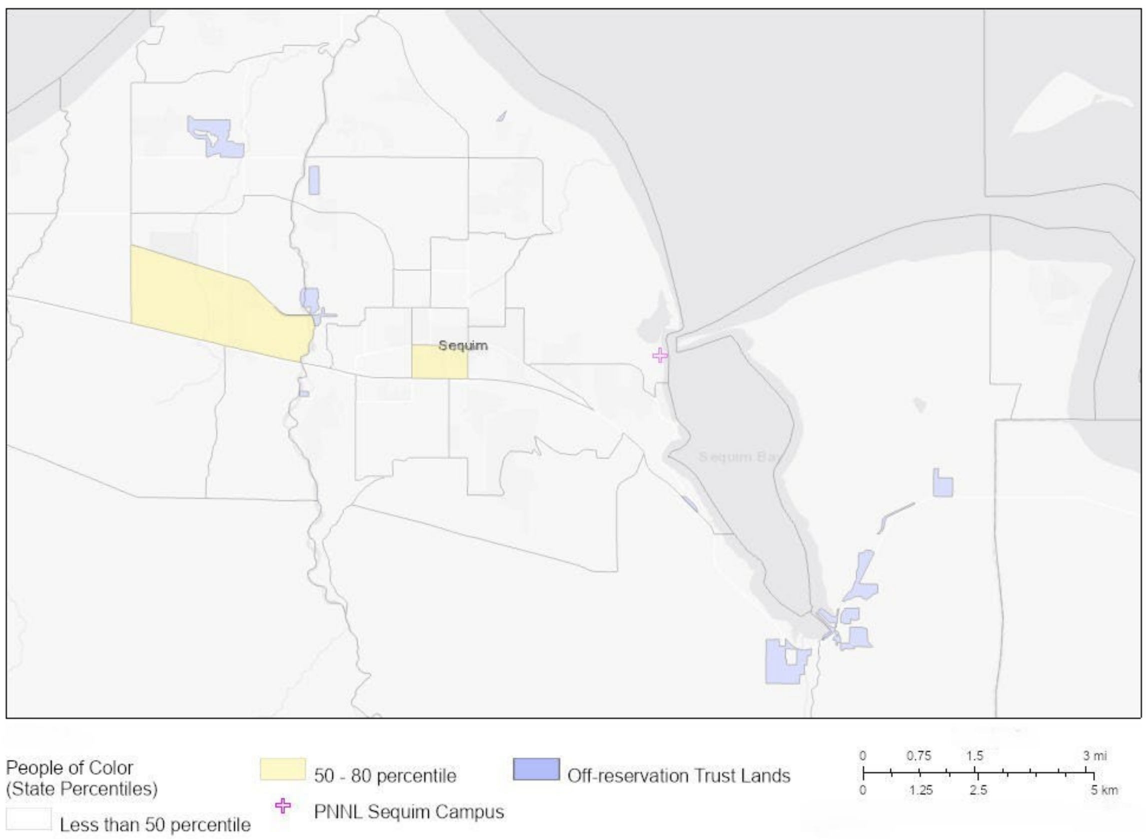

Figure 3.3. Minority Populations Near the Proposed Action Area.

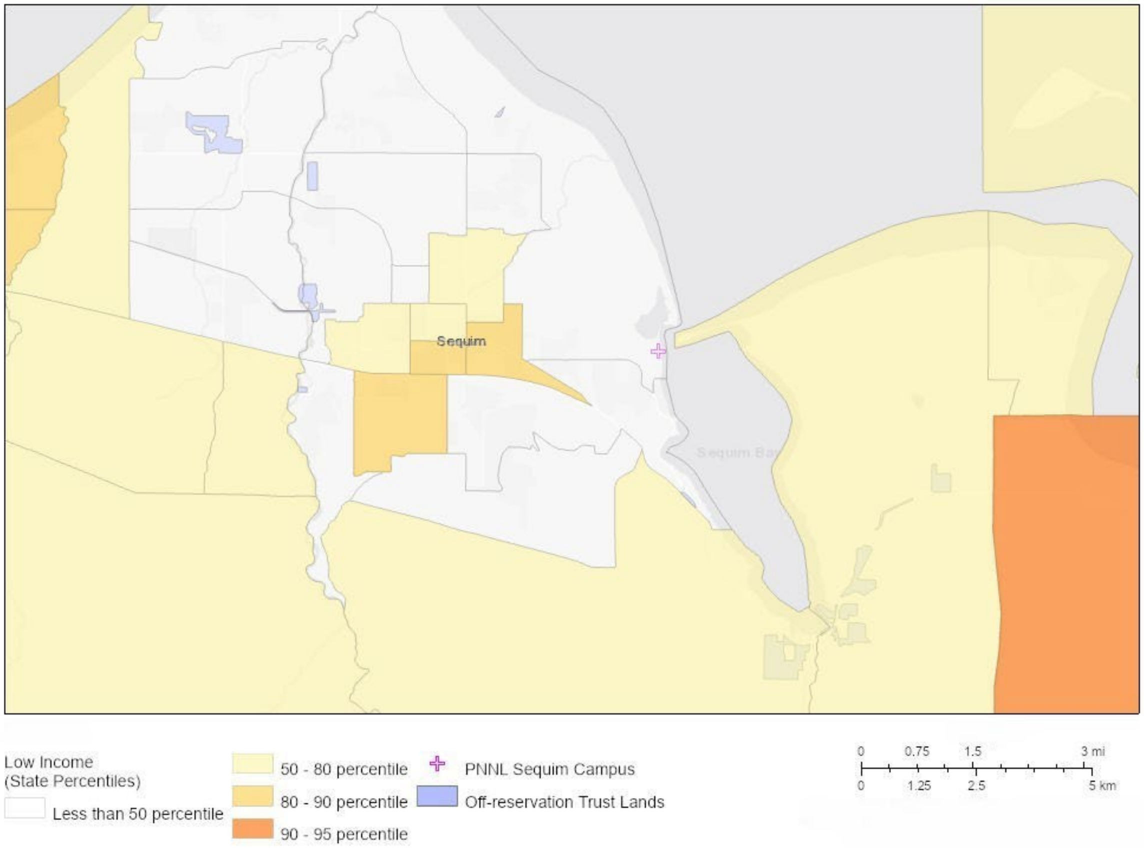

Figure 3.4. Low-Income Populations Near the Proposed Action Area.

3.1.9.2 Environmental Consequences

Over a 20-year period, multiple research projects may occur using the activities described in the Proposed Action. Currently, there are no known impact pathways associated with the research activities that have been determined to affect minority or low-income populations disproportionately; therefore, deployment of research activities under the Proposed Action is not expected to have the potential for disproportionately high and adverse impacts on minority or low-income groups, as defined above. Hence, thresholds for environmental justice-related impacts are not reached. Some Tribal resources may be affected by the Proposed Action; these impacts are discussed in Section 3.1.5.

3.1.9.3 Cumulative Effects

Because the impact pathways associated with the Proposed Action are not specific to minority or low-income populations, disproportionately high and adverse impacts on these groups combining the Proposed Action with past, present, and reasonably foreseeable future projects would not be expected.

3.1.10 Traffic and Transportation

3.1.10.1 Affected Environment

The Proposed Action area is subject to various boating activities and some public and private boat launch areas. No land vehicle use is associated with the Proposed Action, and, therefore, traffic and transportation discussions are limited to on-water transit by research vessels. The PNNL-Sequim campus has a dock located at the inlet to Sequim Bay. It is anticipated that Proposed Action activities will be deployed by research vessels or cooperating agency boats that would either launch from the PNNL-Sequim dock or launch from nearby marinas (typically John Wayne Marina).

3.1.10.2 Environmental Consequences

It is anticipated that the PDC, as described in the PBA, for the number of Proposed Action activities that could occur annually or concurrently would limit the number of vessel excursions and boat traffic in the Proposed Action area (DOE 2023). Given that recreational and commercial boat traffic is common in the area, the deployment of research vessels is not likely to be an observable increase or adverse impact on these waters. Additionally, as a condition of U.S. Army Corps of Engineers (USACE) permits, projects are inherently limited in impacting the public use of navigable waters of the U.S.

Small research vessels and the R/V Resilience may contain oils and hazardous substances. Spill kits will be onboard. In the unlikely event of an accidental discharge from a research vessel, it will be reported to Washington Department of Ecology to properly address the condition. Current guidance includes (1) stopping the spill and warning others in the area immediately, (2) shutting off any ignition sources, (3) containing the spill, and (4) reporting the spill immediately to the Washington Emergency Management Division and the National Response Center (Ecology 2024b).

The majority of research vessels are smaller vessels not designed for occupation. The R/V Resilience is a larger vessel and includes a sink and head. All vessels with sewage will be equipped with a Coast Guard-approved marine sanitation device. The discharge of untreated sewage to waters of the U.S. is prohibited unless it is three miles offshore and not in a No-Discharge Zone. As of 2018, Puget Sound is a No-Discharge Zone, and no discharge will occur within the Proposed Action area. Graywater from sinks will be disposed of upland, following pollution prevention measures and best management practices.

3.1.10.3 Cumulative Effects

The closest marina to the PNNL-Sequim campus is the John Wayne Marina, which can accommodate 302 vessels and has public access. Multiple recreational docks are present in Sequim Bay in addition to John Wayne Marina. Additionally, a public boat launch and six mooring buoys are present at Sequim Bay State Park. In the future, the currently unused public dock may be refurbished and placed back into use.

Recreational and commercial boat traffic is present in Sequim Bay and the Strait of Juan de Fuca. Traffic is highly dependent on various WDFW crabbing and fishing seasons, as well as Tribal seasons. John Wayne Marina can see approximately 40 and 120 boats on Saturdays and Sundays during crabbing and fishing seasons, respectively. Less boat traffic is present on weekdays. Commercial and recreational vessels can also be in transit to other areas within the Salish Sea to conduct fishing or harvesting activities. Cargo ships and whale watching vessels traveling in and out of Puget Sound are present in the Strait of Juan de Fuca, along with traffic stemming from multiple marinas, public and private boat launches, and docks.

PNNL research activities in the Proposed Action area would add minimal vessel traffic levels compared to the current baseline.

3.1.11 Human Health and Safety

3.1.11.1 Affected Environment

The total number of work-related injuries or illnesses that resulted in death, days away from work, job transfer or restriction, or other recordable cases are termed "total recordable cases." From 2018 to 2022, the total recordable cases of injuries and illnesses at PNNL averaged 0.87 cases per 100 full-time workers (DOE 2024c). The PNNL incidence rate is well below the Bureau of Labor Statistics rate for Washington State private industry of 2.7 cases per 100 full-time workers for the same period (BLS 2024).

Within the Proposed Action area, physical hazards from on-water and in-water deployments and operations are managed using Local Notices to Mariners, buoys, communications with John Wayne Marina, U.S. Coast Guard permitting, and USACE permitting.

3.1.11.2 Environmental Consequences

To help assure human health and safety, certain research activities under the Proposed Action will require safety lights and signals, as described by the U.S. Coast Guard. Researchers consider the impacts of fishing and crabbing seasons, avoiding heavily trafficked areas to the extent practicable. Research activities comply with all notification and permitting requirements, many of which have the purpose of assuring the health and safety of the public.

Over a 20-year period, many research projects may occur using the research activities described in the Proposed Action. These researchers would be a subset of the up to 135 staff anticipated to occupy the PNNL-Sequim campus over the next 20 years. However, conservatively assuming that all 135 staff participate in the research activities under the Proposed Action, if the current PNNL average incidence of 0.89 total recordable cases per year and workers work 250 days per year, approximately 1 injury per year could be expected within the working staff population at the PNNL-Sequim campus under the Proposed Action.

Staff at PNNL use activity risk controls such as training, adherence to work procedures, pre-job work briefings, approvals by health and safety professionals, and other relevant safety and disposal requirements. Because management practices and future research activities at the PNNL-Sequim campus would be similar in nature to current practices and activities, the potential impacts to human health and safety are expected to remain low.

3.1.11.3 Cumulative Effects

The activities described in Section 1.3.2 are expected to result in increasing utilization of Sequim Bay and the Strait of Juan de Fuca for recreational and commercial activities. Increasing utilization of these areas can increase the chances of public interaction with research activities that may result in human health or safety concerns. However, due to the utilization of best management practices, notifications, and other safety-related requirements, cumulative effects to public health and safety as a result of the Proposed Action are expected to be minimal.

3.1.12 Visual Resources

3.1.12.1 Affected Environment

Visual resources are the natural and manmade physical features that give a particular landscape its character. Visual resources include landforms, vegetation, water, color, adjacent scenery, scarcity, and manmade modifications. Evaluating the aesthetic qualities of an area is a subjective process because the value that an observer places on a specific feature varies depending on their perspective and judgment. DOE does not have a standardized approach to the characterization and management of visual resources, nor could DOE identify any formal visual resource study performed for the PNNL-Sequim campus location or Sequim Bay in general. A qualitative visual resource assessment was conducted to determine whether alterations associated with planned project activities would alter the visual environment. The baseline assessment was guided by the standardized approach developed by the U.S. Bureau of Land Management (BLM) in their Visual Resource Inventory Manual (BLM 1986).

The BLM approach identifies three mapping distance zones that qualitatively describe how landscapes are observed under good viewing conditions. The zones are as follows:

- Foreground-middleground zone: Areas seen from highways, rivers, or other viewing locations less than 4.8 to 8 km (3 to 5 mi) away. This is the point where the texture and form of individual plants are no longer apparent in the landscape.
- Background zone: Areas seen from beyond the foreground-middleground zone, but less than 24 km (15 mi) away. Vegetation in this zone is visible just as patterns of light and dark.
- Seldom-seen zone: Areas that are hidden from view or not distinguishable and more than 24 km (15 mi) away.

Classifications were derived from an inventory of scenic qualities, sensitivity levels, and distance zones for particular areas:

- Class I: Very limited management activity; natural ecological change.
- Class II: Management activities related to solitary small buildings and dirt roads may be seen but should not attract the attention of the casual observer.
- Class III: Management activities may attract attention but should not dominate the view of the casual observer; the natural landscape still dominates buildings, utility lines, and secondary roads.
- Class IV: Management activities related to clusters of two-story buildings, large industrial/office complexes, and primary roads, as well as limited clearing for utility lines or ground disturbances, may dominate the view and be the major focus of viewer attention.

Sequim Bay is visible by communities lining its shoreline, and some roadways that have a view of the watershed through breaks in vegetation. The viewshed of the Strait of Juan de Fuca has some shoreline visibility by those communities to the northeast and northwest of Sequim Bay, but much of the viewshed is distant by 1.6 km (1 mi) to over 8 km (5 mi). These water bodies are also visible to boating traffic entering and exiting the bay.

3.1.12.2 Environmental Consequences

Using the BLM approach, the shoreline areas of foreground-middleground to the west, east, and south of Sequim Bay and south of the Strait of Juan de Fuca are consistent with a Visual Resource Management Class III rating, and the further offshore areas are consistent with a Visual Resource Management Class I rating. The natural landscape dominates the view from all areas; however, some structures on the surface and their operations during the day and lights during the night would be noticed by the casual observer. Most visibility would occur from the marine navigation route entering and exiting the bay, or within the Proposed Action area. It is likely that the deployment and operation of research activities are not visible from the background zone or from the seldom-seen zone. For future research activities, viewers from key shoreline observation points would not be likely to detect any meaningful visual changes in Sequim Bay or the offshore areas designated in the Strait of Juan de Fuca. Continued periodic movements of equipment on the shoreline, marine transport activities, and night lighting of above water structures would not change noticeably. From key observation points, these future activities would not cause noticeable visual impacts from the current baseline.

3.1.12.3 Cumulative Effects

The anticipated visual resource impacts of the Proposed Action were evaluated in the context of the reasonably foreseeable future actions identified in Section 1.3.2. Taken together, those actions and the Proposed Action result in cumulative visual effects on the local area. However, as discussed above, the likely impacts of the Proposed Action would be minor in the context of the existing viewshed. The Proposed Action's contribution to cumulative visual resource impacts would be minimal.

3.1.13 Noise and Vibration

3.1.13.1 Affected Environment

This section assesses noise and vibration impacts to non-ecological resources. For aquatic and terrestrial resource impact assessment from noise and vibration, please see either Section 3.1.6 (Aquatic) or 3.1.7 (Terrestrial). Formal background noise analyses have not been performed for Sequim Bay or the nearby offshore waters; however, the background noise levels in these water resources are likely coming from vessel traffic. Noise levels at the adjacent PNNL-Sequim campus are typical of low population density areas, where most sound and vibration emanate from vehicular traffic and operation of heating and ventilation systems. Areas where noise may be elevated compared to background and areas where noise may be lower than background are listed below.

Recreational docks and boat launches can be found around the Proposed Action area; these areas can have increased noise due to higher concentrations of boat use. See Section 3.1.10 (Traffic and Transportation) for a description of these areas. Following the natural shoreline of Sequim Bay from east to west, a large portion of the east side is residential use, followed by commercial and Tribal use of southern Sequim Bay by the Jamestown S'Klallam. On the western side of Sequim Bay, Sequim Bay State Park, John Wayne Marina, and PNNL are present, interspersed between residential properties. North of PNNL, spanning the shoreline adjacent to the Strait of Juan de Fuca Research Area, uses include commercial farms and recreational county parks. Additionally, the western portion includes an area near the Dungeness National Wildlife Refuge. To the northeast of the Strait of Juan de Fuca Research Area is the Protection Island National Wildlife Refuge, which houses large, undisturbed nesting bird populations.

3.1.13.2 Environmental Consequences

The Washington State maximum permissible sustained environmental noise levels (WAC 173-60) limit daytime noise to 57 A-weighted decibels (dBA) for residential locations from a commercial source. Sounds originating from temporary construction activities are exempt from Washington State maximum permissible noise provisions from 7:00 a.m. to 10:00 p.m.; these exemptions would apply to installing research equipment, as described under the Proposed Action. It is unlikely that in-water deployment or installation activities would occur outside those hours. The only Proposed Action research activity likely to generate noise that could be heard by others would be vessel traffic. Washington State law limits vessel traffic noise levels and does not allow vessels that exceed 75 dBA to operate within state waters (RCW 79A.60.130). Research vessels associated with the Proposed Action would abide by state laws limiting noise emissions. The R/V Resilience has hybrid capabilities, and when operating with electric power, minimizes sound emissions when compared to traditional diesel engines.

3.1.13.3 Cumulative Effects

Taken together, reasonably foreseeable future actions as described in Section 1.3.2 and the Proposed Action would result in small cumulative noise impacts on the local area. The likely impacts of deployment and operations noise would be minor and kept within a limited area. The Proposed Action contribution to cumulative noise impacts would be minimal.

3.1.14 Waste Generation and Disposal

None of the Proposed Action activities will generate waste that would be disposed in the Proposed Action area. Any equipment maintenance or waste generated from vessel use will be disposed of according to federal, state, and local regulations, as described in the PNNL-Sequim waste management program discussed in DOE 2022.

3.1.15 Intentional Destructive Acts

3.1.15.1 Affected Environment and Consequences

Before 2001, DOE NEPA documents did not typically include an analysis of intentional destructive acts. After the events of September 11, 2001, DOE implemented measures to minimize the risk and consequences of potential intentional destructive acts on its facilities, which could include marine research infrastructure such as the PNNL-Sequim dock. Consistent with DOE guidance, DOE currently analyzes the potential impacts of intentional destructive acts in NEPA documents. DOE (2002) provided guidance for this analysis.

It is not possible to predict whether intentional destructive attacks would occur or the nature or types of such attacks. Nevertheless, DOE has evaluated security scenarios involving intentional destructive acts to assess potential vulnerabilities and identify improvements in security procedures and response measures. Security at its facilities is a critical priority for DOE. Therefore, DOE continues to identify and implement measures to defend and deter attacks at PNNL. DOE maintains a system of regulations, Orders, programs, guidance, and training that form the basis for maintaining, updating, and testing site security to preclude and mitigate any potential intentional destructive attacks.

The Proposed Action is not expected to increase the risk of an intentional destructive act. If an intentional destructive act were to occur, the consequences would likely be similar to an accident caused by natural disaster, equipment failure, or inadvertent worker actions. DOE has analyzed accidents such as earthquakes, fires, and airplane crashes, which could cause a release of materials or destruction of materials like an intentional destructive act. If an intentional destructive act were to occur, the resulting consequences to workers and the public would be like those occurring from natural or human-caused events.

3.1.15.2 Cumulative Effects

Intentional destructive acts may target other facilities or areas within or near the Proposed Action area, including the PNNL-Sequim campus. Intentional destructive acts targeting the PNNL-Sequim campus could cause a release of chemical or radioactive materials from facilities to the environment, but radiological inventories in new PNNL-Sequim campus buildings would be less than Hazard Category 3, and a release, if one occurred, would not result in adverse impacts off the PNNL-Sequim campus (DOE 2022). If an intentional destructive act were to occur, the resulting consequences to workers and the public would be similar to those occurring from natural or human-caused events. The Proposed Action would not increase the likelihood of an intentional destructive act or the resulting consequences.

3.2 Irreversible and Irretrievable Commitment of Resources

Deployment of research activities would require an irreversible and irretrievable commitment of resources such as diesel fuel for vessels. The amount would depend on the number of projects over specific time durations. This resource is not unique or regionally in short supply, and DOE use of this resource would not result in any shortage or impact on other regional users.

The proposed research activities are not anticipated to irreversibly or irretrievably affect other natural resources except through possible sampling of sediments or eelgrass as described in Section 3.1.6.2. Sampling would result in a loss of the resource in the immediate area but bounds on sample size in the PBA will prevent net loss of habitat. The future actions described in Section 1.3.2 combined with the Proposed Action would result in negligible cumulative-resource impacts on the local area. The timing of the Proposed Action likely would occur episodically over the 20-year span, such that the likelihood of "peak" demand for resources is not anticipated to be an issue. The impacts from the Proposed Action to resources in the region would be relatively minor in the context of total future development in the area.

3.3 Environmental Impacts of the No-Action Alternative

Under the No-Action Alternative, DOE would continue to perform the previously authorized scope of research activities in Sequim Bay and the Strait of Juan de Fuca until existing authorizations expire in the winter of 2025 (USFWS 2023; USACE 2023). After the expiration of authorizations, DOE would no longer be able to perform research activities in Sequim Bay and in the Strait of Juan de Fuca with the potential to affect ESA-listed resources and EFH. Without the expansion of authorized research, as described in the Proposed Action, DOE would be unable to meet future mission needs. Activities with no effect to ESA-listed resources and EFH could continue, but these activities are limited in scope and scale and would not be able to support anticipated future DOE research missions. Impacts of the No-Action Alternative, in all the resource areas described above for the Proposed Action, are, therefore, expected to be less than or similar to those associated with current research activities, which have no potential for significant impacts to the environment.

GHG emissions under the No-Action Alternative would result from marine vessel use and are anticipated to have no change when compared to current emission levels. Total annual CO_2e emissions under the No-Action Alternative are estimated to be 62.8 CO_2e. This annual amount of GHG emissions is equivalent to emissions from one gasoline-powered passenger vehicle driven 161,000 total miles (EPA 2024a). Considering total emissions resulting from vessel use associated with the No-Action Alternative, over a 20-year period from 2025 to 2045, the No-Action Alternative is calculated to result in a total social cost of greenhouse gases equal to $300,000 (in 2023 dollars), using the 2.0 percent discount rate.

3.3.1 Adverse Impacts

PNNL-Sequim is the only DOE national laboratory providing marine research capabilities to help meet mission needs. Under the No-Action Alternative, PNNL-Sequim campus' marine research capabilities to support the nation's strategic goals in marine science, national security, energy, and the environment for DOE and other federal sponsors over the next 20 years would be substantially reduced. This could result in questions about the impacts of marine energy development going unanswered, and delays in development of renewable energy devices. Declines in research capabilities could lead to losses in new employment opportunities.

3.3.2 Beneficial Impacts

The aquatic resources in Sequim Bay and nearby waters of the Strait of Juan de Fuca would be undisturbed from future research activities with potential to affect ecological resources. Less marine research would occur in Sequim Bay, resulting in decreased vessel use compared to the Proposed Action and a correlated reduction of greenhouse gas emissions. GHG emissions under the No-Action Alternative are estimated to be 69 percent of the emissions expected under the Proposed Action over a 20-year time frame.

3.4 Comparison of Impacts of the Proposed and No-Action Alternatives

Table 3.10 provides a summary of the potential impacts of the Proposed Action and No-Action Alternatives. More detailed discussion of each impact area is provided in the preceding sections.

Table 3.10. Potential Environmental Impacts Associated with Proposed Action and the No-Action Alternative.

Impact Area	Proposed Action	No-Action Alternative
Land Use	No Change	No Change
Air Quality	Minimal increase in greenhouse gas emissions from vessel use.	No Change
Soil and Geological Resources	Land and soil disturbance is limited to shoreline areas and will be temporary, with land returned to original conditions.	No Change
Water Resources	Most activities will have no impact. Best management practices will minimize effects on water quality and assure compliance with Washington State turbidity and mixing zone criteria. Marine energy devices and tidal turbines are expected to have a small impact on water flows.	No Change
Cultural and Historic Resources	No Change	No Change
Aquatic Ecology Resources	During deployment, research activities can cause minor, temporary behavior changes for aquatic species such as avoidance or foraging disruption. Research activities can lead to loss of aquatic habitat for varying amounts of time, but large or systemic loss of habitat is not expected. Acoustic devices, non-eye-safe lasers, marine energy devices, and tidal turbines have the potential to have adverse effects to aquatic resources during operation. DOE has developed measures to avoid or minimize impacts from research activities to aquatic ESA-listed species and habitats, and essential fish habitat. These measures will reduce impacts to fish, birds, mammals, and habitat, reducing the adverse effects of the Proposed Action to both protected and nonprotected resources. Mitigation will be required of certain activities to assure no net-loss of habitat quality.	No Change
Terrestrial Ecology Resources	Research activities can cause minor, temporary behavior changes to terrestrial species that utilize aquatic environments. Acoustic devices, non-eye-safe lasers, marine energy devices, and tidal turbines have the potential to have adverse effects on terrestrial resources during operation. DOE has developed measures to avoid and minimize impacts to protected terrestrial species. These measures will extend to nonprotected species, reducing the adverse effects of the Proposed	No Change

	Action. Impacts to tidal land areas are anticipated to be minimal and temporary, with land returned to original conditions.	
Socioeconomics	No Change	No Change
Environmental Justice	No Change	No Change
Traffic and Transportation	Small increase in vessel traffic due to research activities.	No Change
Human Health and Safety	Negligible changes in estimated injuries per year.	No Change
Visual Resources	Research activities would not likely cause meaningful visual changes.	No Change
Noise and Vibration	Research vessels may temporarily cause noise while performing research or traveling. Noise impacts to ecological resources are evaluated in the aquatic and terrestrial ecology sections.	No Change
Waste Generation and Disposal	No Change	No Change
Intentional Destructive Acts	No Change	No Change
Irreversible and Irretrievable Commitment of Resources	Research vessels would consume diesel or other fuel. Sampling of sediments and eelgrass could occur episodically with controls.	No Change

4.0 ENVIRONMENTAL PERMITS AND REGULATORY REQUIREMENTS

PNNL is required to carry out operations in compliance with all federal, state, and local laws and regulations; Presidential Executive Orders; DOE Orders; and procedures (DOE/PNSO 2024). Environmental regulatory authority over DOE is vested in federal, state, and local agencies. Federal, state, and local laws apply to research activities. The environmental regulatory framework includes requirements regarding access, use, and environmental protection. It is anticipated that the following environmental permits, consultations, or other regulatory compliance would be required for future marine research activities adjacent to the PNNL-Sequim campus. The anticipated required permits are identified by issuing agency in the discussion below. If additional permitting needs are identified, appropriate permits will be acquired before research activities begin.

- **Clallam County Department of Community Development (CCDCD).** The CCDCD regulates compliance with the *Washington State Shoreline Management Act* in partnership with Ecology (RCW 90.58). PNNL currently maintains a Shoreline Substantial Development Permit Exemption for research activities (SHR 2023-00016; expires 1/16/2029) that will require a modification or a new permit to cover the Proposed Action.
- **Washington State Department of Ecology (Ecology).** Ecology regulates compliance with the *Coastal Zone Management Act of 1972* (16 USC § 1451 et seq.) through the Washington State Coastal Zone Management Program for projects that take place within Washington's coastal zone. PNNL currently maintains a consistency determination for research activities (WDE-NWS-2015-1063 [Ecology 2016]; expires 2/28/2025). If USACE determines the Proposed Action is eligible for a permit type with a coastal zone management consistency concurrence, no new consistency determination would be required by Ecology. A new consistency determination will be required if an individual permit is pursued.
- **Washington State Department of Fish and Wildlife (WDFW)**. WDFW regulates compliance with *Construction Projects in State Waters* (RCW 77.55), requiring projects in and near state waters to get a Hydraulic Project Approval (HPA) to protect sensitive resources. PNNL currently maintains an HPA permit for research activities (2021-6-36+02 [WDFW 2021]; expires 1/18/2026) that may require changes to cover the Proposed Action.
- **Washington State Department of Natural Resources (WDNR).** WDNR regulates access rights for state-owned aquatic lands to allow for activities that do not interfere with the use of the land. PNNL currently maintains an Aquatic Lands Right of Entry license for research activities in Sequim Bay and the Strait of Juan de Fuca (23-106407 [WDNR 2024b]; expires 2/28/2029). A new license will be required to cover the Proposed Action. Some proposed activities may require an easement with WDNR.
- **U.S. Army Corps of Engineers (USACE).** USACE regulates compliance with laws such as Section 10 of the *Rivers and Harbors Act of 1899* (33 U.S.C. § 401 et seq.) and Section 404 of the *Clean Water Act* (33 U.S.C. § 1251 et seq.). USACE jurisdiction is within waters of the United States, including tidal and non-tidal waters and territorial seas, and requires authorization for the construction of any structure in or over these areas or any discharge of fill material into these areas. PNNL currently maintains a USACE Individual Permit for research activities (NWS-2015-1063 [USACE 2016]; expires 2/28/2025). A new USACE permit will be required to cover the Proposed Action.
- **Protection of Plant and Animal Species**. Federal agencies must preserve and protect plant and animal species and their critical habitats to the extent feasible given the agency's mission. The ESA (16 U.S.C. § 1531 et seq.), *Bald and Golden Eagle Protection Act* (16 U.S.C. § 668-668d et seq.), and *Migratory Bird Treaty Act* (16 U.S.C. § 703 et seq.) all identify requirements that must be met to

protect native plant and animal species and the ecosystems upon which they depend. The Proposed Action is covered under an ESA consultation with NMFS (2024) and USFWS (2024).

- **Cultural and Historic Resource Protection**. Federal agencies must preserve and protect cultural resources in a spirit of stewardship to the extent feasible given the agency's mission. DOE responsibilities are defined by several regulations and policies, including the *NHPA* (54 U.S.C. § 300101 et seq.), the *Archaeological Resources Protection Act of 1979* (16 U.S.C. § 470aa et seq.), the *Native American Graves Protection and Repatriation Act* (25 U.S.C. § 3001 et seq.), and the *DOE American Indian Tribal Government Interactions and Policy* (DOE 2009). DOE has consulted with the Washington State Historic Preservation Officer and local Tribes on the Proposed Action.

5.0 PUBLIC, AGENCIES, AND TRIBAL GOVERNMENT NOTIFICATIONS

5.1 Public Notice of Intent

On August 13, 2024, DOE sent notifications of its intention to prepare this EA to interested parties on its stakeholder list, and the recipients were invited to send their questions or comments regarding the EA to DOE for consideration. The notification briefly identified an anticipated time frame for the draft EA and a point of contact for questions and comment submittal.

NEPA distribution list:

- Kate Dexter, City of Port Angeles
- Nathan West, City of Port Angeles
- Brandon Janisse, City of Sequim
- Matthew Huish, City of Sequim
- Kathy Downer, City of Sequim
- Dan Butler, City of Sequim
- Vicki Lowe, City of Sequim
- Rachel Anderson, City of Sequim
- Harmony Rutter, City of Sequim
- Nicole Hartman, City of Sequim
- Christy Cox, Clallam Conservation District
- Randy Johnson, Clallam County
- Mark Ozias, Clallam County
- Mike French, Clallam County
- Todd Mielke, Clallam County
- Bruce Emery, Clallam County
- Rebecca Mahan, Clallam County Marine Resources Committee
- Suzy Ames, Clallam Economic Development Council
- Colleen McAleer, Clallam Economic Development Council
- Jonathan W. Smith, Sr., Confederated Tribes of the Warm Springs Reservation of Oregon
- Allison O'Brien, Department of Interior
- Ellie Ausmuss, Friends of Dungeness National Wildlife Refuge
- Darlene Hollum, Hoh Tribe
- William Ron Allen, Jamestown S'Klallam Tribe
- Kate Dean, Jefferson County
- Heidi Eisenhour, Jefferson County

- Greg Brotherton, Jefferson County
- Mark McCauley, Jefferson County
- Josh Peters, Jefferson County
- Joe Holtrop, Jefferson County Conservation District
- Jansen Tidmore, Jefferson County Economic Development Corporation
- Linda Benson, League of Women Voters of Clallam County
- Francis Charles, Lower Elwha Klallam Tribe
- Anthony Hillaire, Lummi Nation Tribe
- Timothy J. Greene, Sr., Makah Tribe
- NOAA NEPA Inbox, National Oceanic and Atmospheric Administration
- Katherine Renshaw, National Oceanic and Atmospheric Administration
- David Brownell, North Olympic History Center
- President, Olympic Peninsula Audubon Society
- Jeff Johnston, Olympic Region Clean Air Agency
- Amber Caldera, Port Gamble S'Klallam Tribe
- Connie Beauvais, Port of Port Angeles
- Steven Burke, Port of Port Angeles
- Doug Woodruff, Quileute Tribe
- Eran Kennedy, Sequim Chamber of Commerce
- Beth Pratt, Sequim Chamber of Commerce
- Leonard Forsman, Suquamish Tribe
- Pam Sanguinetti, U.S. Army Corps of Engineers
- John Robertson, U.S. Coast Guard
- Casey Sixkiller, U.S. Environmental Protection Agency
- Rebecca Chu, U.S. Environmental Protection Agency
- Karen Burgess, U.S. Environmental Protection Agency
- Andrew Baca, U.S. Environmental Protection Agency
- Krishna Viswanathan, U.S. Environmental Protection Agency
- Jennifer Brown-Scott, U.S. Fish and Wildlife Service
- Derek Kilmer, U.S. Representative
- Heather Hall, Washington Department of Fish and Wildlife
- Danielle Zitomer, Washington Department of Fish and Wildlife
- Jill Wood, Washington Department of Health

- Laura Watson, Washington State Department of Ecology
- Vince McGowan, Washington State Department of Ecology
- Fran Sant, Washington State Department of Ecology
- Joe Thomas, Washington State Department of Ecology
- SEPA Mailbox, Washington State Department of Ecology
- Olympic Region Mailbox, Washington State Department of Natural Resources
- Birdie Davenport, Washington State Department of Natural Resources
- Chris Chappell, Washington State Department of Natural Resources
- Allyson Brooks, Washington State Historic Preservation Officer
- Steve Tharinger, Washington State Legislature
- Kevin Van De Wege, Washington State Legislature
- Lauren Bromley, Washington State Parks and Recreation Commission
- Mike Chapman, Washington State Representative
- Maria Cantwell, Washington State Senate
- Patty Murray, Washington State Senate

This sentence is a placeholder and will summarize the comments and responses received as a result of the notification to the distribution list identified above.

5.2 Draft Environmental Assessment Public Review

This section is a placeholder and will summarize the comments on the Draft EA and the public meetings.

6.0 REFERENCES

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10 CFR Part 1022. *Code of Federal Regulations*, Title 10, *Energy*, Part 1022, “Compliance with Floodplain and Wetland Environmental Review Requirements.”

36 CFR Part 60. *Code of Federal Regulations*, Title 36, *Parks, Forestry, and Public Property*, Part 60, “National Register of Historic Places.”

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APPENDIX A

PROGRAMMATIC BIOLOGICAL ASSESSMENT (PBA)

Pacific Northwest
NATIONAL LABORATORY

Programmatic Biological Assessment/Essential Fish Habitat Assessment

Marine Research and Equipment Testing at Pacific Northwest National Laboratory - Sequim

August 2023

JM Becker
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U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Programmatic Biological Assessment/Essential Fish Habitat Assessment

Marine Research and Equipment Testing at Pacific Northwest National Laboratory - Sequim

August 2023

Prepared for:
National Marine Fisheries Service
Oregon and Washington Coastal Office
Lacey, Washington

And

U.S. Fish and Wildlife Service
Western Washington Fish and Wildlife Conservation Office
Lacey, Washington

Prepared on behalf of
the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Richland, Washington 99354

Acronyms and Abbreviations

AC	Alternating Current
ADCP	Acoustic Doppler Current Profiler
ASV	Autonomous Surface Vehicles
AUV	Autonomous Underwater Vehicle
BOSS	Buried Object Scanning Sonar
CPS	Coastal Pelagic Species
DOE	U.S. Department of Energy
DPS	Distinct Population Segment
DVL	Doppler Velocity Log
EFH	Essential Fish Habitat
EIA	Effect Isopleth Arcs
EMF	Electromagnetic Field
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
FMP	Fisheries Management Plan
GPS	Global Positioning Satellite
HAPC	Habitat Areas of Potential Concern
LiDAR	Light Detection and Ranging
MHHW	Mean Higher High-Water
MLLW	Mean Lower Low Water
MMO	Marine Mammal Observer
MPE	Maximum Permissible Exposure
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOHD	Nominal Ocular Hazard Distance
PBA	Programmatic Biological Assessment
PDC	Project Design Criteria
PFFP	Portable Free Fall Penetrometers
PNNL	Pacific Northwest National Laboratory
PNSO	Pacific Northwest Site Office
PSO	Protected Species Observer
PTS	Permanent Threshold Shift
RMS	Root Mean Square
SEL	Sound Exposure Level
SPL	Sound Pressure Level
UAV	Unmanned Aerial Vehicle

UAS	Unmanned Aerial System
UMSLI	Unobtrusive Multi-static Serial LiDAR Imager
USCG	U.S. Coast Guard
WDFW	Washington Department of Fish and Wildlife
WDNR	Washington Department of Natural Resources
WT	Water Tracing

Contents

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1.0 Introduction

1.1 Background

The Pacific Northwest National Laboratory (PNNL) – Sequim, historically known as the Marine Sciences Laboratory (MSL) in Sequim, Washington, is managed and operated by Battelle on behalf of the U.S. Department of Energy (DOE) Pacific Northwest Site Office (PNSO). The site provides capabilities for future energy research, climate change effects analyses, wetland and coastal ecosystem restoration, and other environmental research involving marine resources. In-water research projects at specific locations in and near Clallam, Sequim and Dungeness Bays, Washington, have supported DOE research and development needs aimed at national goals focused on sustainable energy and environments. Past research projects conducted by PNNL-Sequim staff have complied with Section 7 of the Endangered Species Act (ESA) and Section 305(b)(2) of the Magnuson-Stevens Fisheries Conservation and Management Act (MSA).

1.2 Consultation History

Research projects with specific activities in Sequim Bay are currently covered under National Marine Fisheries Service (NMFS) WCR- 2015-3761, and U.S. Fish and Wildlife Service (FWS) OlEWFW00-2016-1-0176, including supplements. DOE PNSO also had two previous consultations with NMFS and FWS, collectively known as "the Services" for activities near Dungeness Spit, under WCR-2014-1354 and OlEWFW00-2014-1-0672 (placement of a Light Detection and Ranging [LiDAR]) buoy); OlEWFW00-2018-1-0911 and WCR-2018-8853 (Benthic Habitat Mapping). Additionally, similar work is taking place in Clallam Bay under WCR-2018-10566 and 01EWFW00-2018-I-1605.

This Programmatic biological and essential fish habitat assessment (PBA) addresses these previously consulted activities, expands project activities that could occur in larger identified aquatic environments, and assesses effects to ESA-listed marine species, designated critical habitats, marine mammals, and essential fish habitats that are known to occur in these areas. This Programmatic document will identify the potential for specific activities to adversely affect protected species and habitats and will define a roadmap for working with project design criteria to streamline consultation as required by Section 7 of the ESA and Section 305(b)(2) of the MSA.

1.3 Proposed Action

DOE PNSO, through PNNL, proposes to perform research activities 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 (Figure 1.1). The research areas are described in more detail in Section 1.4. 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. These research activities are described in detail in Chapter 2.

Figure 1.1. Geographic Project Areas include Sequim Bay and Strait of Juan de Fuca from Sequim Bay North to Dungeness Spit and East to Protection Island.

1.4 Geographic Description of Aquatic Resources

Activities will take place in: Sequim Bay, the Strait of Juan de Fuca, Battelle/DOE owned Sequim parcels and the Tidal Marsh Area.

1.4.1 Sequim Bay Research Area

Sequim Bay is a 2,024 hectare (ha) salt-water body connected to the Strait of Juan de Fuca by a relatively narrow channel (200 meters (m) wide at mean lower low water [MLLW])) between Travis Spit and the PNNL Sequim Campus pier and floating dock (Figure 1.2). The tidal exchange 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. The bay has a maximum depth of approximately 30.4 m at MLLW. The bay is bordered by residential properties, PNNL-Sequim and includes a small boat marina (John Wayne Marina). Recreational and commercial vessel traffic is common throughout the potential project area. 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. 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 area proposed for PNNL research includes all of Sequim Bay from the connection to the Strait of Juan de Fuca to the approximate 2 m depth (MLLW) to the south (Figure 1.2), waterward of the MLLW except for Battelle or DOE-owned land and tidelands (Figure 1.3). Research activities will also use Battelle or DOE-owned land adjacent to the shoreline and tidelands (e.g., marsh, wetlands) for research purposes described in Section 2 (e.g., Crawlers) (Figure 1.3).

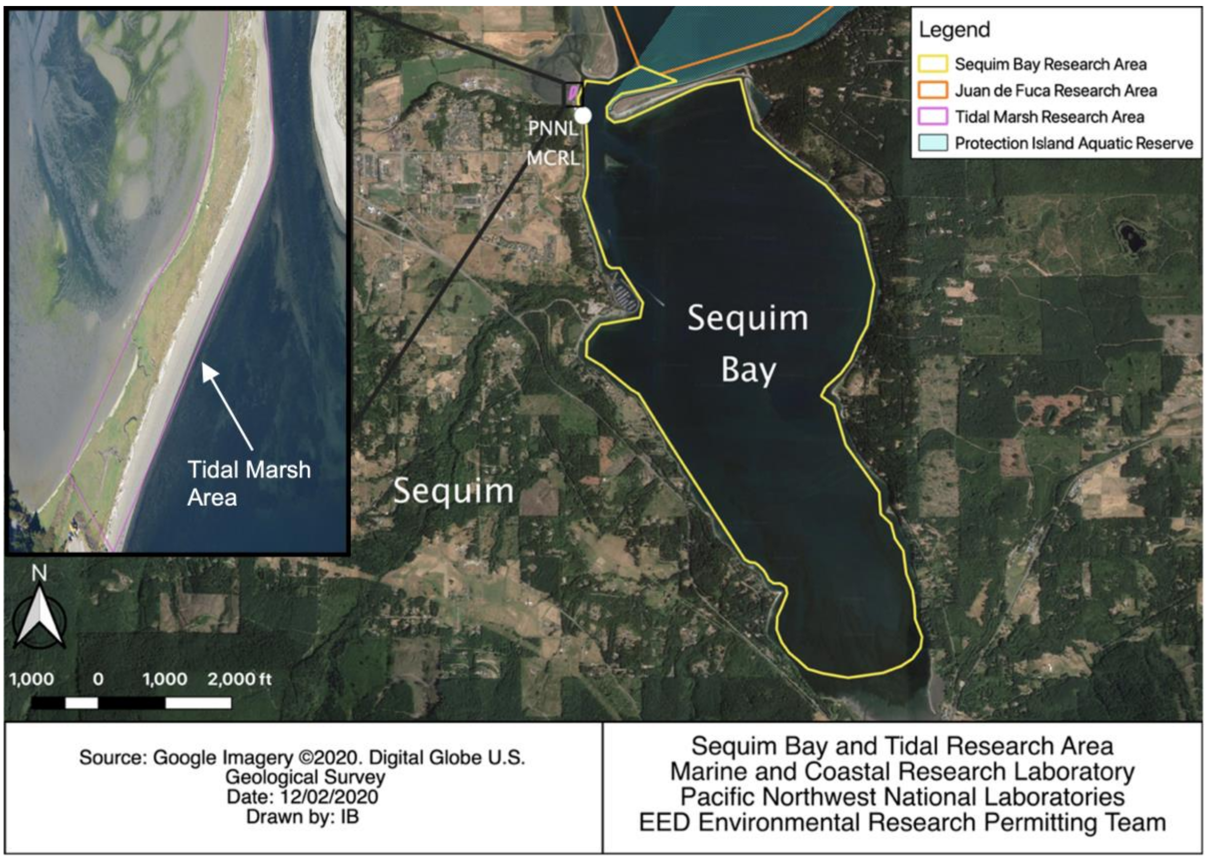

Figure 1.2. Sequim Bay Research Area and Tidal Marsh Area

Figure 1.3. PNNL-Sequim Tidelands and Marsh included in the Sequim Bay Research Area

1.4.2 Sequim Bay Research Area – Tidal Marsh Area

The Tidal Marsh Area (Figure 1.3 and Figure 1.4) within the Sequim Bay Research Area consists of areas below and above MHW along Bugge Spit. 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*).

Figure 1.4. Approximate boundary of the Tidal Marsh area along Bugge Spit using Ecology 2016 Shoreline Photographs. The full area extent is the Battelle/DOE owned parcels.

1.4.3 Juan de Fuca Research Area

The proposed Juan de Fuca research area is a semi-triangular area as shown in Figure 1.5. 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 (Figure 1.5), comprising a total area of approximately 7250 Ha. Water depth within this area is mostly 10 to 50 m, reaching to >70 m 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).

There are USFWS-managed national wildlife refuges at both Dungeness Spit and Protection Island. 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 (Figure 1.5). 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.

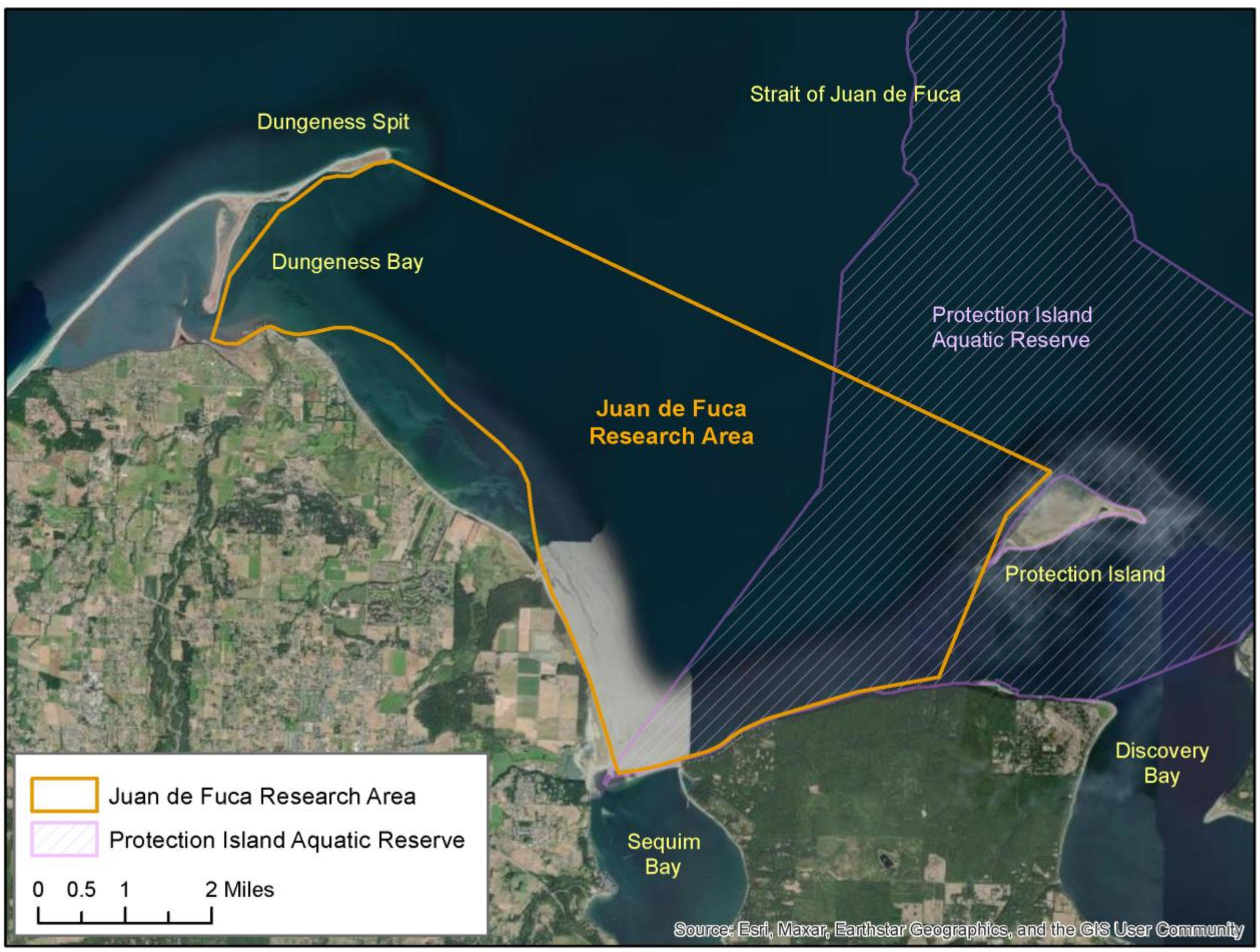

Figure 1.5. Juan de Fuca Research Area and boundaries of the Protection Island Aquatic Reserve

2.0 Description of Research Activities and Project Design Criteria

Various activity types (generally described in Section 1.3) and Project Design Criteria (PDC) of the proposed research activities are individually highlighted in the following sections. PDC are set requirements which bound activity types, with the PNNL process being described in Section 6. 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 related to those activity types will be met, including verification or notification requirements. Any activities outside of existing PDCs will require individual consultation or future modification of this PBA. Modifications may also occur on an annual basis when DOE PNSO and the Services discuss this programmatic document and potential revisions, including the review of monitoring results and modifications to monitoring and/or activities. A thorough description of these procedures adopted internally by PNNL are detailed in Section 6.

Additionally, all activities described in Chapter 2.0 will be subject to the following overarching PDC:

1. All devices and associated structures will be removed at the project end.
2. No significant alteration of the shoreline will occur for 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 (Sections 4.9 and 4.3).
4. Anchor 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 treated with non-toxic protection such as ammoniacal copper zinc arsenate).
7. Any activities in contact with the seabed surface will move sunflower sea stars by hand if encountered in the area of disturbance (if they do not move freely [Section 3.1.10]) beyond the area, to the maximum extent practicable. Note: PDC was created in anticipation of potential ESA listing of the sunflower sea star.
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, avoidance], mortalities), the project must notify PNNL Biological Resources SME who will then notify the Services.
10. PNNL will submit a notification or verification email to the Services as stated below for all activities.

Once PNNL, on behalf of DOE, has determined that the project meets all activity-type-specific and overarching PDC above, PNNL will proceed with either a notification or verification email (Appendix A) to the Services (Section 6). Notifications require PNNL to inform the Services of an activity, prior to its start, via email to PNNL-wa.wcr@noaa.gov and USFWS. Notifications do not require a response from the Services. Verification requests will be sent via email by PNNL to the Services with the intent of gaining concurrence that PNNL is applying all appropriate PDC. Timeframes and responsibilities for these functions are further outlined in Section 6. Multiple reasons drive the verification request process, including the need to review of PDC adoption over an extended period of time or impacts of novel activities. As stated explicitly in the below PDC, specific activities requiring verification may also be subject to compensatory mitigation. Those activities being in Sections 2.1, 2.3.1, 2.13 and 2.14. All other activities will not be subject to mitigation.

2.1 Floating Platforms and 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 8 square feet (sq ft), the maximum dimensions of buoys evaluated under this PBA are 100 sq ft to account for the potential deployment of larger oceanographic buoys. Buoys larger than 100 sq ft will be evaluated as platforms. Community/research scale marine energy devices (Section 2.13) 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.

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 sq ft. Areas above the floats, accounting for up to 50% of the total surface can be solid (e.g., metal or wood sheets/planks), whereas the remaining walkable, 50% semi-solid (grated) areas include materials with at least 60% open space to allow for light penetration to the water column. Solid platforms are in-water structures (e.g., photovoltaic panels, buoys over 100 sq ft), no larger than 400 sq ft with floats (e.g., encapsulated foam) providing buoyancy which shade 100% 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 1 day to 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.

Project Design Criteria 2.1

The following PDC apply to all the activities described within Section 2.1, along with overarching PDC within Section 2.0:

- 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% grated and all grating must have a minimum of 60% 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).
- Structure designs that involve non-biofouling light-penetrating materials would be preferred.

- 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.
- Platforms would be constructed of corrosion resistant, non-toxic materials such as encapsulated polyethylene foam, aluminum, fiberglass, or wood treated with non-toxic protection such as ammoniacal copper zinc arsenate.
- Floating platforms and buoys would be anchored using diver-installed helical anchors (preferred), concrete or corrosion resistant metal anchors.
- 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.
- A minimum distance of 10 ft will be maintained between floating platforms and buoys, with a maximum of 15 buoys, 5 grated platforms and 3 solid platforms being deployed at one time across the entire action area (comprising Sequim Bay [Figure 1.2] and the portion of the Strait of Juan de Fuca depicted in Figure 1.5).
- Infrastructure to support or suspend equipment may be needed in the form of buoys and floating platforms, with an average of 0 – 7 and maximum of 25 deployments per year.
- Verification for any activities deployed between February 16 and July 15 for 60 days or more would require compensatory mitigation using the modified PNNL Puget Sound Nearshore 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 2.1.1. Buoy and platform types and deployment timeframes relative to requirements.

Duration	Buoy (max 100sq ft [3m diameter])	Grated Platform (max 400 sq ft [20ft x 20ft])	Solid (Non-Grated) Platform (max 400sq ft [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[1]	Verification and Mitigation	Verification and Mitigation	Verification and Mitigation

[1] "outside work window" includes deployments from Feb 16 to July 15.

2.2 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.

Project Design Criteria 2.2

The following PDC apply to all the activities described within Section 2.2, along with overarching PDC within Section 2:

- Installations are limited to PNNL-Sequim pier, ramp or float (i.e., floating dock) locations that would extend into the water column.
- Instruments will be installed by hand and would not disturb the benthos.
- The maximum surface area per device would be 6 sq ft with a range of 0-20 deployments per year and maximum of 40 deployments per year, with no more than 20 being deployed at any given time.
- The maximum dimensions of 6 sq ft per instrument will inherently limit fully solid surfaces and would be limited to sensor supporting structures (i.e., cage to hold multiple sensors).

All deployments will be notification only.

Table 2.2.1. Sequim dock installation deployment timeframes relative to requirements.

Duration	Dock Installations
1-14 Days	Notification
15-45 Days	Notification
Greater than 45 Days	Notification
Greater than 60 Days, and Outside Work Window	Notification

2.3 Seabed Installations

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.

2.3.1 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 (days to years). The maximum footprint of such devices would be approximately 50 sq ft, excluding associated cabling size.

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.

Project Design Criteria 2.3.1

The following PDC apply to all the activities described within Section 2.3.1, along with overarching PDC within Section 2.0:

- 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.
- Seabed installations for purposes of "Seagrass Macroalgae and Intertidal Research" will be allowed by following relevant Section 2.3.1, Section 2.9 and overarching PDC.
- The deployments will be temporary for the duration of the project.
- Various scientific equipment and prototypes would be installed in the Sequim Bay and Juan de Fuca research areas, with a range of 0-15 deployed per year, a maximum of 35 per year, and no more than 15 deployed at any given time across both areas.
- Seabed installation structures will not exceed 50 sq ft, excluding cabling.
- Verification for any activities deployed between February 16 and July 15 for 60 days or more would require compensatory mitigation using the modified PNNL Puget Sound Nearshore 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 2.3.1.1. Deployment timeframes for seabed installation of sensors and equipment, relative to requirements.

Duration	Seabed installations
1-14 Days	Notification
15-45 Days	Verification
Greater than 45 Days	Verification
Greater than 60 Days, and Outside Work Window[1]	Verification And Mitigation

[1] "outside work window" includes deployments from Feb 16 to July 15.

2.3.2 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.

Project Design Criteria 2.3.2

The following PDC apply to all the activities described within Section 2.3.2, along with overarching PDC within Section 2.0:

- Burial within the substrate would be performed by divers using hand tools or with the aid of a water jet.
- Probes, markers, and/or targets will be spaced at least 1.5 ft apart.
- A yearly range would be 0 - 80 deployments, with a maximum of 150 being deployed at any given time.
- No probes, markers or targets will be in place for more than 2 years.

Verification by the Services is required for all deployment durations regardless of the number of probes, markers, and/or targets (Table 2.3.2.1).

Table 2.3.2.1. Deployment timeframes for seabed installation of subsurface probes, markers, and targets relative to requirements.

Duration	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

2.4 Vessel Use

Research vessels, in conjunction with additional PBA activities, 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. Routine vessel activities are inherently exempt from the PBA as the action is “No Effect”.

Project Design Criteria 2.4

The following PDC apply to all the activities described within Section 2.4, along with overarching PDC within Section 2.0:

- Vessels would be operated according to maritime regulations using standard safety and environmental practices, would follow ESA/MMPA harassment/approach regulations, and would maintain spill prevention plans.
- There are no limitations on numbers of vessels or trips.

Table 2.4.1. Vessel Use deployment timeframes relative to requirements.

Duration	Vessel Use
1-14 Days	Notification
15-45 Days	Notification
Greater than 45 Days	Notification
Greater than 60 Days, and Outside Work Window	Notification

2.5 Autonomous Vehicle Surveys

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 (Section 2.5). 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.

Unmanned aerial systems (UAS) are systems where 3 components are combined for flight: a person with or without an automatic/autonomous algorithm control, communication and 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.

Project Design Criteria 2.5

The following PDC apply to all the activities described within Section 2.5, along with overarching PDC within Section 2.0:

- ASVs will include standard automatic identification systems.
- A range of 0-10 AUVs/SAVs with a maximum of 30 could be deployed within a given year, with a maximum of 10 being deployed at any given time.
- Systems will be under observation during daily deployments.
- Marine grade or appropriately encased drones will be used.
- A range of 0-60 UAS with a maximum of 150 deployments will occur within a given year, with a maximum of 10 being deployed at any given time.

- All PNNL projects are bound by FAA regulations. All pilots will hold or obtain a pilot's license before operating a drone, as per FAA regulations.
- 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.
- 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.
- NMFS guidance for marine areas to avoid flying drones near marine wildlife will be followed (NMFS 2023).
- Flights within 200 yds from Protection Island and the boundary drawn around Dungeness Spit in Figure 1.2 are not allowed (PNNL 2023).

Table 2.5.1. Autonomous Aquatic Vehicle (AUVs, ASVs and UAS) deployment timeframes relative to requirements.

Duration	Autonomous Aquatic Vehicles (AUVs, ASVs and UAS)
Not Applicable	Notification

2.6 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 one-time 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, invertebrates, fish, and marine mammals.

2.6.1 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. The longest bore coring device would be a gravity corer with a sample size of 3 m long with a 10 cm diameter. 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.

Project Design Criteria 2.6.1

The following PDC apply to all the activities described within Section 2.6.1, along with overarching PDC within Section 2.0:

- A typical range of 0-12 surveys requiring sediment collection could take place within a year, with an annual maximum of no more than 30 surveys.
- Sediment samples would be spaced at least 27 yds apart, or 10 yds apart if devices are limited to 1 sq ft or less of surface sediment disturbance.
- A maximum volumetric limit of 1 yd^3 per survey and 30 yd^3 per year across both sites (whole action area).

- Sediment sampling surveys are typically of short duration (< 7 days); thus, notification or verification are not duration dependent.

Sediment Collection Surveys are notification only.

Table 2.6.1.1. Sediment collection surveys relative to requirements.

Duration	Sediment Collection Surveys
Not Applicable	Notification

2.6.2 Benthic Characterization Surveys (No Sediment Sampling)

A variety of benthic characterization may be conducted through different means, 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 Section 2.6.2 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 ~15 cm below the sediment surface and has a surface area of ~500 cm2.

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.

Seabed characterization could also be performed using fully autonomous amphibious bottom crawlers such as the Otter or SeaOx Surf Zone Crawlers (Figure 2.1). These crawlers can operate to depths of 100m 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.

Figure 2.1. C-2 Innovations SeaOx with Tow Sled

Project Design Criteria 2.6.2

The following PDC apply to all the activities described within Section 2.6.2, along with overarching PDC in Section 2.0:

- Non-intrusive benthic characterization surveys equipment (e.g., benthic crawlers) would be spaced at least 3 ft apart and would require notification only.
- Intrusive sediment characterization events (e.g., PFFP) would be spaced 80 ft apart and would not sample within the same area within the same year.
- Benthic research for purposes of "Seagrass Macroalgae and Intertidal Research" will be allowed by following relevant Section 2.6.2, Section 2.9 and overarching PDC.
- 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); [species-specific forage fish spawning areas near the Sequim Campus are depicted in Figure 5.1 in Section 5.0); 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).

Benthic characterization surveys (without sediment sampling) are typically of short duration (< 7 days); thus, notification or verification are not duration dependent.

Table 2.6.2.1. Benthic Characterization Survey deployment timeframes relative to requirements.

Duration	Benthic Characterization Surveys (no sediment collection)
Non-intrusive surveys and intrusive events with distances > 80 ft apart	Notification
Intrusive characterization events < 80 ft apart	Verification

2.7 Water Column Sampling: Plankton, Invertebrates and Additional Parameters

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 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.

Project Design Criteria 2.7

The following PDC apply to all the activities described within Section 2.7, along with overarching PDC within Section 2.0:

- Vertebrate biota would be returned to the water if incidentally captured.
- An average number of 0-15 water, plankton, and invertebrate species sampling events could take place within a year, with an annual maximum of no more than 30.

Table 2.7.1. Water Column Sampling deployment timeframes relative to requirements.

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

2.8 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 in situ. This in situ 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.

Project Design Criteria 2.8

The following PDC apply to all the activities described within Section 2.8, along with overarching PDC within Section 2.0:

- Rhodamine water tracing (WT) dye will be below a 20ppb concentration.
- Follow manufacturers use guidelines and limit to minimum concentrations needed for application.
- Measurement devices used will not exceed dimensions listed within existing PDC.

Table 2.8.1. Dye and Particulate Release deployment timeframes relative to requirements.

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

2.9 Seagrass, Macroalgae, and Intertidal Research

Research and survey activities in and around submerged aquatic vegetation 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.

Project Design Criteria 2.9

The following PDC apply to all the activities described within Section 2.9, along with overarching PDC within Section 2.0:

- A total of up to 215 ft^2 (20 m^2) area including submerged aquatic vegetation could be disturbed (including collection) in the project areas within a given year. Accounting for 108 ft^2 (10 m^2) in the Sequim Bay Research Area and 108 ft^2 (10 m^2) in the Juan de Fuca Research Area.
- PNNL will not collect more than 10 percent of the eelgrass in any given collection area (e.g., 1.08 ft^2 out of 10.8 ft^2 (0.1 m^2 out of 1 m^2).
- Transplants and/or SAV specimens will be collected by hand in shallow water or with a small research vessel at deep-water habitats.
- PNNL will record the number of plants removed and document locations with a GPS or alternative means (e.g., mapping).
- Research projects will not significantly alter the habitats that are being investigated.
- “Seabed installations” and “Benthic Characterization Surveys” for purposes of "Seagrass, Macroalgae and Intertidal Research" will be allowed by following relevant general and Section PDC. The deployments will be temporary for the duration of the project (days to years) and equipment and cables will be removed when the project is over.
- For greenhouse gas measurements, in the Tidal Marsh Area (Figure 1.4), PVC collars would be no more than 1 ft diameter inserted 4 in into the sediment in order to interface with flux chambers.
- Sediment cores would be limited to 2 cu ft in volume and 4 in diameter.
- Push point samplers (hollow metal rods) will be limited to no more than 1 in diameter and 1 cu ft of total volume disturbance.

Habitat effects would occur at project initiation; therefore, effects are considered independent of project duration.

Table 2.9.1. Seagrass, Macroalgae and Intertidal Research deployment timeframes relative to requirements.

Duration	Seagrass, Macroalgae and Intertidal Research
Not Applicable	Notification

2.10 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. An example system is the Unobtrusive Multi-static Serial LiDAR Imager (UMSLI) and other systems developed by Florida Atlantic University (Figure 2.2).

Figure 2.2. Versions of the UMSLI Developed by Florida Atlantic University, Approximately 81 cm (32 in.) Tall, 107 cm (42 in.) Wide.

The UMSLI system incorporates both red and green laser systems with specifications for each described in Table 2.1. The red laser system is eye-safe for both humans and marine animals and is functional out to approximately 10 m, 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 20 m from the source. It is used to detect animals approaching the system, then automatically turns off once the animal or object is 10 m from the source.

Table 2.1. Specifications of the UMSLI Green and Red Laser Systems

	Green	**Red**
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 nJ
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 automated underwater vehicle (AUV), or from a system deployed above the water on an aircraft unmanned aerial vehicle (UAV). Examples of aerial bathymetry systems are the Leica Chiroptera 4X that can penetrate to a depth of 25 m, or the Leica Hawkeye 4X that penetrates to depths of 50 m. 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 200 m 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 miniRANGER-UAV. This is an eye-safe (Class 1) LiDAR at 905 nm, with a range of 250 m at 60% reflectivity.

Project Design Criteria (PCD 2.10)

The following PDC apply to all the activities described within Section 2.10, along with overarching PDC within Section 2.0:

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

Table 2.10.1. Light Emitting Devices deployment timeframes relative to requirements.

Duration	Eye Safe Light Emitting Devices	Non-Eye Safe Light Emitting Devices
1-14 Days	Notification	Verification
15-45 Days (Weeks)	Notification	Verification
Beyond 45 Days	Verification	Verification
Greater than 60 Days, and Outside Work Window	Verification	Verification

2.11 Acoustic Device Operation

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. Equipment such as echosounders and sub-bottom profilers are used for detection of 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 2.2 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. Because many of these sound sources operate at sound pressure levels greater than established thresholds, these could have adverse effects on birds, marine mammals and fish. Analyses of these effects using standard NMFS and FWS protocols are presented in Section 4 of this PBA.

Additional acoustic technologies may be used in PNNL-related research. These include single and multibeam echosounders, sonars, and acoustic cameras (Table 2.3). 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). Furthermore, those devices that do operate within hearing range would have a source level low enough to not cause injury or behavioral effects (see Chapter 4).

Table 2.2. 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[1]	**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 sub-bottom 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%

Device[1]	Operating Frequency	Max Source Level (dB re 1 μPa at 1 m)	Duty Cycle
Navy J11 projector2	30 Hz –10 kHz	158	continuous sound
Bluefin-21 SAS Sonar5	4–24 kHz	200	50%
Benthowave spherical transducer6	20–200 kHz	180–200	Up to 50%
Benthowave piston transducer7	3.5–100 kHz	180–220	Up to 50%

[1]all devices are considered non-impulsive sound sources
[2]Detailed Analysis provided in Appendix C
[3]Device is aimed downward from approximately 5 m above the substrate
[4]Directional beam w/ 10° arc, not omnidirectional
[5]Similar to eBOSS sub-bottom profiler
[6]Similar to Navy J11
[7]Similar to Stationary 38 kHz echosounder

Table 2.3. Examples of Active Acoustic Devices and Operation Parameters that would not Exceed Harassment Levels for Marine Mammals or Fish.

Device	Operation Frequencies	Source Level (dB re 1 μPa at 1 m)
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 (ADCP)	300 kHz–6 MHz	*NA due to operation frequency outside hearing range*

Project Design Criteria (PCD 2.11)

Overarching PDC within Section 2.0 will apply to all activities described in Section 2.11, along with the following PDC applicable to devices operating at frequencies within the hearing ranges of protected species and sound pressure levels above applicable thresholds (Table 4.7 and Table 4.8 in Section 4.11):

- Sound and pressure levels above thresholds emitted by instruments operating at frequencies within the hearing range of protected species (Table 4.7 and Table 4.8 in Section 4.11) 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).

- PNNL will use one or more Protected Species Observers (PSO) (Section 2) for any sound-emitting instruments with effect isopleths greater than 5 m. The intent of this practice is to shutdown operation of the equipment for the duration of time an individual of the species is observed within the distance where effects could occur.
- In Section 4.11, PNNL proposes time limits for use of sound sources with injury isopleths greater than 20 m or behavioral isopleths greater than 50 m. **Reinitiation of consultation** would occur if the proposed time limits for injury isopleths greater than 20 m or behavioral isopleths greater than 50 m (Section 4.11 of DOE 2020) 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- reinitiate consultation

– 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.

- The maximum distance at which marbled murrelets can reliably be detected (even under good visibility conditions [Beaufort sea state of 2 or less]) is 50 m (USFWS 2013). Thus, for potential murrelet **injury** effects from sound pressure levels above thresholds the number of PSOs to be used will be based on the area that can reliably observed by each PSO being within 50 m, as follows.

– Observers will survey a maximum distance of 50 m.

– If area too large to be covered by PSOs given the above visibility constraint, reinitiate consultation.

- For marbled murrelet **behavior** effects, use PSOs to extent practicable, given that behavior effect isopleths are greater than injury effect isopleths and the consequences of behavioral changes are less than those of injury, as follows.

– 0–5 m – Vessel staff are observers

– 5–50 m – 1 designated PSO

– 50–250 m – 2 designated PSO with binoculars

– >250 m – 3 designated PSO with binoculars.

- Discontinue operation when marine mammal or marbled murrelet is observed in the surveyed area.
- 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 4.8 in Section 4.11).

- In Section 4.11, PNNL proposes 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, marbled murrelets, or fish, or any combination of these). **Reinitiation of consultation** would occur if the proposed time limits for injury isopleths greater than 20 m or behavioral isopleths greater than 50 m are exceeded.
- Proposed 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.

Table 2.11.1. Acoustic Device Operation deployment timeframes relative to requirements.

Duration	Acoustic Emissions with No Potential to Effect (marine mammals, fish, and murrelet)[a]	Acoustic Within Hearing Range (marine mammals, fish, and murrelet)[b]
1-14 Days	Notification	Verification
15-45 Days (Weeks)	Notification	Verification
Greater than 45 Days	Notification	Verification
Greater than 60 Days, and Outside Work Window	Notification	Verification

[a] Devices operating at frequencies outside the hearing ranges of protected species, or devices operating at frequencies within the hearing ranges of protected species but at sound pressure levels below the applicable effect thresholds (Table 4.7 and Table 4.8 in Section 4.11).
[b] Devices operating at frequencies within the hearing ranges of protected species and at sound pressure levels above the applicable effect thresholds (Table 4.7 and Table 4.8 in Section 4.11).

2.12 Electromagnetic Field (EMF) Operations

Devices and cables which may emit electromagnetic fields during research are addressed below.

2.12.1 EMF Devices

EMF devices used in PNNL research will produce variable levels of EMF up to 1.25 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 cables and 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.

Project Design Criteria (PDC 2.12.1)

The following PDC apply to all the activities described within Section 2.12.1, along with overarching PDC within Section 2.0:

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

Table 2.12.1. Electromagnetic Device Operations deployment timeframes relative to requirements.

Duration	EMF Operations
14 Days	Notification
45 Days (Weeks)	Notification
Greater than 45 Days	Notification
Greater than 60 Days, and Outside Work Window	Notification

2.12.2 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. 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 (days to years).

Project Design Criteria (PDC 2.12.2)

The following PDC apply to all the activities described within Section 2.12.2, along with overarching PDC within Section 2.0:

- Cables could be anchored to the seabed using diver-installed screw or helical anchors, small concrete blocks or corrosion resistant metal mooring.
- Any singular cable diameter will not exceed 1 ft.
- A maximum of 40 cables will be deployed in research areas at any given time.
- Cables will be either housed together or spaced appropriately to avoid entanglement and clutter.
- Cable installations for purposes of "Seagrass Macroalgae and Intertidal Research" will be allowed by following relevant Section 2.3.2, Section 2.9 and overarching PDC.
- The deployments will be temporary for the duration of the project.

Table 2.12.2.1. Deployment timeframes for seabed installation of sensors, equipment, and cable types relative to requirements.

Duration	Cables
1-14 Days	Notification
15-45 Days	Notification
Greater than 45 Days	Notification
Greater than 60 Days, and Outside Work Window[1]	Verification

[1] "outside work window" includes deployments from Feb 16 to July 15.

2.13 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. The following section excludes tidal turbines, which are described in Section 2.14. 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 Sequim Bay and Juan de Fuca Research Areas and could power microgrids. Wave energy converters (WEC) tend to have fewer moving parts that could interact with marine life than tidal turbines. 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. 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. Any devices which are classified as buoys (see Section 2.1), will be viewed independently from this section and will not be subject to the PDC in Section 2.13.

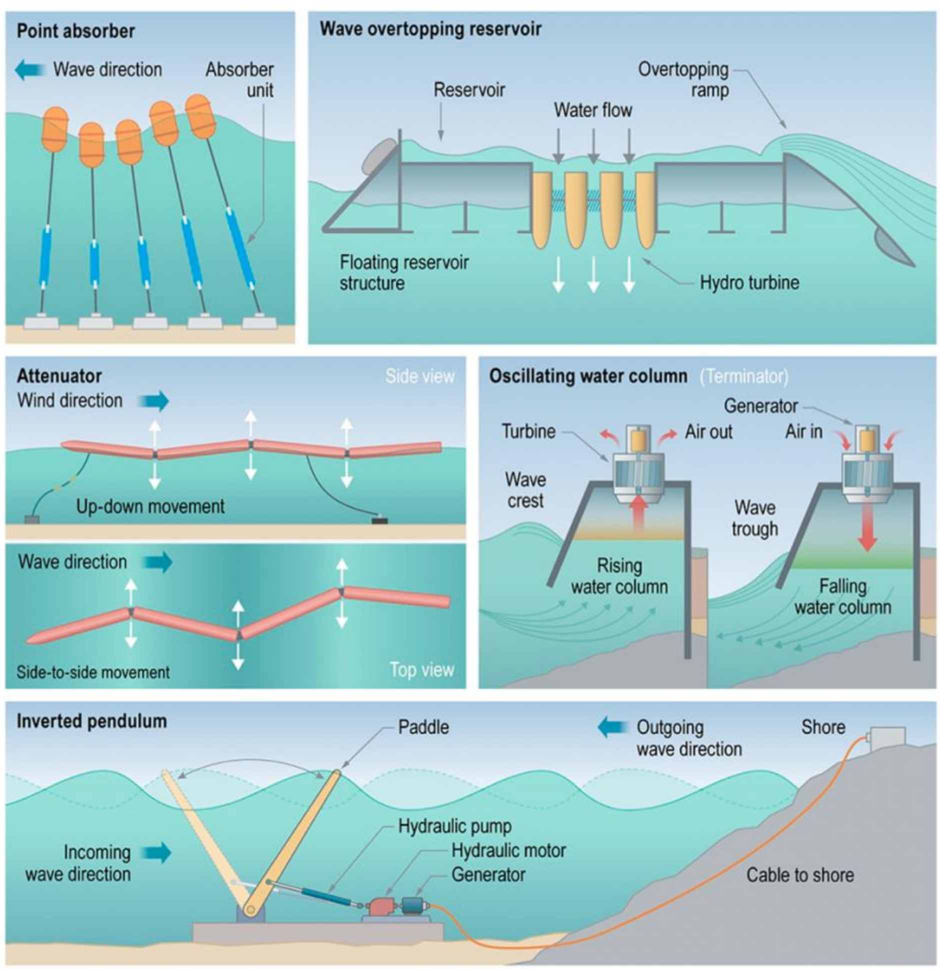

Figure 2.3. Examples of types of marine energy devices (WECs) and movement style (Augustine et al. 2012).

Project Design Criteria 2.13

The following PDCs apply to all the activities described within Section 2.13, along with overarching PDC within Section 2:

- Community and research scale marine energy devices will include many types and forms. For those devices that can include best management practices (BMPs) to prevent impacts to species (i.e., screens around moving parts), a list is detailed below:
- – Any combination of the below BMPs will be used and will be detailed in the biological review to document BMP adoption sufficient to prevent impacts to species. The minimum number of BMPs adopted being 1.
- – 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.
- – Divers will confirm anchoring on unconsolidated habitat.
- – Generators/turbines and/or exposed rotating parts will be housed in a manner to prevent impingement or areas of entrapment.
- – Exposed rotating parts will operate at a speed of 10 m/s or less.

- Wave overtopping reservoirs will be designed in a way to allow for a minimum of 50% water exchange between surface water and reservoir water.
- New and/or novel products/technologies of quality sufficient to avoid impacts to protected species, documented in a biological review.
- Employ a PSO during operation. 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.

- Projects unable to adopt BMPs above, will require verification regardless of duration.
- A range of 5-7 deployments with a maximum of 150 deployments will occur in any given year.
- Devices would be anchored using diver-installed helical anchors (preferred), concrete or corrosion resistant metal anchors.
- 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.
- Devices will not be considered power plants associated with the delivery of electrical power to the US grid.
- Verification for any activities deployed between February 16 and July 15 for 60 days or more would require compensatory mitigation using the modified PNNL Puget Sound Nearshore 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 2.13.1. Community and Research Scale Marine Energy Devices deployment timeframes relative to requirements.

Duration	Community and Research Scale Marine Energy Devices (With BMPs)	Community and Research Scale Marine Energy Devices
14 Days	Notification	Verification
45 Days (Weeks)	Notification	Verification
Beyond 45 Days	Verification	Verification
Beyond 60 Days Outside Work Window[1]	Verification and Mitigation	Verification and Mitigation

[1] "outside work window" includes deployments from Feb 16 to July 15.

2.14 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 (Figure 2.4 and Figure 2.5). 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. PNNL would not install tidal turbines for the purpose of connecting to the US 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.

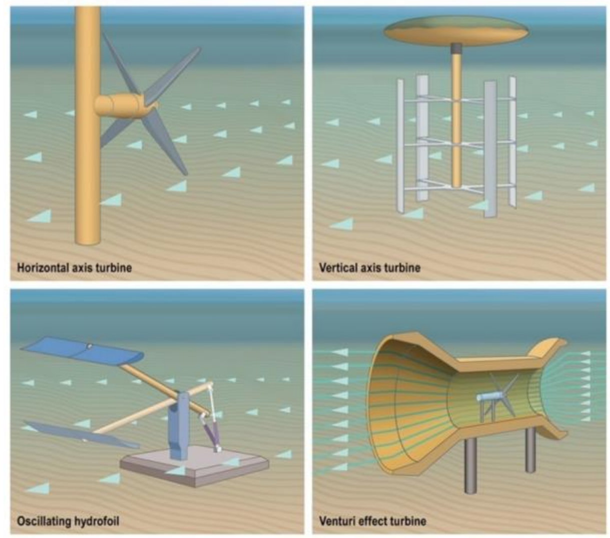

Figure 2.4. Examples of tidal turbines (Augustine et al. 2012)

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 each of the four representative locations were made based on the available water depth and clearance considerations. The maximum potential size for horizontal axis turbines at each location is provided in Table 2.5, and for vertical-axis turbines in Table 2.6. Deployments at other locations within the Sequim Bay or Juan de Fuca project areas would need to be assessed in a similar fashion and may be subject to additional monitoring.

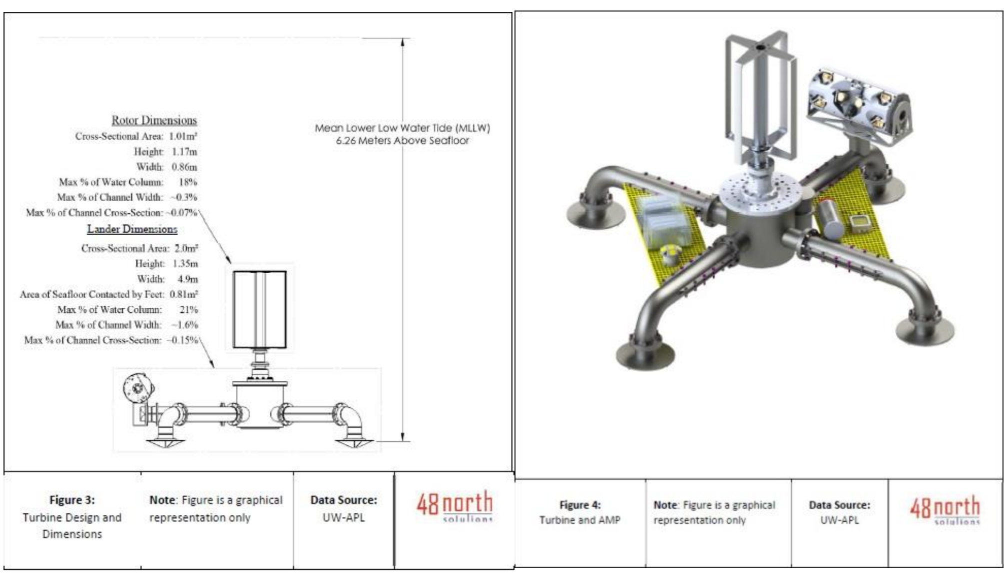

Figure 2.5. Example Research-Scale Vertical Shaft, Substrate-Mounted Tidal Turbine (APL, University of Washington)

For example, 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. 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 Table 2.5 and Table 2.6. Four representative stations have been selected for further analysis: three are close to Travis Spit and one is close to The Middle Ground (Figure 2.6). Characteristics of these four locations are presented in Table 2.4. Nevertheless, deployments could occur throughout the Sequim Bay and Juan de Fuca areas.

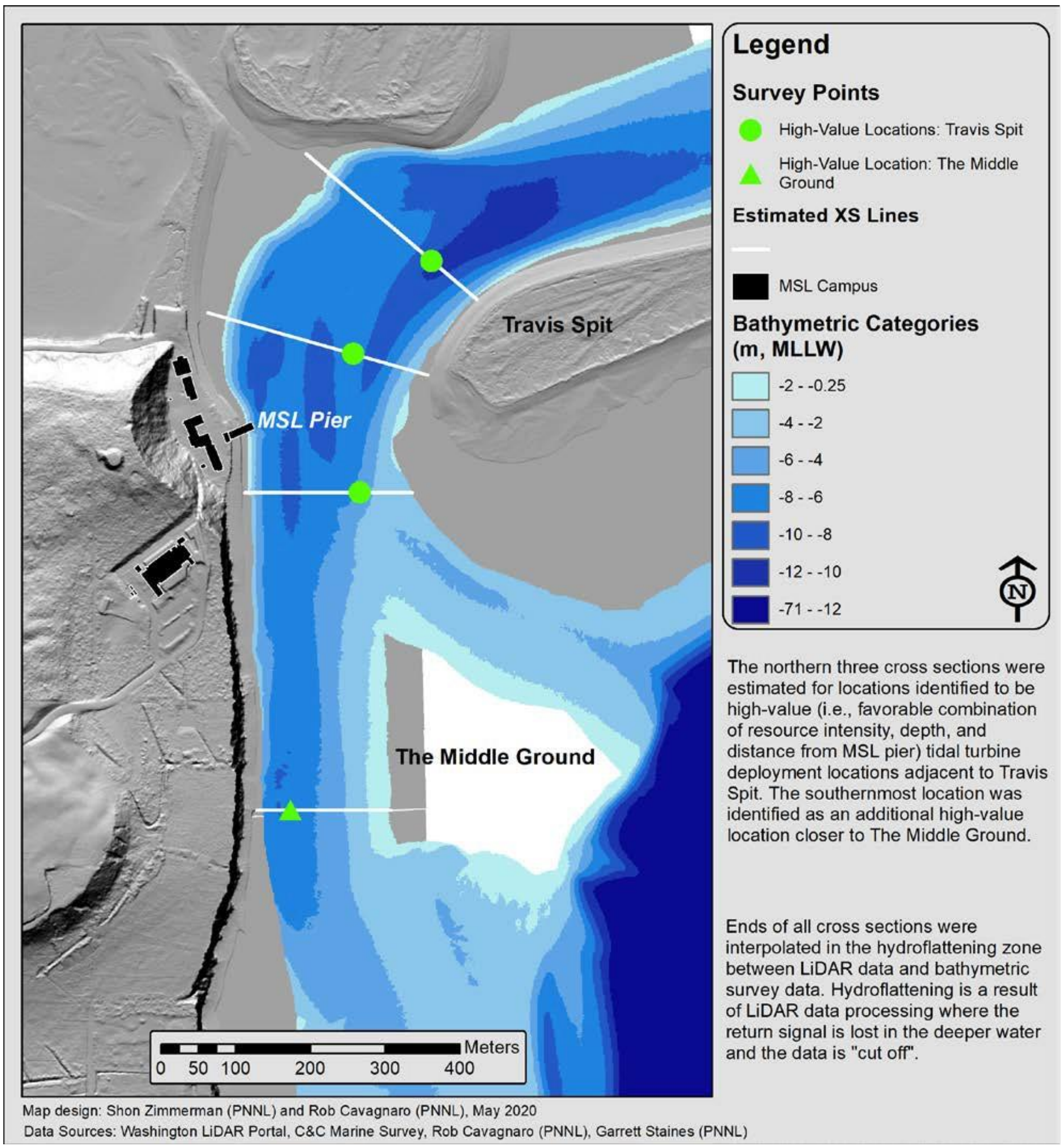

Figure 2.6. Location of Four Representative High-Value Turbine Locations within the Sequim Bay Inlet Channel

Table 2.4. Characteristics of Four Representative High-Value Turbine Locations

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

Table 2.5. Maximum Size, Power, and Speed of Horizontal-Axis Turbines at Four Representative Locations

Site	Max Turbine Diameter (m)	Max Area (m^2)	Max % of 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 2.6. Maximum Size, Power, And Speed of Vertical-Axis Turbines at Four Representative Locations

Site	Max Turbine Height (m)	Max Turbine diameter (m)	Max Area (m^2)	% of 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

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. It is thus unlikely that turbine manufacturers would support/fund a PNNL-Sequim non-realistic 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. 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% of global research and development effort [Isaksson et al. 2020].

Overall, PNNL does not intend to limit the turbine type (to only vertical axis) or number (only one horizontal axis operating at any given time), or operation (tip-speed ratio to a maximum of 2 or 2.5, i.e., not at a tip-speed ratio exceeding 3 or approaching 5). A commitment to fully limiting turbine type, number or operation could severely hamper PNNL's ability to conduct needed research based on emerging market needs and concurrently limit development of monitoring information needed by the Services to inform the broad extent of potential future commercial applications. However, PNNL will use an adaptive approach to deploy up to 1 tidal turbine at a time, which over time is intended to expand up to 5 turbines deployed at a time with a maximum of 10 turbines deployed in any given year. This intent is provided for information purposes at this time, as subsequent additions will rely on future adaptive management between DOE and the Services. 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 Services including monitoring results during turbine deployment.

Project Design Criteria (PDC 2.14)

The following PDC apply to all the activities described within Section 2.14, along with overarching PDC within Section 2:

- An adaptive approach will be considered under the PBA, with a total of 1 tidal turbine allowed to be deployed at a time in the first year. More turbines may be permitted afterward, depending on further collaboration with the Services.
- Underwater monitoring as detailed in Section 5.3 will be followed, including notification of the Services if a target (i.e., seabird, marine mammal, fish) is detected within 1 m, and shutdown until further consultation in the event of blade strike of a target.
- Any turbines and associated structures placed on the seafloor will be done so slowly, in a controlled manner, to minimize turbidity plumes.
- Reinitiation of consultation will also occur if underwater monitoring reveals collision of a possible protected species (i.e., seabird, marine mammal, fish).
- Divers will confirm placement of turbines avoid rocky outcrops.
- 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.

- Verification for any activities deployed between February 16 and July 15 for 60 days or more would require compensatory mitigation using the modified PNNL Puget Sound Nearshore 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 2.14.1. Tidal Turbine Research deployment timeframes relative to requirements.

Duration	Tidal Turbine Research
14 days	verification
45 days (weeks)	verification
Beyond 45 days	verification
Beyond 60 Days Outside Work Window	Verification and Mitigation

[1] "outside work window" includes deployments from Feb 16 to July 15.

3.0 Species and Habitats under NOAA Fisheries and USFWS Jurisdictions

The following section provides a summary of species and habitats that may occur in the study area of Sequim Bay and in the Strait of Juan de Fuca between Dungeness Bay and Protection Island.

3.1 Threatened or Endangered Species and Critical Habitats

The following are federally listed species known to be seasonally present in the Sequim Bay project area or nearby Gibson Spit waters and, if applicable, their designated critical habitats:

1. Puget Sound Chinook (*Oncorhynchus tshawytscha*) NMFS evolutionarily significant unit (ESU) (threatened) (79 FR 20802); designated critical habitat (79 FR 20802)
2. Hood Canal summer-run chum (*Oncorhynchus keta*) NMFS ESU (threatened) (70 FR 37160); designated critical habitat (70 FR 52629)
3. Puget Sound steelhead (*Oncorhynchus mykiss*) NMFS distinct population segment (DPS) (threatened) (72 FR 26722)
4. North American green sturgeon (*Acipenser medirostris*) NMFS southern DPS (threatened) (71 FR 17757); designated critical habitat (74 FR 52299)
5. Pacific eulachon (Columbia River smelt) (*Thaleichthys pacificus*) NMFS southern DPS (threatened) (75 FR 13012)
6. Puget Sound bocaccio (*Sebastes paucispinis*) NMFS Puget Sound/Georgia Basin DPS (endangered) (81 FR 43979); and designated critical habitat (82 FR 7711)
7. Puget Sound yelloweye rockfish (*Sebastes ruberrimus*) NMFS Puget Sound/Georgia Basin DPS (threatened) (81 FR 43979); and designated critical habitat (82 FR 7711)
8. Southern resident killer whale (*Orcinus orca*) NMFS DPS (endangered) (70 FR 69903); designated critical habitat (71 FR 69054)
9. Humpback whale (*Megaptera novaeangliae*) NMFS (endangered) (79 FR 20802).
10. Sunflower sea star (*Pycnopodia helianthoides*) NMFS proposed (threatened) (88 FR 16212)
11. Bull trout (*Salvelinus confluentus*) FWS Coastal-Puget Sound DPS (threatened) (77 FR 13248)
12. Marbled murrelet (MAMU) (*Brachyramphus marmoratus*) FWS (threatened) (57 FR 45328)
13. Short-tailed albatross (*Phoebastria albatrus*) FWS (endangered) (74 FR 23739)

3.1.1 Chinook Salmon

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). Limited information exists on Chinook salmon habitat use of marine waters. 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 primary constituent element 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.

3.1.2 Chum Salmon

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). 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). 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 primary constituent element 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.

3.1.3 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), 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 Juan de Fuca Research Area include the Dungeness River, Cassalery Creek and Gierin Creek, tributaries to Sequim Bay (WDFW 2011). Critical habitat for Puget Sound steelhead DPS has been proposed; however, it does not include the whole of Sequim Bay and its tributaries and open water in the Strait of Juan de Fuca where PNNL research would occur have been excluded. The critical habitat does include many of the streams that feed these areas (78 FR 272650 CFR 226.212). The nearshore migration pattern 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.

3.1.4 North American Green Sturgeon and Critical Habitat

There are two distinct populations of North American green sturgeon; a southern DPS and a northern DPS, based on genetics and fidelity to their spawning site (NMFS 2018). The southern DPS is listed as threatened under the ESA and critical habitat was designated (Figure 3.1), while the northern DPS is listed as a species of concern (NMFS 2020d). The southern DPS of North American green sturgeon spawns in the Sacramento River basin (California), while the northern DPS spawns in the Rogue River (Oregon) and the Eel and Klamath Rivers (northern California) (NMFS 2018; NMFS 2020e). However, the two populations may co-occur throughout the habitat range. 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 rkm 74; NMFS 2020d). While Sequim Bay is not designated critical habitat, the waters to the north of the bay have been designated (Figure 3.1). 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). Green sturgeon are not likely to occur in the Sequim Bay Research Area but may occur in the Juan de Fuca Research Area because of the substrate type, cover and food resources, and other available habitat in the vicinity.

3.1.5 Pacific Eulachon

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. 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).

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.

3.1.6 Puget Sound Bocaccio

Bocaccio are a large Pacific Coast rockfish. Bocaccio are most commonly found between 50–250 m depth, but may reside as deep as 475 m. They are late to mature, slow-growing, and a long-lived species, potentially living to 50+ years (NMFS 2019a; NMFS 2012b). 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 2012b). 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) (Figure 3.1), although it has been updated to include fish residing within the Puget Sound rather than fish originating from the Puget Sound (81 FR 43979). Although unlikely, bocaccio could occur in the Sequim Bay and Juan de Fuca Research Areas. Prey items include small fishes and invertebrates (PSI and UW 2019).

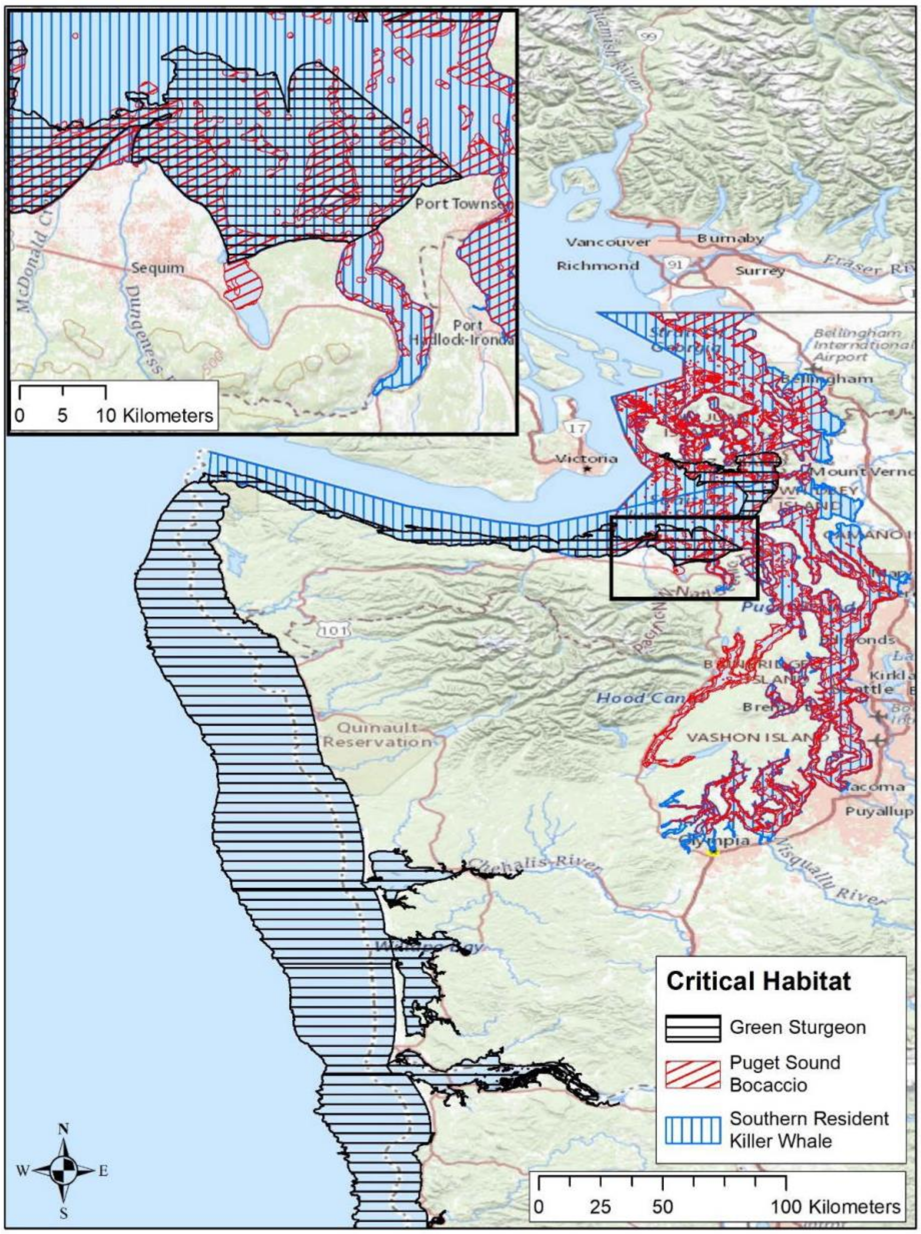

Figure 3.1. Critical Habitat for the Southern DPS of Green Sturgeon, Puget Sound Bocaccio, and Southern Resident Killer Whales. Data Source: NOAA Fisheries (NMFS 2020a; NMFS 2020b; and NMFS 2006).

3.1.7 Puget Sound Yelloweye

Yelloweye rockfish are a large, long-lived Pacific Coast rockfish (40–50 cm, 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 25–475 m deep but are most commonly found between 91–180 m. 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 Juan de Fuca and Sequim Bay research areas (79 FR 68041), although it has been updated to include fish residing within the Puget Sound rather than fish originating from the Puget Sound (82 FR 7711). Although unlikely, yelloweye rockfish could occur in Sequim Bay and the Juan de Fuca Research Areas. They feed upon invertebrates and small fishes (PSI and UW 2019).

3.1.8 Southern Resident Killer Whale DPS and Critical Habitat

Killer whales are the world's largest dolphin (NMFS 2019e). The southern resident killer whale is one of three distinct forms of killer whales (residents, transients, and offshores) recognized in the northeastern Pacific Ocean. Resident killer whales in U.S. waters are distributed from Alaska to California (NMFS 2019e), with four distinct communities recognized: Southern, Northern, Southern Alaska, and Western Alaska. They use echolocation in foraging, social interactions, and navigation (71 FR 69054). Resident killer whales consume salmon and other fish and live in stable matrilineal pods. However, only southern resident DPS are present in the project area. 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).

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 (Figure 3.1; 71 FR 69054; 84 FR 49214). 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 Juan de Fuca Research Area are part of the designated critical habitat (Figure 3.1; NMFS 2006; NMFS 2019b). Although Sequim Bay was excluded from this critical habitat designation (71 FR 69054), 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. Primary constituent elements of critical habitat essential for conservation of the southern resident killer whale include (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 (71 FR 69054).

Killer whale habitat utilization is dynamic, and specific breeding, calving, or resting areas are not currently documented (71 FR 69054).

3.1.9 Humpback Whale, California/Oregon/Washington Stock

The humpback is a baleen whale. The California/Oregon/Washington (North Pacific) Stock is defined to include humpback whales that feed on plankton, crustaceans, and small fish off the West Coast of the United States. Humpback whales in the North Pacific feed in coastal waters from California to Russia and in the Bering Sea. A relatively large number (the precise number is not known) of shipboard sightings of the species (largest along the entire Washington and Oregon coast) occurred between 1991 and 2008 off the mouth of the Strait of Juan de Fuca (NMFS 2011b). 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 1360 kg (3000 lb) 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 Juan de Fuca Research Area, just outside of Sequim Bay. However, they would be very unlikely to occur in Sequim Bay (NMFS 2011b).

3.1.10 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 25 m 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% declines in California and Oregon, and 92-99% decline in Washington (Figure 1; Hamilton et al. 2021; Harvell et al. 2019). This decline has led the IUCN 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). Sunflower sea stars are capable of movement (Heady et al. 2022) and would be able to move to suitable locations by themselves if disturbed and would tolerate being gently relocated by scuba divers if needed.

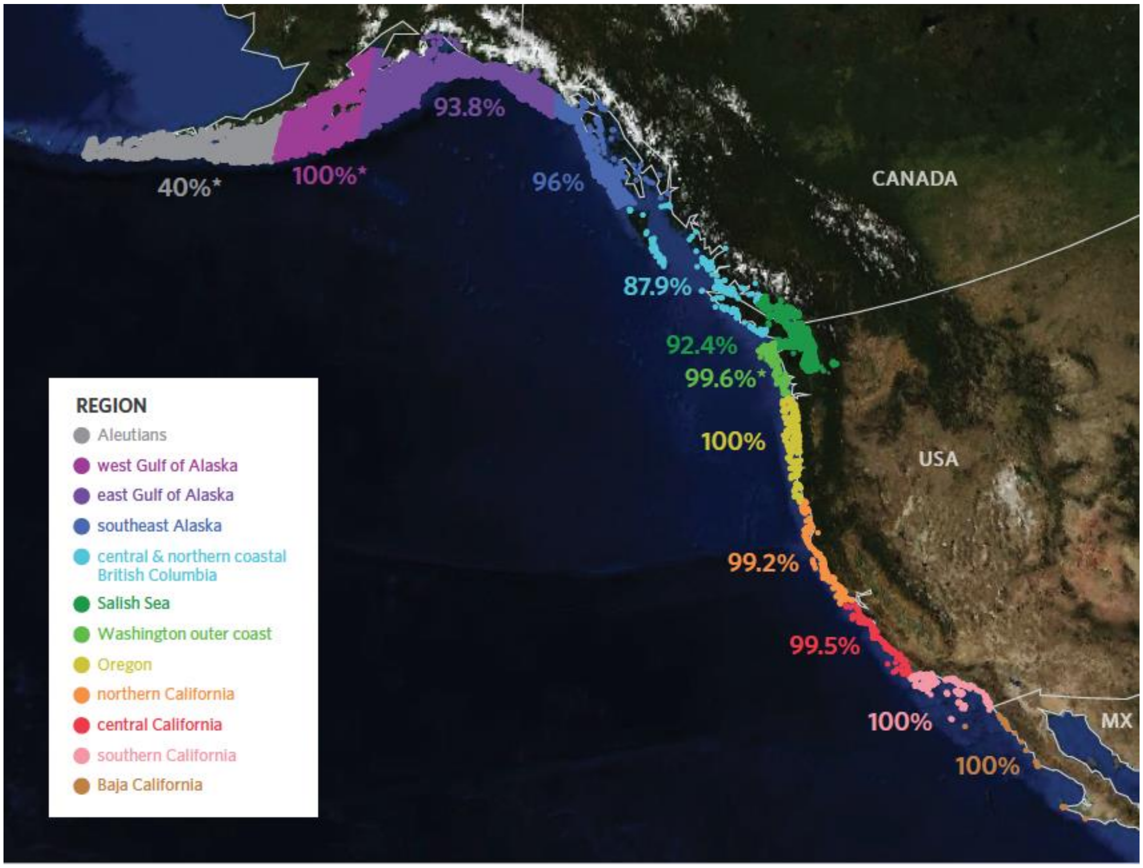

Figure 3.2. Estimated percent declines in sunflower sea star population density due to the sea star wasting syndrome outbreak in 2013-2017 (Heady et al. 2022).

3.1.11 Bull Trout

Bull trout in the Sequim Bay area are part of the Coastal-Puget Sound DPS which is one of the five coterminous populations of bull trout (USFWS 2017) and is part of the Coastal Evolutionary Unit (USFWS 2015). The Coastal Recovery Unit is located within western Oregon and Washington. Major geographic regions include the Olympic Peninsula, Puget Sound, and Lower Columbia River basins. The Olympic Peninsula and Puget Sound geographic regions also include their associated marine waters (Puget Sound, Hood Canal, Strait of Juan de Fuca, and Pacific Coast), which are critical in supporting the anadromous life history form, unique to the Coastal Recovery Unit. The core area (contains the natal streams of one or more local populations of bull trout) to which bull trout in the Sequim Bay area belong is the lower Dungeness River-Gray Wolf River (USFWS 2015). In 1999, this population was considered depressed because of declining abundance, likely influenced by road density, sedimentation, urbanization, poaching, and competition and hybridization from introduced brook trout (64 FR 58910).

Within the Coastal Recovery Unit, waterbodies used by foraging bull trout are often shared among multiple core areas/populations and are outside of the boundaries of the natal core areas. Bull trout in the Sequim Bay area belong to the Strait of Juan de Fuca foraging, migrating, and overwintering (FMO) area. FMOs contribute to successful overwintering survival and dispersal among core areas and are important for genetic mixing and long-term population resiliency, especially for the anadromous and fluvial (spawning and rearing in tributary streams and migrating to larger rivers to mature) life history forms (USFWS 2015; USFWS 2017).

Because bull trout forage on salmon fry and eggs, streams accessible to salmon both within core areas and in independent tributaries in FMOs outside of core areas have been identified as freshwater foraging habitat for bull trout. Independent tributaries in FMOs used by bull trout on the Olympic Peninsula are not believed to support spawning populations of bull trout and are only accessible to bull trout by swimming through marine waters from core areas (USFWS 2004). Bell Creek independent tributary is located east of the Dungeness River and empties into the western portion of Sequim Bay in a lagoon just to the north of the PNNL-Sequim Campus (Figure 4.1). This habitat is located outside and east of the lower Dungeness River-Gray Wolf River core area and is within watersheds not believed to support spawning (USFWS 2004).

In the Strait of Juan de Fuca FMO, conservation of drift cell processes is crucial for maintaining essential accretionary landforms, especially Dungeness Spit and the six spits and embayments associated with Washington Harbor and Sequim Bay (USFWS 2015). Sediment processes of erosion, transport, and deposition play an important role in nearshore ecosystem function, including forming suitable habitats for forage fish spawning (Parks et al. 2013). Forage fish are an important prey resource for bull trout. Forage fish are small, pelagic schooling fish which are important as forage for predatory fish, birds, and mammals. In coastal areas of western Washington, subadult (and adult) bull trout feed on Pacific herring (*Clupea pallasii*), Pacific sand lance (*Ammodytes hexapterus*), and surf smelt (*Hypomesus pretiosus*) in marine waters (USFWS 2004; USFWS 2017). Spawning areas for these species occur in Sequim Bay in the vicinity of the PNNL-Sequim Campus. Sequim Bay contains Pacific sand lance spawning sites, including just north (about 100 m) and south (about 50 m) of the PNNL Sequim pier area. Sand lance spawning occurs at high tide in shallow water on sand-gravel beaches between November and February (Essington et al. 2018) and juvenile sand lances rear in nearshore waters along Puget Sound during the summer (Penttila 2007). Sand lance spawning sites appear to be used on a perennial basis (Penttila 2007). Surf smelt spawn in summer along the Strait of Juan de Fuca on high intertidal beaches of sand and gravel, under only a few inches of slack water on the high tide (Penttila 2007). Juvenile surf smelt linger in spawning areas and feed in shallow waters throughout Puget Sound (Penttila 2007). With sand lance, surf smelt, and herring likely common in the nearshore waters of Sequim Bay, it would be expected that subadult bull trout present in Sequim Bay would opportunistically forage in areas of forage fish concentrations. Although foraging bull trout are likely to concentrate in forage fish spawning areas, they likely can be found throughout accessible estuarine and nearshore habitats (USFWS 2004).

Because bull trout exhibit a patchy distribution, even in pristine habitats fish should not be expected to simultaneously occupy all available habitats (USFWS 2004). Because of the nearby Bell Creek and forage fish spawning areas in Sequim Bay, and to be conservative, it is assumed that bull trout use Sequim Bay for foraging and overwintering in Sequim Bay and moving between Bell Creek and the Dungeness River core area.

Designated bull trout critical habitat is of two primary use types: (1) spawning and rearing and (2) FMO. Critical habitat generally encompasses one or more core areas and may include

FMO areas, outside of core areas, that are important to the survival and recovery of bull trout (USFWS 2017). Critical habitat for the bull trout includes Sequim Bay and Bell Creek (75 FR 63897) (part of the Strait of Juan de Fuca FMO) which flows into Washington Harbor on the west side of Sequim Bay just north of the PNNL-Sequim Campus (Figure 4.1). In marine nearshore areas (e.g., Sequim Bay), the inshore extent of critical habitat is the mean higher high-water line, which extends offshore to a depth of 10 m (32 ft) relative to the mean low low-water line.

3.1.12 Marbled Murrelet

Avian surveys have been conducted annually during spring (typically in May) on PNNL-Sequim Campus (including the waterfront and nearshore marine environment in Sequim Bay and the forested uplands) from 2013 through 2019 and the marbled murrelet (MAMU) was not recorded (see Appendix D in Duncan et al. 2019). These surveys were general avian surveys that took place during daytime, not at dawn or dusk during the species' peak inland activity and were not conducted with the same rigor as surveys that specifically target the murrelet (Evans Mack et al. 2003). Because murrelets are difficult to detect, even when specifically targeted (61 FR 26256), these surveys suggest the species may not use upland forests at the PNNL-Sequim Campus but are by no means conclusive.

Christmas Bird Counts (CBC) have also been conducted within a 15 mi radius area centered just northeast of the City of Sequim since 1975 (Sequim-Dungeness CBC survey) (OPAS 2019; Boekelheide 2019). Individual CBC surveys conducted at the PNNL-Sequim Campus from 2010–2017 (Buenau 2019) and at the lagoon north of campus (which are part of the larger Sequim-Dungeness CBC survey area) (Boekelheide 2019) have not recorded murrelets. However, other individual CBC surveys within the Sequim-Dungeness CBC survey area have reported murrelets in low numbers (OPAS 2019), including in west Sequim Bay (south of the PNNL-Sequim Campus) and east Sequim Bay (Boekelheide 2019). Christmas Bird Counts (CBC) conducted at the Sequim Campus from 2010-2017 and at the lagoon north of campus (part of the larger Sequim-Dungeness CBC survey area) have not recorded MAMUs. However, other individual CBC surveys within the Sequim-Dungeness CBC survey area have reported murrelets in low numbers (OPAS 2019), including in west Sequim Bay and east Sequim Bay (both south of the PNNL-Sequim Campus). MAMUs have also been sighted year-round near John Wayne Marina (located about 1 mi south of the PNNL-Sequim campus on the west side of Sequim Bay) but the specific locations of these sightings and whether the individuals were on the water or in flight are not reported (ebird 2022). Webster et al. (2018) conducted seabird surveys for a five-week period during June and July 2018 between the southwest corner of Travis Spit, the PNNL-Sequim dock, and Gibson Spit located just to the north (which comprises the northern portion of the proposed deployment area). Observation periods were 30 minutes each during daytime hours, scheduled to occur during tidal exchanges, both flood and ebb, and during times of slack current. No MAMUs were observed. Washington Department of Fish and Wildlife (WDFW) has conducted aerial surveys for murrelet species as a group in the eastern part of the Strait of Juan de Fuca in December and January from 1999 through 2020 (WDFW 2022). Survey results indicate consistently higher estimated densities of murrelets in the central portion of Sequim Bay (generally densities between 83-16,571), than in the bay channel and along the bay margins (generally 0-82). None of the above-referenced surveys is adequate spatially or temporally to characterize MAMU annual use of the open waters of Sequim Bay, and specifically the proposed tidal turbine deployment area in Sequim Bay channel.

Lacking Sequim-Bay and deployment-area-specific habitat use data, the general description of the use of Sequim Bay provided by Ralph et al. (1995) (as summarized in the FWS letter

01EWFW00-2021-I-0226) in their discussion of MAMU populations in Washington and their marine habitat preferences may be applicable.

Surveys were conducted in the late 1980s/early 1990s to quantify the general, seasonal distribution and abundance of all marine waterbird species in Puget Sound, which includes the inland marine areas of Washington. Winter surveys were from light aircraft and summer surveys were from small boats and light aircraft. MAMUs were believed to reach peak abundance in Sequim and Discovery Bays during the fall period, with a density of 2.5 birds/km2 based on surveys (n = 13) of open water greater than 20 m deep. No locations of similar habitat in Puget Sound had as high a density during any season of the year. Densities reported for Sequim and Discovery Bays during surveys conducted during spring (n = 17), summer (n = 2), and winter (n = 18) were 0.0, 0.33, and 0.92 birds/km2. The winter density was also the highest of any location of similar habitat in Puget Sound during that season. The proportion of individual censuses with MAMUs present was generally around 20 percent in each season, with the exception of summer when the species was observed on 50 percent of surveys, but the summer sample size was very small (n = 2) (Ralph et al. 1995). Thus, given the limitations of this data (not current and not covering Sequim Bay specifically) MAMU detectability or occurrence in the open waters of Sequim Bay in general may be expected to be sporadic. Further, MAMUs may be expected to use shallow marine areas close to freshwater streams (Pastran et al. 2021), as well as areas of tidal mixing where prey may concentrate (Ralph et al. 1995). The Sequim Bay inlet channel is one such area, but this area was not reported by Ralph et al. (1995).

Anecdotal observations of the species occur during the breeding season but less frequently than during the non-breeding season at John Wayne Marina (eBird 2019), located about one mile south of the PNNL-Sequim Campus. Thus, it is likely murrelets are also present in Sequim Bay, although perhaps less frequently to the north than further south in the bay.

Adult murrelets feed the chick at least once per day, returning from the ocean to the nest primarily at dawn and dusk. Fledging occurs at about 28 days after hatching, when fledglings fly directly to the marine environment (USFWS 2019a). Murrelets appear to be solitary in their nesting habits, but they are frequently detected in groups in the forest (61 FR 26256). MAMUs have a tendency to return to the same nesting areas (WDNR and USFWS 2019). The species has been observed at some inland sites during all months of the year (61 FR 26256). Potential lifespan is 20 years (WDNR and USFWS 2019).

MAMUs generally forage during the day and are most active during early morning and late afternoon (Strachan et al. 1995). MAMUs spend a considerable amount of time on the surface (loafing, preening) in any given day. Murrelets dive to depths of 3 to 36 m when foraging and may spend 75% of a 30-minute foraging bout underwater (USFWS 2017).

The MAMU is known to occur in Clallam County, Washington where there is critical habitat for the species in the terrestrial environment near the southwest end of Sequim Bay (61 FR 26256), about 3.5 mi south of the PNNL-Sequim Campus. Critical habitat extends in low-mid-elevation forest along the fringes of most of Olympic National Park. Two components of murrelet habitat are essential: terrestrial nesting habitat and associated forest stands, and marine foraging habitat used during the breeding season (61 FR 26256).

3.1.13 Short-Tailed Albatross

The short-tailed albatross is a large pelagic bird that nests on isolated windswept offshore islands, with restricted human access. The majority of the species nest on islands near Japan, with the only known nesting in the USA occurring around Hawaii. The species uses marine habitat for foraging. The North Pacific marine environment of the short-tailed albatross is characterized by coastal regions of upwelling and high productivity and expansive, deep water beyond the continental shelf (65 FR 46643). Even though, the species range extends into the Strait of Juan de Fuca north of Sequim Bay (USFWS 2019b), the likelihood of the species occurring in the action area is discountable. The albatross would not be exposed to project activities in Sequim Bay or the adjacent project reas in the Strait of Juan de Fuca, therefore the species was not evaluated.

3.2 Protected Marine Mammals

The following species, covered under the Marine Mammal Protection Act of 1972 (MMPA), are known to be present in Sequim Bay and Juan de Fuca waters:

1. Southern resident killer whale (*Orcinus orca*)
2. West coast transient (Bigg's) killer whale (*Orcinus orca*)
3. Humpback whale (*Megaptera novaeangliae*)
4. Gray whale (Eastern North Pacific Stock) (*Eschrichtius robustus*)
5. Minke whale (*Balaenoptera acutorostrata*)
6. Dall's porpoise (*Phocoenoides dalli*)
7. Harbor porpoise (Northern Oregon/Washington Coast and Washington Inland Waters Stocks) (*Phocoena phocoena*)
8. California sea lion (*Zalophus californianus*)
9. Harbor seal (Washington Inland Waters Stocks) (*Phoca vitulina*)
10. Northern elephant seal (*Mirounga angustirostris*).

3.2.1 Southern Resident Killer Whale

Southern resident killer whales, as described above, are covered under ESA as well as MMPA.

3.2.2 West Coast Transient (Bigg's) Killer Whale

West Coast transient killer whales (also commonly known as Bigg's killer whales) live to 30–50 years. Males typically grow to 6–8 m (*c*. 5,900 kg), while females grow to 5–7 m (3,000–3,900 kg). They feed upon marine mammals, including Dall's porpoise, harbor porpoise, harbor seals, and Stellar sea lions (Shields and Veirs 2019). They are not migratory, but their home range is distributed from southeast Alaska to California, and they can be found throughout this distribution at any time of the year. Much of their movement within this range is relative to their prey availability (Shields and Veirs 2019). The occurrence of Bigg's killer whales in the Salish Sea has increased since the early 2000s, and they have been documented in the Straits of Georgia and Juan de Fuca, to channels such as Hood Canal, Saanich, and Hammersley Inlets, and Sansum Narrows (Shields and Veirs 2019). Bigg's killer whales are typically found in the Salish Sea during April-May and August-September (Shields and Veirs 2019).

3.2.3 Humpback Whale, California/Oregon/Washington (North Pacific) Stock

Humpback whales, as described above, are covered under ESA as well as MMPA.

3.2.4 Gray Whale, Eastern North Pacific Stock

Gray whales are large baleen whales. Females are slightly larger than males and in general adult gray whales can grow up to 14.9 m, weighing 36,000 kg, and live for 55–70 years. They feed upon benthic amphipods and inhabit shallow coastal waters. Most of the Eastern North Pacific stock migrates to the northern Bering and Chukchi Seas to feed, but some remain off the Pacific Coast. Gray whales migrate south in the fall to breed off the coast of Baja California. Gray whales have been sighted near Protection Island (WDNR 2010) and because they are found in shallow coastal waters, may occur near the Gibson Spit waters, but would be unlikely to occur in Sequim Bay.

3.2.5 Minke Whale

Minke whales are the smallest of the baleen whale species, and their populations are stable (NMFS 2019f). Males are slightly smaller than females, and the species can be up to 11 m long, weighing 9,072 kg (NMFS 2019f). They are opportunistic feeders, with a diet that typically consists of crustaceans, plankton, and small fish (NMFS 2019f; Haug et al. 1995). Minke whales migrate north to feed in the spring and summer and moves south to breed in the fall (Haug et al. 1995). They have been sighted in the Strait of Juan de Fuca, outside Sequim Bay.

3.2.6 Dall's Porpoise

Dall's porpoise are very fast swimmers. Males grow slightly larger than females with lengths ranging from 1.8–2.3 m for males and 1.8–2.1 m for females. Both males and females weigh 122.5 kg on average (maximum 159 kg) (American Cetacean Society 2017). Dall's porpoise are opportunistic feeders, typically feeding on squid and fishes, and occasionally feeding on crustaceans (NMFS 2019c). They do not typically migrate and are year-round residents in many of their ranges. Ranges include Baja California, Mexico to Alaska, and in the Bering Sea to Japanese waters (American Cetacean Society 2017). They have been sighted in the Strait of Juan de Fuca, outside Sequim Bay.

3.2.7 Harbor Porpoise, Washington Inland Waters Stocks

Harbor porpoises are small marine mammals. Adult males and females typically grow to 1.4–1.9 m, although females are heavier than males (76 kg compared to 61 kg). Their diet consists of demersal and benthic species, including herring, capelin and cephalopods. They inhabit waters east of Cape Flattery year-round and are often found in harbors, bays, and estuaries in water less than 200 m deep (Carretta et al. 2019) and may potentially occur in Sequim Bay and waters off of Gibson Spit.

3.2.8 California Sea Lion, Pacific Temperate Population

The California sea lion (*Zalophus californianus*) temperate population inhabits shallow coastal and estuarine waters along the coasts from Baja California into Canadian waters; however, major rookeries are not located near Washington coasts or the Puget Sound (Carretta et al. 2019). California sea lions are deep diving and feed mainly in upwelling areas on many prey types, including squid, anchovies, mackerel, rockfish, and sardines. It is possible that they may occur in Sequim Bay and Gibson Spit waters.

3.2.9 Harbor Seal, Washington Inland Waters Stocks

The harbor seal (*Phoca vitulina*) is part of the "true seal" family. The Washington Inland Waters Stock inhabits marine and estuarine areas along the Washington coast from Cape Flattery through the Puget Sound and San Juan Islands (Carretta et al. 2019), and commonly occur in Sequim Bay and Gibson Spit waters. Harbor seals are not considered to be a highly migratory species and generally remain local. Harbor seals mate at sea and females give birth during the spring and summer. They are deep and shallow divers and feed upon fish, shellfish and crustaceans.

3.2.10 Northern Elephant Seal

Northern elephant seals are in the phocid family and are also considered true seals. Males can be very large (> 4 m in length and up to 2,041 kg [Marine Mammal Center 2019]), approximately 2 to 10 times heavier than females (LeBoeuf et al. 2000). Females are typically 3 m in length, weighing 680 kg (Marine Mammal Center 2019). Northern elephant seals typically feed on cephalopods (squids and octopi) and teleosts (fish) but have also been known to feed on crustaceans (lobster, krill, shelled species), elasmobranchs (sharks and rays), cyclostomes (lamprey and hagfish), and tunicate (invertebrate marine animals) (Antonelis et al. 1994). They breed in winter (December to March) in Baja California, Mexico, to Oregon, USA (LeBoeuf et al. 2000; Haley et al. 1994). A lone female has used beaches at the entrance to Sequim Bay as a haulout location between 2016 and 2019. The most recent sightings on PNNL property (near the pier and on Travis Spit) were in July 2019. Individuals have also been observed to use the nearby Dungeness Spit, Protection Island, and Smith/Minor Islands as haulout locations (Jeffries et al. 2000).

3.3 Essential Fish Habitat

The Magnuson-Stevens Act defines EFH as those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity, and provides a means to address non-fishing impacts to EFH. EFH for this project area has been identified for the following species:

1. Pacific Coast Groundfish – All life stages
2. Coastal Pelagic Species – All life stages (including market squid, krill, and finfish)
3. Pacific Salmon – Juveniles and adults

3.3.1 Pacific Coast Groundfish

The Pacific Coast Groundfish Fisheries Management Plan (FMP) manages 94 species across a large and ecologically diverse area from Washington to southern California, including the Strait of Juan de Fuca (PFMC 2019b). Information on the life histories and habitats of these species varies in completeness, but the majority of the included species are those that live on or near the bottom of the ocean. It is impractical to describe and identify EFH for each life stage of the managed species. Thus, the description and identification of EFH must include habitat for an individual species but may be designated for an assemblage of species (PFMC 2019b).

EFH for this assessment includes all waters and substrate at depths less than or equal to 3,500 m to mean higher high-water level (MHHW). EFH for the Pacific Coast Groundfish also includes habitat areas of potential concern (HAPC), which for Washington includes all waters and the sea bottom in state waters from the 3 nautical mile boundary of the territorial sea shoreward to MHHW (PFMC 2019b). HAPCs for groundfish include estuaries, canopy kelp forests, seagrass beds, and rocky reefs, some of which can be found within Sequim Bay or the surrounding nearshore areas.

There are four groups of groundfish with species that potentially occur in the project area based on their occurrence in Puget Sound, per Appendix B.2 of the groundfish FMP (PFMC 2019a): flatfish; rockfish; roundfish; and sharks, skates, and chimaeras. There are several flatfish species that could potentially occur in the project area, including: butter sole (*Isopsetta isolepsis*), dover sole (*Microstomus pacificus*), Pacific sanddab (*Citharichthys sordidus*), and English sole (*Parophrys vetulus*). Although each of these species have different habitat requirements depending on life stage, they may be encountered in shallow-water coastal, bay, and estuarine habitats utilizing soft mud to sandy substrates and eelgrass beds. Rockfishes potentially in the project area include species such as the two rockfish species discussed under the ESA section (4.1). In addition, the brown rockfish (*Sebastes auriculatus*) may also occur in the project area as they are common in waters less than 53 m. Roundfish potentially in the project area include lingcod (*Ophiodon elongatus*) and Pacific cod (*Gadus macrocephalus*).

Lingcod are common in Puget Sound occupying intertidal areas to depths of 475 m. Larvae and juveniles mature in the sandy and rocky substrata in subtidal zones and are common in estuaries. Pacific cod (*Gadus macrocephalus*) occur in Puget Sound in shallow, soft-bottom habitats from 50 to 300 m in depth. From the subcategory of sharks, skates, and chimaeras, the spiny dogfish (*Squalus acanthias*) may occur in the project area. Most dogfish inhabit waters less than 350 m deep, and they occur from the surface and intertidal areas to greater depths. Small juveniles (<10 years old) are pelagic, while subadults and adults are mostly sublittoral-bathyal (PFMC 2019a).

3.3.2 Coastal Pelagic Species

The coastal pelagic species (CPS) fishery includes four finfish species, market squid, and krill. Species managed under the CPS FMP include the following:

1. Pacific Sardine (*Sardinops sagax*)
2. Pacific Mackerel (*Scomber japonicus*)
3. Northern Anchovy (*Engraulis mordax*)
4. Jack Mackerel (*Trachurus symmetricus*)
5. Market squid (*Loligo opalescens*)
6. Krill (*Euphausiid spp.* [most prevalent *E. pacifica*] and *Thysanoessa spinifera*).

All life stages of CPS finfish inhabit the water column and are not typically associated with bottom substrate. Most CPS finfish spawn several times a year when water temperature conditions are optimal. Both eggs and larvae are found near the surface near spawning adults at depths less than 50 m. CPS finfish eat phytoplankton and zooplankton by filter feeding or ingestion. Market squid inhabit the water column but are also associated with bottom substrate during spawning events and egg development, prefer oceanic salinities, and are rarely found in bays and estuaries. Market squid prey on copepods as juveniles, and small crustaceans and fish as adults. The EFH boundary for each individual CPS finfish and market squid is defined to be all marine and estuarine waters from the shoreline along the coasts of California, Oregon, and Washington, offshore to the limits of the exclusive economic zone (about 370 km [230 mi]). The EFH boundary is further characterized as being above the thermocline where sea surface temperatures range from 10°C to 26°C (50°F to 79°F). The southern boundary is not described here since it does not concern the project area.

The EFH boundary for larvae, juvenile, and adult *Euphausiid pacifica* and other krill species, except *T. spinifera*, is defined to occur from the shoreline seaward to the 1829 m (6000 ft) isobath, from the U.S.-Mexico border north to the U.S.-Canada border, and from the surface to 400 m (1312 ft) deep. This area is the same as for *T. spinifera* except that the isobath is measured out to 914 m (3000 ft) and depth is to 100 m (328 ft). CPS finfish are somewhat unpredictable and not particularly dependent on any single habitat type or spatially discrete location. HAPCs were thus not considered for CPS (PFMC 2019c).

3.3.3 Pacific Salmon

EFH for Pacific Coast salmon includes all water bodies currently or historically occupied by Pacific Fishery Management Council (PFMC)-managed Chinook salmon and Coho salmon in Washington, Oregon, Idaho, and California as well as Puget Sound pink salmon in Washington (PFMC 2016; 79 FR 75449). The geographic extent of EFH for Puget Sound Chinook salmon and Coho salmon includes the estuarine and marine areas extending from the extreme high tide line in nearshore and tidal submerged environments within state territorial waters out to the full extent of the exclusive economic zone (370.4 km) offshore of Washington, Oregon, and California north of Point Conception. The EFH for Puget Sound pink salmon is the same except the geographic extent is constricted to only include state territorial waters north and east of Cape Flattery, Washington. Estuaries like Sequim Bay are important HAPCs because they provide shallow, protected, nutrient rich habitat for marine organisms (PFMC 2014). Juvenile salmonids utilize estuarine aquatic vegetation beds (e.g., eelgrass, kelp) for refuge from predators taking advantage of the abundance of food resources as they transition to the open ocean.

4.0 Effects on Federally Protected Species, Marine Mammals, and Habitats

Each research activity described in Chapter 2 is assessed for adverse effects to protected species, critical habitats, and EFH. While impacts for each activity are described below, projects may involve more than a single activity type. Cumulative effects to habitats and species are also assessed. Overarching and activity-specific PDC, as well as other activity-specific monitoring, mitigation and BMPs that bound the impacts described below are identified in Chapters 2 and 5.

4.1 Surface Platforms and Buoys

Impacts from deployment and operation of surface platforms and buoys (potentially consisting of buoys, grated platforms, and solid platforms [Section 2.1]) are summarized in Table 4.1. Deployment of structures to float on surface waters in the action area (comprising Sequim Bay [Figure 1.2] and the portion of the Strait of Juan de Fuca depicted in Figure 1.4) have the potential to affect species through entanglement in mooring lines (note that the attachment of mooring lines to the seabed is considered under seabed installation activities [Section 4.3]) or shading of benthic substrate and the water column.

Species with pelagic life stages may come into contact with mooring lines, but fish species are not expected to be at risk for entanglement. Marine mammals, due to their larger size, may come into contact with mooring lines, but would most likely bump the line and continue in the same direction of travel. Projects would be required to reduce excess slack in mooring lines. Slack would be avoided through use of tensile materials that do not produce looping during slack tidal conditions, and/or use of mid-line floats that help keep vertical mooring lines taut. When a platform is deployed, marker buoys would accompany the deployment, and a buoy would “weathervane” around the surface platform, continually keeping any horizontal and vertical mooring lines semi-taut. Further, the environmental conditions track around the compass, and rarely would switch directions (180°) suddenly, such that the buoy would be pushed into a platform (causing enough slack in the horizontal mooring line to potentially form a loop). Even in the unlikely event that the winds were directly opposite the current, the drag area of the submerged platform hull is likely to be greater that the above-water portion of the marker buoy exposed to the wind, making it unlikely that the buoy would be pushed into a surface platform (causing enough slack in the horizontal mooring line to potentially form a loop). Fish, birds, and marine mammals that occur in Sequim Bay and the defined project area in the Strait of Juan de Fuca may be affected temporarily by deployment of platforms or buoys through temporary disruption in foraging, or avoidance of the small deployment areas, but these effects are anticipated to be minor as these species can forage in nearby unaffected pelagic and benthic habitats. As described in Section 3.2, marine mammals at risk of entanglement rarely occur in Sequim Bay and project areas in the Strait of Juan de Fuca. Furthermore, mooring line densities will be low and will be kept taut. As such, the risks of entanglement, are expected to be negligible.

Photic zone habitats in the nearshore areas of the overall project area would be minimally affected by grated platform deployments as these are constructed using grating or other light penetrating materials that let sunlight penetrate the water column (Section 2.1). Buoys would similarly have a relatively small shade footprint (Section 2.1), and would change location with tidal, wind, and wave movements and would similarly minimally affect critical habitat. Minor effects of each could include decreased light penetration and primary productivity, prey and forage fish productivity, bottom habitat diversity, and fish movement and prey capture, but are not expected to decrease the overall quality of critical habitat for each ESA-listed fish species in Table 4.1 and the quality of EFH for managed species, as structures will be placed at a distance 10 ft or more apart, with a set maximum of 15 buoys, 5 grated platforms and/or 3 solid platforms being deployed at one time across the entire action areas. However, buoys and grated platforms would be considered to potentially have more than minor adverse effects on critical habitat and EFH depending on deployment duration (Section 2.1). Shading by overwater structures may reduce or eliminate SAV or epibenthic organisms, thus reducing prey resources and refuge (Simenstad et al. 1999; Nightingale and Simenstad 2001b), though the significance of the effects is unclear. For example, Williams et al. 2003 observed that the ferry terminal structure did not seem to impede fry movement. Evidence is not present to suggest overwater structures can aggregate salmonid predators, including migratory birds (Taylor and Willey 1997, Nightingale and Simenstad 2001b).

Solid platforms would have a larger shade footprint than grated platforms or buoys (Section 2.1) and may have potentially more than minor adverse effects on critical habitat and EFH during even shorter deployments than buoys due to increased footprint. Any Section 2.1 activities deployed longer than 60 days outside the bull trout Tidal Reference Area 10 (Port Townsend) in-water work window would require compensatory mitigation using the modified PNNL Puget Sound Nearshore Habitat Conservation Calculator, thus minimizing structure effects.

Table 4.1. Likelihood of Impact between Federally Protected Species, Marine Mammals, Critical Habitat, and EFH with Operation of Surface Platforms and Buoys in the Project Areas.

Species or Habitat	Surface Platforms (Grated and Solid)	Buoys
NMFS Species or Critical Habitat		
Fish	Minor, temporary avoidance impact during deployment	Minor, temporary avoidance impact during deployment
Cetaceans	Minor, temporary avoidance impact during deployment; minor for entanglement with mooring lines	Minor, temporary avoidance impact during deployment; minor for entanglement with mooring lines
Pinnipeds	Minor, temporary avoidance impact during deployment; minor for entanglement with mooring lines	Minor, temporary avoidance impact during deployment; minor for entanglement with mooring lines
Sunflower Sea Star	Minor, temporary avoidance impact during mooring attachment	Minor, temporary avoidance impact during mooring attachment
EFH		
Pacific Coast Groundfish	Minor, temporary disruption of foraging during deployment	Minor, temporary disruption of foraging during deployment
Coastal Pelagic Species	Minor, temporary disruption of foraging during deployment	Minor, temporary disruption of foraging during deployment
Pacific Salmon	Minor, temporary disruption of foraging during deployment	Minor, temporary disruption of foraging during deployment
USFWS Species or Critical Habitat		
Bull Trout	Minor, temporary avoidance impact during deployment	Minor, temporary avoidance impact during deployment
Marbled Murrelet	Negligible	Negligible

4.2 PNNL Sequim Dock Installations

Impacts from dock sensor installations (Section 2.2) are summarized in Table 4.2. Installation of equipment or instruments on the PNNL-Sequim floating dock, pier and pilings that would extend into the water column from the structure or be attached to pilings would be limited to these locations, would be installed by hand and would not disturb the benthos. Therefore, it is unlikely that any protected species would be affected by the installation activity other than temporary avoidance by pelagic species during deployment and removal of equipment. These effects would be minor as these species can forage in nearby unaffected pelagic habitats. Installation activities on the dock and pilings would have negligible effects to benthic species and would not disrupt benthic habitats. Potential effects of installation of equipment at the PNNL Sequim dock and pilings are summarized in Table 4.2.

No effects are expected to critical habitats from dock/pier equipment installation activities, other than minor and temporary disruption of foraging for species that feed on pelagic prey. Temporary disruption in foraging for CPS and Pacific salmon may occur during deployment and removal activities, but the short duration of these activities would have minimal adverse effects on EFH for these species. For the benthic Pacific coast groundfish EFH, it is expected that deployment and retrieval of equipment from the PNNL-Sequim dock/pier would have negligible effects. Further, sensors would have a very small surface area and would thus have a miniscule shade footprint (Section 2.2), such that shading effects are anticipated to be minor for even longer duration deployments.

Table 4.2. Likelihood of Impact between Federally Protected Species, Marine Mammals, Critical Habitat, and EFH with Dock Sensor Installations and Seabed Installations in the Project Areas.

Species or Habitat	PNNL Sequim Dock Installations	Seabed Installations
NMFS Species or Critical Habitat		
Fish	Minor, temporary avoidance impact during deployment	Minor, temporary avoidance impact during deployment
Cetaceans	No Impacts	Minor, temporary avoidance impact during deployment
Pinnipeds	Negligible	Minor, temporary avoidance impact during deployment
Sunflower Sea Star	Negligible	Minor, temporary avoidance and habitat impact during deployment
EFH		
Pacific Coast Groundfish	Minor, temporary disruption of foraging during deployment	Minor, temporary disruption of foraging during deployment
Coastal Pelagic Species	Negligible	Minor
Pacific Salmon	Negligible	Minor
USFWS Species or Critical Habitat		
Bull Trout	Minor, temporary avoidance impact during deployment	Minor, temporary avoidance impact during deployment
Marbled Murrelet	No Impacts	No Impacts

4.3 Seabed Installations

Impacts from seabed installations (Section 2.3), are summarized in Table 4.2 above. Seabed surface installations greater than 60 days outside the tidal work window would also require mitigation in any given year. Species that associate with the benthos as primary habitat or foraging habitat in Sequim Bay (sunflower sea star, green sturgeon, Puget Sound bocaccio, and Puget Sound yelloweye rockfish) may be affected by seabed installation activities, although it is likely that the rockfish species would rarely occur within either the Sequim Bay or Juan de Fuca research areas due to lack of preferred habitat and appropriate depth. PDC for anchoring of instruments and equipment to the seabed (including cables running from the PNNL Sequim Campus shoreline to instruments in Sequim Bay channel) require a method that minimizes sedimentation and avoids areas with macroalgae or other submerged aquatic vegetation, unless the specific focus of the research is on such areas, in which case they would be considered under Section 2.9 instead. Species that forage in Sequim Bay may be temporarily affected by seabed installation activities through disruption of access to habitat near the in-water work. The footprint of individual projects would be small (Section 2.3) relative to the overall expanse of Sequim Bay and the Strait of Juan de Fuca, thus nearby, unaffected foraging habitat would occur in abundance adjacent to the specific project areas, and any effects during installation would be considered negligible. Direct disturbance of the sunflower sea star would be unlikely as the species is currently observed only occasionally in Sequim Bay (Section 3.1.10). However, any sunflower sea stars encountered would either move themselves (movement at 160 cm per minute [Heady et al. 2022]) or would be moved by hand, as appropriate, to avoid impacts from seabed installations (Section 2.3.1 and 2.3.2).

Bull trout critical habitat may possibly be affected by seabed installation activities in Sequim Bay. However, these effects are expected to be minor given the small overall footprint for potential seabed installation activities to occur, the temporary nature for installation activities and eventual removal of equipment and instruments, and the availability of critical habitat outside of these project areas.

All critical habitats identified for Sequim Bay (Puget Sound Chinook, Hood Canal summer chum, green sturgeon, Puget Sound bocaccio, Puget Sound yelloweye rockfish, Southern resident killer whales) may possibly be affected by seabed installation activities in Sequim Bay and the Strait of Juan de Fuca. However, these effects are expected to be minor given the small overall footprint for potential seabed installation activities to occur, the temporary nature for installation activities and eventual removal of equipment and instruments, and the availability of critical habitat outside of these project areas.

Effects to EFH from seabed installation and placement activities include disturbance of benthic habitat or temporary loss of habitat. The Pacific coast groundfish managed fishery group may be affected by this research activity. Such disturbance would also affect an HAPC, i.e., off Washington, all waters and sea bottom in state waters from the three nautical mile boundary of the territorial sea shoreward to MHHW. However, such a small disturbance area from individual projects would be insignificant. The seagrass HAPC for Pacific coast groundfish would not be disturbed for most installations because these areas would be specifically avoided. The CPS managed group and Pacific salmon adults and juveniles are not typically associated with sediment habitats with the exception of spawning market squid. However, market squid are rarely found in bays and estuarine waters and would not be expected to be abundant in the Sequim Bay project area; some squid could be found in the Juan de Fuca research area. Thus, seabed installation activities may have minor effects to EFH for Pacific Coast groundfish but would have minor effects on EFH for CPS and Pacific salmon.

4.4 Vessel Use

Vessel use in Sequim Bay and the Juan de Fuca research areas (Section 2.4) can include vessel based surveys, including non-invasive benthic surveys through videography, photography, vessel towed sensors/instruments. The activity type is not expected to have more than a minor and temporary effect on protected species and their foraging. Such effects are expected to be minimal for pelagic species as such disturbance would not likely be greater than that caused by typical vessel traffic. Effects to benthic species would be minor as benthic substrate may be temporarily disturbed during anchoring. Vessel use impacts to critical habitats in Sequim Bay and Juan de Fuca research areas are expected to be minimal as the temporary loss foraging opportunities due to vessel operations would not be greater than recreational boating traffic within these areas and there are no expected impacts to benthic habitats. The potential effects of vessel use are summarized in Table 4.3.

Foraging CPS and Pacific salmon could be temporarily displaced by vessels used during deployment and retrieval of scientific instruments or equipment, resulting in temporary lost foraging opportunities. Such effects are likely to be minimal as such disturbance would be similar to typical vessel traffic in all project areas. Groundfish would not be affected by vessel use in the project areas due to their benthic habitat preference. Therefore, vessel activity is expected to have minimal adverse impact on EFH for CPS and Pacific salmon, and no effect on EFH for Pacific coastal groundfish (Table 4.3).

Table 4.3. Likelihood of Impact between Federally Protected Species, Marine Mammals, Critical Habitat, and EFH with Operation of Vessels, Autonomous Vehicles and UASs in the Project Areas.

Species or Habitat	Vessel Use	Autonomous Vehicles (AUV/ASV)	UASs
NMFS Species or Critical Habitat			
Fish	Minor, temporary avoidance impact during deployment	Minor, temporary avoidance impact during deployment	Minor, temporary avoidance impact during deployment
Cetaceans	Minor, temporary avoidance impact during deployment	Minor, temporary avoidance impact during deployment	Minor, temporary avoidance impact during deployment
Pinnipeds	Minor, temporary avoidance impact during deployment	Minor, temporary avoidance impact during deployment	Minor, temporary avoidance impact during deployment
Sunflower Sea Star	Minor, temporary during anchoring	Minor, temporary disruption of habitat during deployment	Minor, temporary avoidance impact during deployment
EFH			
Pacific Coast Groundfish	Minor, temporary during anchoring	Minor, temporary disruption of foraging during deployment	Minor, temporary avoidance impact during deployment
Coastal Pelagic Species	Minor, temporary disruption of foraging during deployment	Minor, temporary disruption of foraging during deployment	Minor, temporary avoidance impact during deployment

Species or Habitat	Vessel Use	Autonomous Vehicles (AUV/ASV)	UASs
Pacific Salmon	Minor, temporary disruption of foraging during deployment	Minor, temporary disruption of foraging during deployment	Minor, temporary avoidance impact during deployment
USFWS Species or Critical Habitat			
Bull Trout	Minor, temporary avoidance impact during deployment	Minor, temporary avoidance impact during deployment	Minor, temporary avoidance impact during deployment
Marbled Murrelet	Minor, temporary avoidance impact during deployment	Minor, temporary avoidance impact during deployment	Minor, temporary avoidance impact during deployment

4.5 Autonomous Vehicle Operations

The use of remote or autonomous or unmanned underwater vehicles (AUV) or surface vehicles (ASV) (Section 2.5) is expected to have minimal effects on protected marine mammals or fish or seabirds as operations would avoid following or otherwise purposely harassing protected species. In many cases the AUV/ASV could carry instruments that have impacts separate from the operation of the vehicle (such as acoustics or lidar) and mitigation for those impacts would further reduce the already minimal effects of operation of the vehicle. Some protected species may temporarily avoid areas during deployment that would result in disruption in foraging. However, these effects are anticipated to be minor as the affected area would be very small in relation to the amount of nearby unaffected pelagic habitats available for foraging. Activities are of short duration, occurring on a daily cycle; therefore, impacts occur mainly at the time of sampling and are thus not considered duration dependent (Section 2.5). Operation of AUV/ASV would have minor effects to benthic species, as some projects may require the use of remote vehicles on the seabed. Operation of UAS (Section 2.5) would affect species if take-off and landing operations are conducted within the action areas. Pinnipeds behavior could be disrupted by the presence of an overhead UAS; it will be required that research areas be inspected prior to UAS deployment, and UAS will not be deployed if there are pinnipeds within 100 m of the deployment area. Further, flights within 200 yds of Protection Island and the boundary drawn around Dungeness Spit in Figure 1.2 are not allowed (PNNL 2023). The effects of AUV/UAS operation are summarized in Table 4.3.

Minor effects are expected to critical habitats from AUV/ASV operations, other than minor and temporary disruption of foraging for species that feed on pelagic prey (e.g., subadult bull trout). Temporary disruption in foraging for CPS and Pacific salmon may occur during AUV/ASV operations, but the short daily duration of these activities (Section 2.5) would have minimal adverse effects on EFH for these species. For the benthic Pacific coast groundfish EFH, it is expected that AUV/ASV operations would have minor effects as they would temporarily affect the benthos.

4.6 Benthic Surveys

Benthic characterization surveys would be conducted on or in the seabed, without collecting sediment as part of the project scope (Section 2.6.1). Sediment collection surveys (Section 2.6.1) would also be conducted using mechanical or manual methods and would be somewhat intrusive. Direct disturbance of the less mobile sea star (movement at 160 cm per minute [Heady et al. 2022]) via sediment collection would be unlikely as the species is currently observed only occasionally in Sequim Bay (Section 3.1.10) and sediment samples would be diffuse at any given time (Section 2.6.1). However, any sunflower sea stars inadvertently captured during sediment collection would be released or be moved by hand during manual sediment collection, as appropriate (Section 2.0). Neither benthic habitat and species characterization nor sediment collection is expected to have more than a minor and temporary effect on foraging opportunities for species that are in the area. Pelagic species that forage in Sequim Bay and the Strait of Juan de Fuca may be temporarily affected by characterization and collection activities, including the use of a portable freefall penetrometer (PFFP) through disruption of access to habitat near the sampling locations. Because nearby, unaffected foraging habitat occurs within and surrounding the project areas, any effects during characterization or collection activities would be considered negligible. Sediment collection will be limited to 30 yd^3 per year combined over the Sequim Bay and Juan de Fuca research areas. Additionally, autonomous crawlers would not be used within known forage fish spawning areas during spawning periods, unless a forage fish survey is first complete to allow work (see USACE 2012). The effects of benthic surveys and sediment sampling are summarized in Table 4.4.

As described in the previous Seabed Installations section, species that associate with the benthos as primary habitat or foraging habitat in Sequim Bay (green sturgeon, Puget Sound bocaccio, Puget Sound yelloweye rockfish) may be affected by benthic habitat and species characterization or sediment collection, although it is likely that the rockfish species would rarely occur within Sequim Bay or in the Juan de Fuca research area due to lack of preferred habitat and appropriate depth. Benthic habitat, species characterization and sediment collection activities are of short duration, occurring on a daily cycle; therefore, impacts occur mainly at the time of sampling and are thus not considered duration dependent (Section 2.6). Characterization and collection activities would affect a very small portion of the research area substrate. Therefore, although benthic species may be affected by characterization or collection, the temporary sampling activity within the project areas would not have more than a minor adverse impact, and these species could move to nearby unaffected habitat.

No effects are expected to critical habitats from benthic characterization surveys or sediment collection, other than minor and temporary disruption of foraging activity and minor substrate disturbance. All critical habitats identified for Sequim Bay and the Strait of Juan de Fuca (bull trout, Puget Sound Chinook, Hood Canal summer chum, green sturgeon, Puget Sound bocaccio, Puget Sound yelloweye rockfish, Southern resident killer whales) may possibly be affected by sediment sampling activities. However, these effects are expected to be minor given the small overall footprint for potential sediment sampling to occur, the temporary nature of sampling, and the availability of available critical habitat outside of these project areas.

Effects to EFH from sediment collection include direct benthic habitat disturbance or temporary loss of habitat. The Pacific coast groundfish managed fishery group may directly be affected by this research activity. Such disturbance would also affect an HAPC, i.e., off Washington, all waters and sea bottom in state waters from the three nautical mile boundary of the territorial sea shoreward to MHHW. However, such a small surface area of disturbance within the Sequim Bay and Juan de Fuca Research Areas would be insignificant. Also, the seagrass HAPC for Pacific coast groundfish would not be disturbed, as the project locations would be devoid of seagrass except as described in Sections 4.9 and 4.3. The CPS managed group and Pacific salmon adults and juveniles are not typically associated with sediment habitats except for spawning market squid. However, market squid are rarely found in bays and estuarine waters and would not be expected to be abundant in Sequim Bay, but some could be found in the Juan de Fuca project area. Thus, sediment collection activities may have minor effects to EFH for Pacific Coast groundfish and EFH for CPS and Pacific salmon.

Table 4.4. Likelihood of Impact between Federally Protected Species, Marine Mammals, Critical Habitat, and EFH from Benthic Surveys, Water Column Sampling, and Dye Releases.

Species or Habitat	Benthic Surveys	Water Column Sampling	Dye and Particulate Releases
NMFS Species or Critical Habitat			
Fish	Minor, temporary avoidance impact during deployment	Minor, temporary avoidance impact during deployment. Some juveniles susceptible to capture	Minor, temporary foraging disturbance
Cetaceans	Minor, temporary avoidance impact during deployment	Minor, temporary avoidance impact during deployment	Minor, temporary foraging disturbance
Pinnipeds	Minor, temporary avoidance impact during deployment	Minor, temporary avoidance impact during deployment	Minor, temporary foraging disturbance
Sunflower Sea Star	Minor effects during sediment collection	No impacts	Negligible
EFH			
Pacific Coast Groundfish	Minor, temporary disruption of foraging during deployment	Negligible	Negligible
Coastal Pelagic Species	Negligible	Minor, temporary disruption of foraging during deployment	Negligible
Pacific Salmon	Negligible	Minor, temporary disruption of foraging during deployment	Negligible
USFWS Species or Critical Habitat			
Bull Trout	Minor, temporary avoidance impact during deployment	Minor, temporary avoidance impact during deployment.	Minor, temporary foraging disturbance
Marbled Murrelet	Minor, temporary avoidance impact during deployment	Minor, temporary avoidance impact during deployment	Minor, temporary foraging disturbance

4.7 Water Column Sampling: Plankton, Invertebrates and Additional Parameters

Water column sampling for plankton, invertebrates and additional parameters, such as vessel based instrument towing would use very common sampling techniques for aquatic and marine research. Pelagic species that forage in Sequim Bay or the Strait of Juan de Fuca may be temporarily affected by this sampling, through disruption of access to habitat and disturbance during foraging near the sampling locations. Because nearby, unaffected foraging habitat occurs within and surrounding the project areas, any effects of water column sampling would be considered negligible as affected species could move to nearby areas.

Sampling that involves suspending equipment on cables or lines would have a small potential for entanglement of pinnipeds and small cetaceans. Research staff will be cognizant of marine mammals in the vicinity of sampling and will avoid deploying equipment if marine mammals are present, in addition to keeping lines and cables under tension. Juveniles of many of the listed fish species could be susceptible to capture during water column sampling. Vertebrate biota captured during sampling would be released (Section 2.7). Species that are primarily benthic, such as the green sturgeon and sunflower sea star, are not likely to be affected by water column sampling due to activities occurring in surface water and above the water column. No benthic research would take place under this activity type. The effects of water column sampling are summarized in Table 4.4.

No effects are expected to critical habitats from water column sampling, other than minor and temporary disruption of foraging activity. All critical habitats identified for Sequim Bay and the Strait of Juan de Fuca (Puget Sound Chinook, Hood Canal summer chum, green sturgeon, Puget Sound bocaccio, Puget Sound yelloweye rockfish, Southern resident killer whales) would likely be minimally affected by water column sampling because of the small overall volume of water affected, the temporary nature for sampling, and the availability of available critical habitat outside of these project areas.

Effects to EFH from water column sampling include temporary loss of foraging habitat. The Pacific salmon and CPS managed fishery groups may be affected directly by this research activity due to the potential capture of small protected species, such as juveniles. However, sampling would occur over very short time periods and affect a very small volume of water within the Sequim Bay and Juan de Fuca research areas such that the overall effect would be insignificant. Species within the Pacific coast groundfish managed group are not typically associated with the water column and are less likely to encounter or be affected by water column sampling. Thus, water column sampling activities may have minor effects to EFH for Pacific Salmon and CPS groups but would have negligible effects on EFH for Pacific coast groundfish.

4.8 Dye 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 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. 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. Instruments used to detect the presence of the dyes or tracers would be suspended in the water, installed on the seabed or a floating platform, or deployed on a surface vessel or AUV; impacts of these various equipment installations are discussed elsewhere.

The presence of the dyes or tracers in the water column would be short term, and they would be quickly diluted, thus impacts to critical habitats and EFHs would be negligible. These effects are summarized in Table 4.4.

4.9 Seagrass, Macroalgae, and Intertidal Research

Most PNNL research activities will be required to carefully avoid impacts to sensitive habitats such as eelgrass beds, submerged aquatic vegetation (SAV), and intertidal areas (overarching PDC #3 in Section 2). 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 (overarching PDC #3 in Section 2). Research projects would not want to significantly alter the habitats that are being researched, given the limit of no more than a total of 33 ft^2 of disturbance (including SAV collection) in any given area in any given year (66 ft^2 total) and the dispersed manner of collection (10 percent of the eelgrass in any given collection area [PDC in Section 2.9]) that would reduce the impact at any given point within a collection area and thus speed natural recovery through vegetative growth.

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% in the Pacific Northwest (Thom et al. 2008). In an unpublished study conducted over 2 years, PNNL monitored eelgrass recovery in 1 m^2 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 1 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 (Section 2.9) 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.

Most marine mammal species would not be found in the nearshore and intertidal areas except an occasional beached pinniped. Smaller marine mammals may forage in macroalgae beds. Juvenile salmon use eelgrass beds and kelp beds for cover and foraging. The sunflower sea star may be found infrequently in nearshore and intertidal areas and could move unaided to a suitable location (movement at 160 cm per minute [Heady et al. 2022]) (Section 3.1.10) or would be moved a short distance away by hand, if encountered in a research area, as appropriate (Section 2.9). The small-scale activities within these areas are not likely to significantly affect the utility of these areas for listed species but can cause minor, temporary disruption of foraging during deployment.

Seagrass and kelp beds are included in the critical habitat for Puget Sound chum and Puget Sound chinook. Because of the small-scale and short-term nature of PNNL research in seagrass, kelp beds, and intertidal areas, impacts to critical habitats are likely be minor. These effects are summarized in Table 4.5. Measures would still be tailored to the extent practicable to achieve a low and dispersed level of disturbance to the benthos (e.g., laid by hand and anchored with helical anchors or hand-placed weighted anchors) as described in Section 2.9 (Seagrass, Macroalgae, and Intertidal Research). However, some small research projects may occur within submerged aquatic vegetation areas.

Seagrass and kelp beds are EFH HAPCs for Pacific groundfish, and EFH for Pacific Salmon. Research in these areas may cause short-term and small-scale restriction of foraging habitat but would represent a small portion of the available EFH in these areas. The research activities would not have long-term detrimental effects on EFH and may ultimately increase the quantity and quality of these habitat areas. The effects are summarized in Table 4.5.

Table 4.5. Likelihood of Impact between Federally Protected Species, Marine Mammals, Critical Habitat, and EFH and Seagrass, Macroalgae, and Intertidal Research and Light Source Operation.

Species or Habitat	Seagrass, Macroalgae, and Intertidal Research	Light Sources, including Laser
NMFS Species or Critical Habitat		
Fish	Minor, temporary disruption of foraging during deployment	Minor, potential for ocular injury from stronger lasers and behavioral disruption for all light sources
Cetaceans	Minor, temporary disruption of foraging during deployment	Minor, potential for ocular injury from stronger lasers and behavioral disruption for all light sources

Species or Habitat	Seagrass, Macroalgae, and Intertidal Research	Light Sources, including Laser
Pinnipeds	Minor, temporary disruption of foraging during deployment	Minor, potential for ocular injury from stronger lasers and behavioral disruption for all light sources
Sunflower Sea Star	Minor, temporary disruption during deployment	Minor, potential for behavioral disruption for all light sources during operation
EFH		
Pacific Coast Groundfish	Minor, temporary disruption of foraging during deployment	Minor, temporary avoidance impact during operation.
Coastal Pelagic Species	Negligible	Minor, temporary avoidance impact during operation.
Pacific Salmon	Minor, temporary disruption of foraging and sheltering during deployment	Minor, temporary avoidance impact during operation.
USFWS Species or Critical Habitat		
Bull Trout	Minor, temporary avoidance impact during deployment	Minor, potential for ocular injury from stronger lasers and behavioral disruption for all light sources.
Marbled Murrelet	Negligible	Minor, potential for ocular injury from stronger lasers and behavioral disruption for all light sources.

4.10 Light Emitting Devices

Flood lights and strobe lights may be required to support photography or monitoring purposes. It is expected that light generation from the artificial sources will be temporary and intermittent, with the exception of shrouded biofouling lights which will be continuous. Shrouded lights are not expected to create impacts above intermittent light sources. 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. For instance, a cat has a measured reflectivity of 44% based on the *tapetum lucidum* and it is assumed that marine mammals would have at least this much based on their underwater optical environment (Zorn et al. 2000). Neither of these factors have been well measured. The topic is mostly based on assumptions of other animals that have been measured (Zorn et al. 2000).

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 2.1, 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 4.6 provides the calculated NOHD distances for the green laser described in Table 2.1 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 4.6 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.

The values in Table 4.6 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.

Table 4.6. Marine mammal MPE and NOHD for 0.25-s and 10-s Exposures to the 532 nm Green Laser described in Table 2.1.

		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

A likely scenario is a single exposure pulse, which would decrease the NOHD values. Figure 4.1 illustrates NOHD values for single exposures for a fur seal (the most sensitive mammal in Zorn et al. [2000]). 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. Figure 4.2 shows the estimated irradiance by distance from the source for attenuation coefficients of 0.4 and 0.7 for the green laser described in Table 2.1. 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/m^2, which suggests a detection range of about 18 to 30 m. Cetaceans are thought to have similar visual abilities (Perrin et al. 2009).

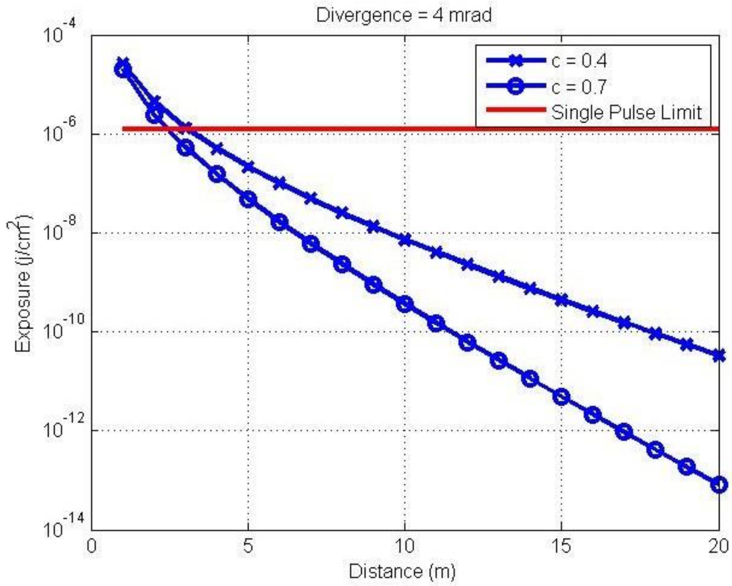

Figure 4.1. Estimated Fur Seal NOHD Ranges for Injury from Single-Pulse Exposures Assuming Attenuation Factors of 0.4 m^{-1} or 0.7 m^{-1}

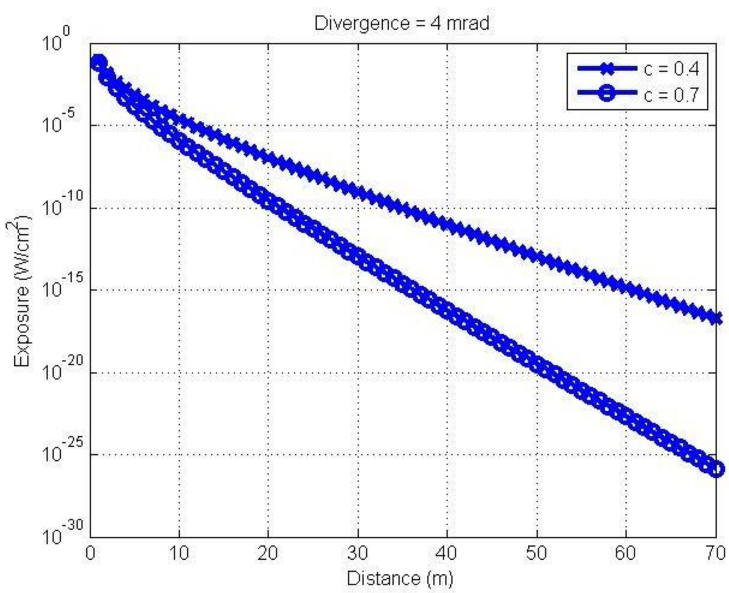

Figure 4.2. Beam Visibility at Zero Scattering Angle (looking directly into the transmitter)

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 and MAMUs would be partially mitigated using trained PSOs during non-eye-safe laser / LiDAR operations (PDC Section 2.10). All non-eye-safe laser / LiDAR operations would be halted if any pinnipeds or murrelets are observed within 50 m of an in-water project site or observed within an area prior to or during aerially scanning (PDC Section 2.10). 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. Overall effects of light source operations on ESA-listed species and marine mammals are summarized in Table 4.5.

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 PDC. Temporary use of light sources during operation could temporarily affect the water column and may discourage use of habitat in the area. 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. Potential effects of light source operations on critical habitats are summarized in Table 4.5.

Artificial light sources (specifically those not known to be potentially harmful to organisms' eyes) may attract forage fish and are deemed to not be potentially harmful to foraging MAMUs (FWS 2018 LOC 01EFW00-2018-I- 1605). 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]). Above- and underwater activities where it may be used are described in Section 2.10 where 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 (DOE 2019). MAMUs are roughly 25 cm in length and may be too small to be detected at 10 m, and the birds may incur effects beyond 10 m. For this reason, the area within 50 m of all underwater activities employing green lasers (based on the attenuation information provided in this section) will be monitored by a PSO for the purpose of shutting down the laser if a MAMU is observed (Section 2.10). 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).

As indicated in this section, aerial bathymetric lidar applications of the green laser have the potential to affect MAMUs on the surface because attenuation is much less in air than in water and may extend hundreds of meters. The areal extent of the laser footprint on surface water (produced by a single emission) and the extent of the overall area of surface water that could be affected by all laser emissions needed to acquire bathymetric data, and within which MAMUs may be affected, would depend on a variety of factors and would be case-specific. Consequently, DOE will initiate verification for aerial bathymetric lidar applications of the green laser to determine the case-specific effects and will collaborate with the Services for case-specific best practices.

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. Potential effects of light source operations on EFH are summarized in Table 4.5.

4.11 Acoustic Device Operation

Underwater noise from human activities is a significant concern for marine mammals, fish, and diving birds 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. 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. PNNL research activities are not likely to include impulsive sound sources, and all the equipment and instruments described below are considered non-impulsive.

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 (Table 4.7). 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 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 (Table 4.7).

Table 4.7. Marine Mammal Underwater Functional Hearing Range and Injury/Behavior Thresholds

Functional Hearing Group	Relevant Species	Functional Hearing Range[1]	Level A (Injury Threshold)[1,2,3]	Level B (continuous/ intermittent)[1,2]
Low-frequency cetaceans	Humpback and Gray whales	7 Hz to 35 kHz	199 dB SEL_{cum}[4]	120 dB_{rms}/160 dB_{rms}
Mid-frequency cetaceans	Killer whale	150 Hz to 160 kHz	198 dB SEL_{cum}	120 dB_{rms}/160 dB_{rms}
High-frequency cetaceans	Harbor porpoise	275 Hz to 160 kHz	173 dB SEL_{cum}	120 dB_{rms}/160 dB_{rms}
Phocid pinnipeds	Harbor seal	50 Hz to 86 kHz	201 dB SEL_{cum}	120 dB_{rms}/160 dB_{rms}
Otariid pinnipeds	California sea lion	60 Hz to 39 kHz	219 dB SEL_{cum}	120 dB_{rms}/160 dB_{rms}

[1] NOAA 2018a
[2] Reference level 1 μPa^2-s at 1m
[3] Thresholds are for non-impulsive sounds
[4] Sound exposure level

Acoustic injuries to fish have primarily been considered for 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 (Table 4.8). 150 dB RMS is an accepted, conservative estimate of the threshold for behavioral effects in fish (Caltrans 2015; Teachout 2012).

MAMU vocalizations range from 480 Hz to 11 kHz (SAIC 2011) and birds in general are not sensitive to frequencies above 20 kHz (Beason 2004) with a peak at approximately 3 kHz (SAIC 2011). Teachout (2012) assumes a functional hearing range of approximately 500 Hz to 12.5 kHz. Thresholds for hearing injury and barotrauma were determined through consensus summarized in SAIC (2011) (Table 4.8). There is very little information about the effect of underwater sound on diving bird behavior; USFWS uses 150 dB_{RMS} as the behavioral threshold (Teachout 2012).

Table 4.8. Functional Hearing Range and Injury and Behavioral Thresholds for Fish and Marbled Murrelet

Fish	Functional Hearing Range	Injury threshold[(a)]		Behavioral threshold
	10 Hz to 4 kHz	187(<2g)/183(>2g) dB SEL_{cum}		150 dB_{rms}
Marbled Murrelet	Functional Hearing Range[(b)]	Injury threshold[(c)]	Barotrauma[(c)]	Behavioral threshold[(b)]
	500 Hz to 12.5 kHz	202 dB SEL_{cum}	208 dB SEL_{cum}	150 dB_{rms}

(a) Caltrans 2015
(b) Teachout 2012
(c) SAIC 2011

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 (Appendix C). The USFWS provides guidance on calculating effects isopleths for pile driving (USFWS 2014) but not for other sound sources. Standard equations were used to estimate injury and behavioral isopleths for MAMUs for a variety of sound sources (Appendix C).

Table 4.9 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. The effect isopleths (distance to the reference sound pressure level) were calculated based on 6 h/d operations and several other parameters described in Appendix C. 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 SEL_{cum} lower than for the other groups of marine mammals). The behavioral isopleth is the same for all marine mammal groups.

Table 4.9. Estimated Injury and behavioral isopleths for different acoustic sources

	Fish Effect Isopleths			Marine Mammal[1] Effect Isopleths		Marbled Murrelet Effect Isopleths		
Sound source[2]	**Injury: <2g**	**Injury: >2g**	**Behavior**	**Auditory Injury**	**Behavior**	**Auditory Injury**	**Barotrauma**	**Behavior**
Benthos Communications Modem[3]	OHR[4]	OHR	OHR	4 m	16 m	OHR	0 m	OHR
EdgeTech eBOSS Sub-bottom Profiler[3, 5]	OHR	OHR	OHR	76 m	215 m	0.1 m	0 m	1,000 m
Navy J-11 Sound Projector[2]	17 m	9.0 m	3.4 m	1.0 m	342 m	0.9 m	0.4 m	3.4 m
Kongsberg SSBL underwater positioning system[3]	OHR	OHR	OHR	30 m	86 m	OHR	0 m	OHR
Simrad 38 kHz echosounder[3, 6]	OHR	OHR	OHR	4,971 m	4,642 m	OHR	23.1 m	OHR
icTalkHF	OHR	OHR	OHR	0.6 m	0	0 m	NC[7]	0 m
Surface Acoustic Pinger (SAP)	OHR	OHR	OHR	32 m	32 m	0.8 m	NC	100 m
APL Custom Transmitter	OHR	OHR	OHR	2 m	22 m	NC	NC	NC
Small-scale tidal turbines[3]	9 m	5 m	1.0 m	41 m	100 m	0.5 m	0.2 m	1.0 m

[1]Marine Mammal injury isopleths are for high-frequency cetaceans; auditory injury isopleths for other marine mammal groups are usually 1 to 3 orders of magnitude smaller. The behavioral isopleth is the same for all marine mammal groups.
[2] Frequencies and sound pressure levels for each source is provided in Table 2.2.
[3]Analysis provided in Appendix C
[4]OHR=outside of hearing range, isopleths not calculated.
[5]eBOSS sub-bottom profiler is aimed downward from approximately 5 m above the substrate
[6]The Simrad echosounder is not omnidirectional, it is directional with a maximum 18-degree arc.
[7]NC = not calculated

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 4.9). 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) (Section 2.11). 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.

Most of the sound sources are outside of the hearing range for fish, and some are also outside the hearing range for MAMU. Sound can still have barotrauma effects if it is outside the hearing range, so those effects are calculated for the MAMU (Table 4.9). Most of the sound sources have fairly small injury isopleths for fish and murrelets and are all are less than 24 m. The Surface Acoustic Pinger and the eBoss sub-bottom profiler may affect the behavior of MAMUs out to approximately 100 m and 1000 m, respectively. However, the eBoss is towed approximately 5 m above the substrate and is pointed down, thus much of the water column is not ensonified at levels that would cause an effect.

Therefore, 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, as detailed in Section 2.11, 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 or EFH. The potential effects of acoustic generating devices on species, critical habitat and EFH are summarized in Table 4.10.

Table 4.10. Likelihood of Impact between Federally Protected Species, Marine Mammals, Critical Habitat, and EFH with Acoustic Operations

Species or Habitat	Impact of Acoustic Operations
NMFS Species or Critical Habitat	
Fish	Minor, potential for injury but most of the likely sound sources are outside of hearing range. Some sounds may cause temporary behavioral disruption.
Cetaceans	Minor to Adverse, potential for injury for all cetaceans, may be classed as adverse impacts to high-frequency cetacean species (i.e., porpoises), other cetaceans have a moderate potential for auditory injury. Behavioral disruption may affect large areas for sources with high sound pressure level.

Species or Habitat	Impact of Acoustic Operations
Pinnipeds	Minor to moderate, potential for injury from some sound sources, but sensitivity is much less than high-frequency cetaceans. Behavioral disruption may affect large areas for sources with high sound pressure level.
Sunflower Sea Star	Indeterminable, hearing ability unknown (Section 3.1.10)
EFH	
Pacific Coast Groundfish	Minor, temporary avoidance impact during operation when sounds are within hearing range.
Coastal Pelagic Species	Minor, temporary avoidance impact during operation when sounds are within hearing range.
Pacific Salmon	Minor, temporary avoidance impact during operation when sounds are within hearing range.
USFWS Species or Critical Habitat	
Bull Trout	Minor, potential for injury but most of the likely sound sources are outside of the fish hearing range. Some sounds may cause temporary behavioral disruption.
Marbled Murrelet	Minor to moderate, potential for injury or behavioral disruption. Several of the potential sound source types operate at frequencies beyond the murrelet hearing range.

The range of sound sources evaluated in Table 4.9 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. 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 in Section 2.11 PDC.

Operation of sound emitting devices will be discontinued when marine mammals or MAMUs are observed in the surveyed area. Operation may recommence after marine mammals or MAMUs have left the surveyed area.

MAMU behavior effect isopleths are likely to extend over much greater distances than injury effect isopleths due to the much lower effect threshold, and the consequences of behavioral effects (e.g., avoidance, temporary threshold shift) are considered relatively minor (compared to those of injury [e.g., permanent threshold shift, barotrauma]), rendering PSO coverage of large areas (based on observer visibility of 50 m) logistically impractical and not commensurate with the level of potential effects. Consequently, PNNL will determine the number of PSOs for any area of behavioral effect based on distance alone, as described in Section 2.9.

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 (Table 4.8). 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.

4.12 Electromagnetic Field Operations

EMF may be generated by devices or cables. All species that occur in the project areas may be affected by electromagnetic fields (EMF) from research equipment that emits such, with those that move slowly (e.g., sea star) being more susceptible. Electromagnetic fields (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 PNNL proposes 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.

As reviewed in Gill and Desender (2020), research to date has largely been limited to controlled laboratory simulations of 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. Potential effects of point source EMF and EMF generated by cable conveyance are summarized in Table 4.11.

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. Potential effects of point source EMF and EMF generated by cable conveyance are summarized in Table 4.11.

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. Temporary EMF fields would be generated during operation and could temporarily affect the groundfish benthic EFH or the CPS and Salmon species pelagic 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. The small relative area and temporary operations are expected to have minimal effects to use of EFH 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. The relatively small area affected renders any effects on overall EFH minor. Potential effects of point source EMF and EMF generated by cable conveyance are summarized in Table 4.11.

Table 4.11. Likelihood of Impact between Federally Protected Species, Marine Mammals, Critical Habitat, and EFH with Electromagnetic Field Devices and Cables, Marine Energy Devices and Tidal Turbine Research.

Species or Habitat	EMF Devices	Cables (EMF)	Community and Research Scale Marine Energy Devices	Tidal Turbine Research
NMFS Species or Critical Habitat				
Fish	Minor, temporary avoidance impact during deployment and operation	Minor, temporary avoidance impact during deployment. Minor effects during operation.	Minor, temporary avoidance impact during deployment. Minor to moderate effects during operation.	Minor, temporary avoidance impact during deployment. Minor to adverse effects during operation.
Cetaceans	Minor, temporary avoidance impact during deployment and operation	Minor, temporary avoidance impact during deployment. Minor effects during operation.	Minor, temporary avoidance impact during deployment. Minor to moderate effects during operation.	Minor, temporary avoidance impact during deployment. Minor to adverse effects during operation.
Pinnipeds	Minor, temporary avoidance impact during deployment and operation	Minor, temporary avoidance impact during deployment. Minor effects during operation.	Minor, temporary avoidance impact during deployment. Minor to moderate effects during operation.	Minor, temporary avoidance impact during deployment. Minor to adverse effects during operation.
Sunflower Sea Star	Minor, temporary avoidance impact during deployment and operation	Minor, temporary avoidance impact during deployment and operation.	Minor, temporary avoidance impact during deployment of seabed-installed devices.	Minor, temporary avoidance impact during deployment of seabed-installed devices. No effects during operation.
EFH				
Pacific Coast Groundfish	Minor, temporary disruption of foraging during deployment	Minor, temporary avoidance impact during deployment. Minor effects during operation.	Minor, temporary avoidance impact during deployment. Minor effects during operation.	Minor, temporary avoidance impact during deployment. Minor effects during operation.
Coastal Pelagic Species	Minor, temporary disruption of foraging during deployment and operation	Minor, temporary avoidance impact during deployment. Minor effects during operation.	Minor, temporary avoidance impact during deployment. Minor to moderate effects during operation.	Minor, temporary avoidance impact during deployment. Minor to adverse effects during operation.
Pacific Salmon	Minor, temporary disruption of foraging during deployment and operation	Minor, temporary avoidance impact during deployment. Minor effects during operation.	Minor, temporary avoidance impact during deployment. Minor to moderate effects during operation.	Minor, temporary avoidance impact during deployment. Minor to adverse effects during operation.
USFWS Species or Critical Habitat				
Bull Trout	Minor, temporary disruption of foraging during deployment and operation	Minor, temporary disruption of foraging during deployment and operation	Minor, temporary avoidance impact during deployment. Minor to moderate effects during operation.	Minor, temporary avoidance impact during deployment. Minor to adverse effects during operation.
Marbled Murrelet	Negligible	Negligible	Minor, temporary avoidance impact during deployment. Minor effects during operation.	Minor, temporary avoidance impact during deployment. Minor to adverse effects during operation.

4.13 Community and Research Scale Marine Energy Devices

Marine energy devices, including wave energy converters (WECs) are described in Section 2.13. 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 and EFH 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). (Note: marine energy devices as described in Section 2.13 are thought to be more benign than tidal turbines [discussed in Section 2.14] with respect to collision risk because there are fewer submerged moving parts that have collision potential [Sparling et al. 2020]). Noise and EMF generated from operation are covered in Sections 4.11 and 4.12, respectively. Devices can extend into the water column from the surface or seabed where they may be installed (Figure 2.3). 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. 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 in Section 2.13 will be followed.

Critical habitats and EFH may be temporarily affected by deployment of marine energy devices. However, the footprint of such installations is expected to be minor compared to nearby unaffected critical habitat and EFH. Table 4.11 summarizes the potential for effects to protected species, critical habitat, and EFH from wave energy devices given implementation of PDC in Section 2.13.

Cetaceans, pinnipeds, and fish may swim away from operating marine energy 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), recent field studies around operating marine energy devices indicate that marine mammals can detect the devices acoustically and use avoidance behaviors to avoid coming near devices.

Critical habitats and EFH may be temporarily affected by deployment of marine energy devices on the seabed, or installation on the surface with a pelagic profile. Operation of marine energy devices with higher approach velocities may entrain forage species. However, the footprint of such installations is expected to be minor with regard to nearby unaffected habitats and EFH (Section 2.13). Table 4.11 summarizes the potential for effects from marine energy devices.

4.14 Tidal Turbine Research

Tidal turbines comprise horizontal and vertical axis turbines (described in Section 2.14) that extend into the water column from installation on the seabed or on the surface. Use of floating platforms for tidal turbine installations is considered in Section 4.1. Noise and EMF generated from operation are covered in Sections 4.11 and 4.12, respectively. Turbine noise is below noise levels typically emitted by fishing and recreational vessels (Sparling et al. 2020). Tidal turbines are thought to have greater collision risk than WECs (discussed in Section 2.13) (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 and EFH 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 4.3. This can also be viewed as a cumulative distribution function (Figure 4.4), 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% 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.

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 poor (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). Wet renewables are predicted to impact seabird populations through collision, disturbance, habitat loss and changes to food availability. However, few devices have been deployed to enable monitoring of impacts and there have been few studies of the ecological implications and magnitude of any impacts to seabird populations (Robbins 2017). A seabird species' vulnerability could differ greatly among deployment locations and thus environmental effects assessments should quantify habitat-use using dedicated and site-specific surveys to reduce uncertainty (Waggitt et al. 2017).

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) (such as described for murrelets in Sections 3.1.12 and Section 5.2.1 and Appendix D]), 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 (Figure 2.6), 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.

Given the lack of documentation showing an increase in fish or marine mammal or diving seabird 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). Consequently, given the substantial layers of uncertainty about effects, DOE chooses to take a conservative approach regarding potential impacts 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 (PDC in Section 2.14) and information obtained from monitoring (Section 5). The monitoring protocols in Sections 5.3 and 5.2 were developed in response to perceived collision risk to MAMUs, marine mammals, and fish. PNNL PSO monitoring will be carried out to gather information about the spatiotemporal distribution of murrelets at the time of turbine deployment and decommissioning (Section 5.2), and subsea detection devices will be used to monitor for potential collisions and nearfield interactions of murrelets, marine mammals, and fish with turbines (Section 5.3).

Critical habitats and EFH may be temporarily affected by deployment of tidal turbines on the seabed, or installation on the surface with a pelagic profile. Collision of forage species may result from tidal turbine operation. However, the footprint of such installations is expected to be minor with regard to nearby unaffected habitats and EFH (Section 2.14). Table 4.11 summarizes the potential for effects from tidal turbines.

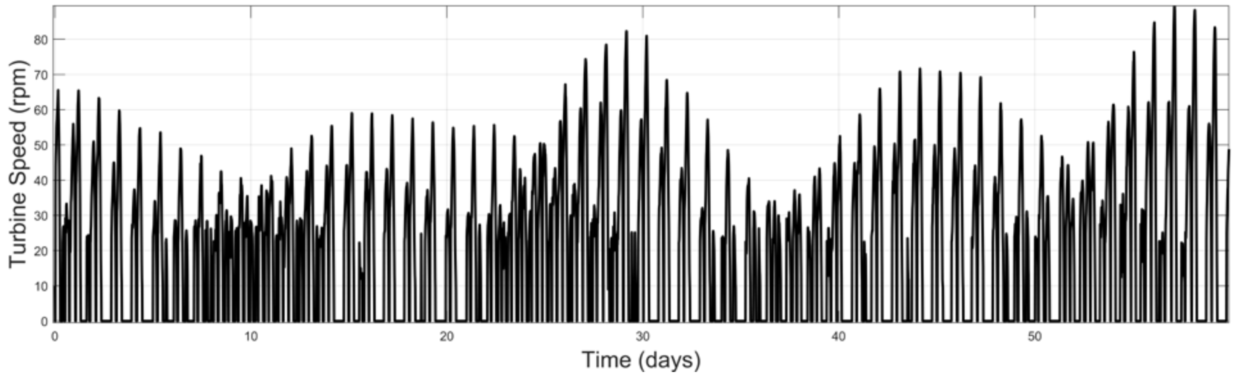

Figure 4.3 Two-Month Simulation of Rotation Rate of an 86-cm Diameter Vertical-Axis Turbine

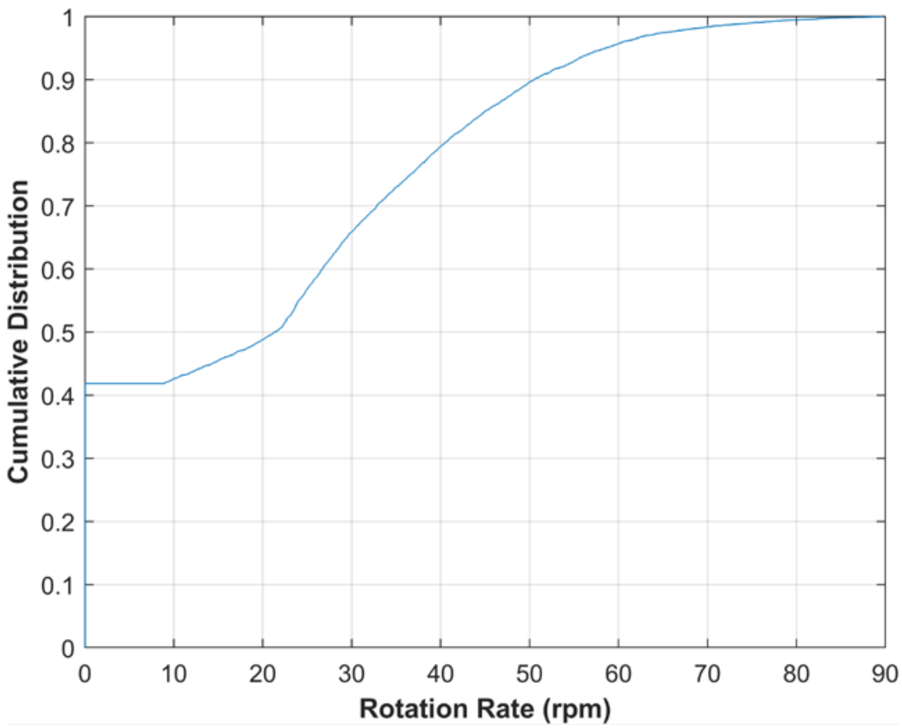

Figure 4.4. Example Cumulative Distribution Function of Turbine Rotation Rate

4.15 Effects Determinations by Species

This section includes effects determinations for all activities combined assuming implementation of activity-specific PDC in Section 2. Effects determinations for NMFS and FWS ESA-listed Species and critical habitat, and NMFS non-listed marine mammals are provided in **Error! Reference source not found.**. Effects determinations for EFH are provided in

Table 4.13.

Table 4.12. NMFS and USFWS ESA-Listed Species, Critical Habitat, and NMFS Non-Listed Marine Mammal Effects Determinations for Combined Research Activities Covering Research Activities Covering the Action Area (Sequim Bay and Juan de Fuca project areas [Figure 1.1])).

NMFS Federally Protected Species/Habitat	Effect Determination	USFWS Federally Protected Species/Habitat	Effect Determination
Puget Sound Chinook	LAA[1]	Bull Trout	LAA
Puget Sound Chinook CH	NLAA[2]	Bull Trout CH	NLAA
Hood Canal Summer Chum	LAA	Marbled Murrelet	LAA
Hood Canal Summer Chum CH	NLAA	Marbled Murrelet CH	NE[3]
Puget Sound Steelhead	LAA		
North American Green Sturgeon	LAA		
Pacific Eulachon	LAA		
Puget Sound Bocaccio	LAA		
Puget Sound Bocaccio CH	NLAA		
Puget Sound Yelloweye rockfish	LAA		
Puget Sound Yelloweye rockfish CH	NLAA		
Southern Resident Killer Whale	LAA		
Humpback Whale	LAA		
Non-ESA-listed Cetaceans	LAA		
Non-ESA-listed Pinnipeds	LAA		
Sunflower Sea Star	NLAA		

[1] LAA = Likely to adversely affect
[2] NLAA = Not likely to adversely affect
[3] NE = No effect

Table 4.13. EFH Effects Determinations for Combined Research Activities Covering the Action Area (Sequim Bay and Juan de Fuca project areas [Figure 1.1]).

Activity	Pacific Coast Groundfish	Coastal Pelagic Species	Pacific Salmon
Surface Platforms and Buoys	Minor effects, NLAA	Minor effects, NLAA	Minor effects, NLAA
PNNL Sequim Dock Installations	Minor effects, NLAA	Minor effects, NLAA	Minor effects, NLAA
Seabed Installations	Minor effects, NLAA	No adverse effects	No adverse effects
Vessel Use	No adverse effects	No to minor adverse effects	No to minor adverse effects
Autonomous Vehicle Surveys	Minor effects, NLAA	Minor effects, NLAA	Minor effects, NLAA
Benthic Surveys	Minor effects, NLAA	No adverse effects	No adverse effects
Water Column Sampling: Plankton, Invertebrates and Additional Parameters	No adverse effects	Minor effects, NLAA	Minor effects, NLAA
Dye and Particulates Releases	No adverse effects	No adverse effects	No adverse effects
Seagrass, Macroalgae and Intertidal Research	Minor effects, NLAA	No adverse effects	Minor effects, NLAA
Light Emitting Devices	Minor effects, NLAA	Minor effects, NLAA	Minor effects, NLAA
Acoustic Devices	Minor effects, NLAA	Minor effects, NLAA	Minor effects, NLAA
EMF Operations	Minor effects, NLAA	Minor effects, NLAA	Minor effects, NLAA
Community and Research Scale Marine Energy Devices	Minor effects, NLAA	Minor effects, NLAA	Minor effects, NLAA
Tidal Turbine Research	Minor effects, NLAA	Minor effects, NLAA	Minor effects, NLAA

* NLAA = Not likely to adversely affect

5.0 Monitoring Protocols

The below protocols are focused on PNNL protected species observer (PSO) requirements (Section 5.1) and tidal turbine deployment monitoring. Section 5.2 presents a monitoring protocol for above water monitoring of marbled murrelets (MAMU). Section 5.3 presents underwater monitoring during tidal turbine deployments.

PNNL will commit to underwater monitoring (Section 5.4) (does not entail in situ monitoring via physical presence by observers) during tidal turbine deployment. PNNL will use the monitoring results and the results of displacement effect research (even if no observation or no effect is documented) to adaptively manage tidal turbine deployments. Monitoring results and any relevant new information will be reviewed annually to make any warranted changes to the monitoring. Changes may include modifications to monitoring design, methods, duration, goals, cessation of monitoring, or additional monitoring. Each year, DOE, NMFS and USFWS will review the PBA, including monitoring for tidal turbine deployment. DOE will report the underwater monitoring results to USFWS and NMFS, and the agencies will collaborate regarding the impacts of tidal turbines, effectiveness of monitoring methods, and path forward for future tidal turbine research and monitoring.

5.1 PNNL Protected Species Observer Guidelines

PNNL PSOs are needed for a variety of project activities. Therefore, requirements are listed below to explicitly guide personnel:

- PSOs will be deemed qualified to monitor using documentation in Section 5.1.1 and as part of their role will provide data forms using the template listed in Section 5.1.2.
- PSOs will follow observing distances stipulated in Section 2 (relative to activity type), which are explicitly listed within the project specific biological review.
- For deployments requiring MAMU PSOs, additional considerations are needed to adequately survey for MAMU. Therefore, a separate Above Water Marbled Murrelet (MAMU) Monitoring (Section 5.2) describes MAMU and specifies additional requirements.

5.1.1 PNNL Protected Species Observer (PSO) Qualifications Form

The form in this section will be part of project documentation for any project requiring a PNNL PSO. The form is project specific and may need to be updated as project scope changes.

Project Number: ______________ Point of Contact: ___________

Certain on-water research activities at PNNL – Sequim or by PNNL project managers (PMs) require PNNL Protected Species Observers (PSO) to observe for marine mammals, including those that are ESA-listed, and/or ESA-listed species within certain distances from the activity location. These observing duties are part of the mitigation procedures to reduce the likelihood of effects on marine mammals or ESA-listed species as described in consultations with the US Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) under the Endangered Species Act and the Marine Mammal Protection Act, as applicable. PSOs at PNNL require on-water experience observing and recognizing marine mammals, including those that are ESA-listed, sufficient for recording presence/absence of individuals belonging to broad taxonomic groups (cetaceans, pinnipeds, etc.) (not necessarily for identifying to species level as is expected of a NMFS-certified MMOs). The PSO at PNNL – Sequim may also be required to identify ESA-listed species (e.g., marbled murrelet) to the species level, in order to not interrupt project operations based on misidentification of similar species. The following list of qualifications (adapted from NOAA Fisheries 2020)[1] is required for PNNL staff to be a PSO. Note that ESA-listed species has been added to Nos. 4 and 7.

1. Visual acuity in both eyes (correction is permissible) sufficient to discern moving targets at the water's surface with ability to estimate target size and distance. Use of binoculars or spotting scope may be necessary to correctly identify the target.
2. Advanced education in biological science, wildlife management, mammalogy or related fields (Bachelor's degree or higher is preferred), or equivalent traditional knowledge.
3. Experience and ability to conduct field observations and collect data according to assigned protocols (this may include academic experience).
4. Experience or training in the field identification of marine mammals (cetaceans and pinnipeds) and ESA-listed species.
5. Sufficient training, orientation or experience with vessel operation and on-water research activities to provide for personal safety during observations.
6. Writing skills sufficient to prepare a report of observations. Reports should include such information as the number, type, and location of marine mammals observed; the behavior of marine mammals in the area of potential sound effects during construction; dates and times when observations and in-water construction activities were conducted; dates and times when in-water construction activities were suspended because of marine mammals, etc.
7. Ability to communicate orally, by radio or in person, with project personnel to provide real time information on marine mammals or ESA-listed species observed in the area, as needed.

The PNNL OSD Biological Resources Subject Matter Expert (SME) will be responsible for determining those staff that qualify as PSOs for observing during on-water research activities. Note that a single staff may function as the PSO for both marine mammals and ESA-listed species if qualified for both. The list of potential PSOs will be provided to the Environmental Research Permitting (ERP) SME and Biological Resources SME for documentation purposes in the project permitting file. This Designated Observer Qualifications Form, with any reporting requirements, will be added to the project Field Permitting Plan. **A short summary will be required by each PSO after activities are complete (project, date, time, location, species observed, notes on behavioral response, etc.), even if no observations were noted.** These will be collated from all

PSOs during applicable project activities and provided to the ERP SME and Biological Resources SME. This will assure end-of-quarter or end-of-year reporting requirements to agencies can be fulfilled by the PNNL compliance team. Also, maintaining a compilation of data from all observation sessions may be useful for input into the Annual Site Environmental Report (ASER) and Environmental Assessments, as needed, and for general project planning.

PNNL OSD EPRP Biological Resources SME has determined that the following staff meet these qualifications and may serve as designated observers for the project listed above.

NAME	Employee ID	Date
____________________	__________________	_______________
____________________	__________________	_______________
____________________	__________________	_______________

5.1.2 PNNL PSO Data Recording Form

Data are recorded for all PSO required projects (Section 2), including any protected species encountered/noted beyond the monitoring focus. One PSO may monitor for multiple protected species, e.g., MAMU and marine mammals. This is reflected in the below data reporting form.

Project Name:
Monitoring Station ID:
Observer(s):
Activity:
Time and Duration:
Describe monitoring site *(including a sketch to the right)*:

Date	*6-digit date (mo-dy-yr)*
Time (survey start and stop)	*4-digit code, military time*
Observer(s)	*first and last name*
Beaufort sea state (USFWS 2013)	*1-2 (survey not conducted or ends if > 2)*
Precipitation	*N = none, D = drizzle, S = shower, L = light rain, R = steady rain, F = fog)*
Tidal stage	*low low, high low, low high, high high, rising, falling*[a]
Elevation	*ft*
Location	*polygons in Figure 2*
MAMU Breeding (April - September), Time of Day	*(yes, no), (dawn, morning, afternoon, dusk)*
MAMU Non-Breeding (October – March), Time of Day	*(yes, no), (dawn, morning, afternoon, dusk)*
Species	*all seabirds, all federally protected species*
Number	*all seabirds, all federally protected species*
Additional Species (e.g., tufted puffin)	*all other species noted in the area (non-exhaustive)*
Group size	*birds separated by 2 m or less at first detection and moving together or, if greater than 2 m, birds exhibiting behavior reflective of birds together (Raphael et al. 2007)*
Behavior at first detection	*federally protected species, seabirds only (on water, diving, flying)*
Breeding/age	*marbled murrelets only (BA = breeding adult = appear brown overall; NBA/I = non- breeding adult/immature = dark blackish gray above and white below with white collar around neck*

[a] Predicted tide cycles can be used to plan surveys for these tidal stages, and tidal stage can be verified post-survey based on the actual tides and survey start and stop times.

Reporting. All survey results will be summarized and sent to USFWS and NMFS on a yearly basis by PNNL EPRP staff.

5.2 Above Water Marbled Murrelet (MAMU) Monitoring

Subsections 5.2.1 through 5.2.4 present general information useful to all proposed applications of MAMU monitoring. The information can be applied to (1) temporary localized above water monitoring for MAMU at PNNL activities requiring a MAMU PSO (e.g., some light emitting activities, some sound emitting activities, local surface monitoring during tidal turbine installation and decommissioning [Sections 2.10, 2.11, and 2.14, respectively]), and (2) the PNNL discretionary (optional) above water MAMU monitoring plan presented in Appendix D, as applicable.

5.2.1 MAMU Species Information

MAMU are generally rare and occur in low densities. Sporadic detectability of the species may be expected in deployment areas, which include potential research areas and hypothetical tidal turbine areas (Section 2.14), if consistent with the seasonal density data discussed above (Section 3.1.12). This perceived variability emphasizes the need to identify the factors that could affect use of the area requiring monitoring and focus monitoring on when those factors occur in order to adequately characterize use. Factors that may affect potential MAMU use of the deployment area are:

- Time of day
- Prey presence
- Tidal stage
- Season (of the year, and breeding versus non-breeding)
- Water depth and distance from shore

Although literature indicates the above factors are variable in their ability to predict MAMU use of any given area across time, spatial scale, and location, it is worthwhile describing them briefly for their potential relevance to use of deployment areas. Such information can be leveraged to enable improved detection of MAMU by MAMU PSO.

Little is known about MAMU spatial distribution and behavior at night. Several authors have found that MAMUs feed near shorelines or narrow channels during the day and move to deeper waters at night (Haynes et al. 2008). Speckman et al. (2000) found higher abundance of MAMUs during high or falling morning tides, especially in shallow areas where Pacific sand lance were abundant. This information indicates that use of the research areas may be more likely to occur during the day, and particularly during the morning, than at night.

One of the major influences on seabird occurrence is the distribution and availability of prey. Although seabirds are expected to show a strong aggregative response to their prey, this is often not the case at small scales, such as that of a monitored area where research or turbine deployment is occurring. At larger scales, seabirds occupy the same general regions as their prey. As the scale becomes finer, the spatial associations between seabirds and prey become weak or highly variable and are dependent on prey patch size and prey abundance (Haynes et al. 2008). For example, the hypothetical tidal turbine deployment area is about 800 m in length and of variable width (200-400 m) (Figure 2.6), comprising an area of roughly 0.24 km^2, which is considered fine-scale habitat where prey occurrence may not correlate with seabird occurrence.

Potential prey of MAMUs includes forage fish as well as aquatic invertebrates (Pastran et al. 2021, Ralph et al. 1995). Spawning areas for Pacific herring (*Clupea pallasii*), Pacific sand lance (*Ammodytes hexapterus*), and surf smelt (*Hypomesus pretiosus*) occur in or near the proposed deployment areas (Figure 5.1). Sand lance spawning occurs at high tide in shallow water on sand-gravel beaches between November and February (Essington et al. 2018) and juvenile sand lances rear in nearshore waters along Puget Sound during the summer (Penttila 2007). Sand lance spawning sites appear to be used on a perennial basis (Penttila 2007). Surf smelt spawn in summer along the Strait of Juan de Fuca on high intertidal beaches of sand and gravel, under only a few inches of slack water on the high tide (Penttila 2007). Juvenile surf smelt linger in spawning areas and feed in shallow waters throughout Puget Sound (Penttila 2007).

Figure 5.1. Sandlance, surf smelt, and herring spawning areas near the PNNL-Sequim Campus (WDNR and WDFW 2023).

The tidal cycle may make prey more available by concentrating prey and providing favorable foraging conditions. Tidal stage has been found to be related to MAMU densities, with MAMUs in southeast Alaska more abundant in surveys at slack tide compared to rising/falling tide (Haynes et al. 2008), and at high or falling morning tides, especially in shallow areas where Pacific sand lance were abundant (Speckman et al. 2000). Information on how seabirds behave within tidal stream environments (micro-habitat, <1 km), above all, is needed (Isaksson et al. 2020).

Densities of MAMUs during the breeding season (April – August [Ralph et al. 1995]) appear to be related to adjacent nesting habitat (Strachan et al. 1995). Murrelets fly inland to nest sites, often multiple times per day during nesting and thus congregate in adjacent marine regions used as staging grounds for inland flight (Haynes et al. 2008). This indicates the possible use of Sequim Bay in general as a staging area for inland flight to the nesting area located at the south end of the bay (Section 3.1.12) but does not speak specifically to potential use of specific project sites in the bay or portion of the action area in the Strait of Juan de Fuca. In some locations, after the breeding season, birds appear to disperse, and are less concentrated in the immediate nearshore coastal waters near nesting habitat. In many areas, however, individuals maintain an association with the inland nesting habit (Strachan et al. 1995).

MAMUs forage by pursuit diving in relatively shallow waters, usually between 20 m and 80 m in depth. The species has also been observed diving in waters less than 1 m and more than 100 m deep (Strachan et al. 1995). Although the majority of birds are found as pairs or as singles in a band about 300 m to 2000 m from shore (Strachan et al. 1995), the above information on water depth, distance from shore as related to time of day, areas of tidal mixing, and prey abundance indicate the potential for use of project sites in the Sequim Bay or portion of the action area in the Strait of Juan de Fuca. The above information should be considered in the PNNL design of any project monitoring protocol for MAMUs to increase chances of detection.

5.2.2 Survey Area

Locations of activities within the project areas in Sequim Bay and the Strait of Juan de Fuca potentially affecting MAMU (e.g., some acoustic and light emitting devices [Sections 2.10 and 2.11, respectively], or the specific location of a tidal turbine at installation [PDC in Section 2.14]) may need to be surveyed for MAMU by PNNL PSO. For example, if a PSO is needed during green laser operations, the PSO could monitor up to (but not more than) 50 m around the deployment area for MAMU, based on visibility limitations under suitable conditions. A PSO could similarly monitor up to 50 m around the tidal turbine deployment location during turbine installation. A PSO monitoring for MAMU within 50 m may also monitor for other protected species (e.g., marine mammals) within and beyond the 50 m.

Detectability of MAMUs is highly dependent on sea state and weather conditions that affect visibility. No monitoring will be conducted when visibility is significantly limited such as during heavy rain, fog, glare or in a Beaufort sea state (USFWS 2013) greater than 2. Under suitable sea state and weather conditions, maximum observer visibility is estimated to be about 50 m using binoculars or spotlight (see Section 5.2.3). A single PSO is assumed to be able to cover an approximate 50 m distance of open water within an 180^0 arc of the observer's position (USFWS 2013). Observers can calibrate the 50 m distance using a buoy towed behind the survey vessel (Haynes et al. 2008).

5.2.3 Labor and Equipment

The size and shape of an activity's area of potential effect will determine the number of requisite surveyors, given a maximum observer visibility of 50 m (Section 5.2.2). For example, an area such as that shown in Figure D.1 in Appendix D would require 2 surveyors to cover 50 m on either side of the vessel. Surveyors will be qualified through Section 5.1.1 and complete the Section 5.1.2 form.

Surveyors are expected to carry: binoculars, spotting scopes (optional), two-way radios (or cell phone), range finders, logbooks, seabird identification guides, and cell phone to contact the PNNL biological SME and vessel. Daytime surveys will require use of binoculars; nighttime surveys will require use of spotlights (Haynes et al. 2008). Surveyors should communicate in order minimize missed detections and reduce the possibility of double counting.

5.2.4 Boat Speed

If moving (for transects), boat speed should be no less than 5 knots and no greater than 10 knots. Observer coverage should not be compromised; therefore, observer's ability to scan dictates the speed of the boat (USFWS 2013).

5.3 Underwater Tidal Turbine Monitoring

DOE proposes to use the best available industry instruments and technologies to evaluate and reduce the risk of species collisions with tidal turbines as identified in the most recent State of the Science Report (currently Copping and Hemery 2020). Target species for monitoring include marine mammals, seabirds (representative of MAMUs), and fish. 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.

While many monitoring instruments and technologies are available, there is no 'one method fits all' solution (Isaksson et al. 2020). For example, information on how seabirds behave within a distance several times the diameter of a tidal turbine (generally not to exceed 10 m) is needed (Isaksson et al. 2020) and may require different survey methods than other protected species. Consequently, PNNL would use the best available marine renewable energy monitoring instruments, such as multibeam sonar or stereo optical camera (see Chapter 10 of 2020 State of the Science Report [Copping and Hemery 2020]), etc., either singly along with a system for data collection, or in configurations of multiple instruments, depending on the nature of the turbine deployment.

At this time, PNNL proposes to deploy, at a minimum, an integrated monitoring system for the duration of tidal turbine deployments with the same basic functionality as the adaptable monitoring package (AMP) under a different trademark or AMP similar to that proposed for monitoring by the Navy and UW (Navy 2020) or used by Bassett (2022) in Agate Pass, WA. Representative test deployments of the UW AMP with contrasting configurations and operational strategies are described in Polagye et al. (2020) and include those tested in Sequim Bay in conjunction with PNNL. Data collected during Sequim Bay testing were used to train a machine learning model to classify targets detected on the multibeam sonar as either seals, diving birds, fish schools, or small targets (which may be individual fish or floating debris) (Cotter and Polagye 2020). In post-processing, 89% of biological targets were accurately grouped into these four categories. DOE's proposed action for tidal turbines is broader than that of the Navy (2020) in terms of the possible type and number of turbines, operating parameters (e.g., tip-speed ratio), depth, location, and deployment duration. The underwater equipment PNNL would use for near-field monitoring could be adapted to address such details.

The PNNL AMP, a customizable commercially available instrumentation platform purchased from MarineSitu can support integration of a variety of sensors. The first evolution of the PNNL AMP will include: 1 hydrophone, 1 multi-beam sonar, 2 stereo optical cameras equipped with artificial illumination (4 lights). One of the main advantages of the AMP is that it is a cabled system – meaning that it has an external power source and data are relayed to the user in real time. All devices operate continuously, with the exception of artificial illumination, which will illuminate the water if a target of interest is detected. However, data from AMP sensors can be collected on a duty cycle, or data acquisition can be triggered by real-time detection of targets (Cotter et al. 2017, Cotter and Polagye 2020). PNNL will prioritize the latter, to adequately capture protected species interactions and reduce data volumes while focusing on targets of interest. The PNNL AMP does not include an acoustic doppler current profiler (ADCP). However, as an external addition, an ADCP will most likely be deployed by various projects throughout the deployment timeframe of the turbine.

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 proposes to 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.

6.0 Project Management

Research projects will be reviewed in the proposal and funded stages to determine if the project scope and life cycle of work are within those described in Section 2, and the locations for project deployment are planned within the geographic area described in Section 1.4. Projects will also be evaluated for incorporation of Project Design Criteria (PDC), as described in Section 2.

For notification-only projects, PNNL will notify NMFS and FWS prior to project field work start. For projects that require verification, PNNL will email NMFS and FWS 30 calendar days prior to field work start with a project summary, including any conservation measures or mitigation to be employed. For any activities requiring adaptive deployments (i.e., tidal turbines) a longer verification timeframe of up to 90 days will be required. The verification clock will begin at receipt of verification email by the Services, which typically occurs within 24 hours. PNNL may contact the Services during the 30-day or 90-day verification period to check on completion of the verification process. Appendix A provides standardized email templates for submission to the Services. Any projects that would take place outside described areas and which may affect federally protected species or habitats would require additional review from the Services. All projects will be tracked and an annual project summary, documenting yearly deployments, will be provided to the Services to describe all projects, including additional potential impacts due to activity design outside of existing project design criteria (PDC).

Internal PNNL best practices will include but are not limited to:

1. Project tracking and permitting.
2. Each project scope will be reviewed and identified for suitable fit under the PBA.
3. As appropriate, a summary of habitats and species that may be affected by the project will include an assessment of impacts.
4. Project scope review will identify PDC and any additional conservation measures that are needed to minimize or avoid adverse effects.
5. Other permits required for project scope will be assigned, including any additional requirements described by the issuing agencies.
6. All project review and permitting materials will be maintained in a PNNL online file system.
7. An annual report of projects will be provided to the Services by the anniversary of the approval of this BPA or issuance of a programmatic biological opinion.
8. Project outcomes and data that provide additional insight into marine organism response or behavior to operations covered in this assessment will be provided to the Services to assist with conservation use for protected species and habitats.
9. Prior to initiating work, field personnel will receive training or briefings, as applicable, regarding the potential presence of threatened or endangered species that may be encountered, their physical characteristics, preferred habitats, how they can be identified, actions to be taken if sighted, and avoidance measures to be followed as detailed in the PDCs and conservation measures. This training or briefing will be prepared and offered by PNNL or external experts, environmental research permitting lead, or biological resources staff.

7.0 Conclusion

The tables in Section 4.15 provide final, overall effects determinations for NMFS and FWS ESA-listed species and their critical habitats and NMFS non-listed marine mammals (Table 4.12) and EFH (Table 4.13) for all research activities combined in the entire action area (Sequim Bay and Juan de Fuca project areas). These determinations are based on the project activities, including PDC, described in Section 2, the potential impacts described in Section 4, and monitoring described in Section 5. On an annual basis, DOE PNSO and the Services will discuss this PBA and update the document as necessary, including the review of monitoring results and modifications to monitoring and/or activities.

8.0 Reinitiation of Consultation

As stated in 50 CFR Section 402.16, reinitiation of consultation will be pursued as required by either the Services or by the Federal agency (DOE PNSO) where discretionary federal agency involvement or control over the action has been retained (or is authorized by law) and if:

1. the amount or extent of take is exceeded relative to the initial take statement;
2. new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered;
3. the identified action is subsequently modified in a manner that causes an effect to listed species or critical habitat that was not considered in the Biological Opinion;
4. a new species is listed, or critical habitat designated that may be affected by the identified action.

In addition, reinitiation of consultation is required where specified in Sections 2.11 and 2.14.

9.0 References

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Appendix A – Template: Notification and Verification Submission to Services

Subject: NOTIFICATION or VERIFICATION. PNNL Sequim Bay Programmatic – Project Title

Body:

Notification: ☐	Verification: ☐
Date Requested By:	Responsible PM/Task Lead:
Date:	
Project #:	Project Title:
NMFS Consultation #:	FWS Consultation #:
Activity Type:	
Describe General Activities (device type etc. and any attachments):	
Work Locations (body of water & coordinates):	
If Near Protection Island - Describe Coordination with WDNR:	
Project Start Date and Duration:	

Appendix B – Template: Annual Report to Services

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

Appendix C – Example Sound Emission Potential Injury and Behavioral Isopleth Calculations

Underwater noise from human activities is a significant concern for marine mammals, fish, and diving birds in and around the Salish Sea. The Pacific Northwest National Laboratory (PNNL)-Sequim performs numerous on-water activities that are research related that include sound emissions. Below are six examples of the types of sound sources that are likely to be used for 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. This list is not exhaustive but is a good reference for the variation in sound sources. Additionally, effect isopleths related to the application of these sound sources is presented along with beginning topics of discussion for those that might need mitigation (e.g., marine mammal observer or protected species observer). Lastly, annual effort estimates are presented as a starting point for discussion to build the necessary information for future permits and authorizations.

Table C.1 below is a summary table of the example sound sources presented in this document. The effect isopleths were calculated based on 6 h/d operations and several other parameters that can be found below with details of each. For marine mammals, the table only shows the high-frequency hearing group as it calculates the largest isopleth for the sound sources investigated.

Table C.1. Acoustic Isopleths for Various PNNL instruments.

Sound source	Fish Effect Isopleths	Diving bird effect isopleths	Marine Mammal effect isopleths
Benthos Communications Modem*	Outside of hearing range	Outside of hearing range non-auditory injury: 0 m	Injury: 3.7 m Behavior: 15.8 m
EdgeTech eBOSS Sub-bottom Profiler*	Outside of hearing range	Outside of hearing range non-auditory injury: 0 m	Injury: 76.3 m Behavior: 215.4 m
Navy J-11 Sound Projector	Injury: <2 g 16.7 m; >2 g 9.0 m Behavior: 3.4 m	Auditory injury: 0.9 m Baro injury: 0.4 m Behavior: 3.4 m	Injury: 1.0 m Behavior: 341.5 m
Kongsberg SSBL underwater positioning system*	Outside of hearing range	Outside of hearing range non-auditory injury: 0 m	Injury: 29.7 m Behavior: 85.8 m
Simrad 38 kHz echosounder*†	Outside of hearing range	Outside of hearing range non-auditory injury: 23.1 m	Injury: 4,971.3 m Behavior: 4,641.6 m
Small-scale tidal turbines	Injury: <2 g 8.8 m; >2 g 4.7 m Behavior: 1.0 m	Auditory injury: 0.5 m Baro injury: 0.2 m Behavior: 1.0 m	Injury: 40.7 m Behavior: 100 m

* Most or all the sound bandwidth is above most fish species' hearing range so the effect isopleths may not apply.
† Effect isopleth is not omnidirectional. The beam pattern of the sound source is 10 degrees and thus the area of potential effect is very small.

C.1 Underwater Communications Modem (two sound sources)

A Benthos ATM-900 underwater modem and surface communications transducer (both units [referred to hereafter as "system"] emit the same sound not overlapping in time) will be operated in Sequim Bay and around the entrance channel of Sequim Bay as a controlled sound source for a maximum of 6 h/d for a maximum of 5 d. The production of controlled sounds from the system are to transfer data and spatial information of sensors underwater. The system is a non-impulsive, omnidirectional pair of sound sources that will be operated intermittently in the frequency band of 22 kHz–27 kHz with an RMS sound pressure level (SPL) of 178 dB re 1 µPa. The pulse duration is 0.001 s and ping rate is 100 Hz (duty cycle of 10%). The system will be mobile and operating at the same time and moving no faster than 0.25 $m \cdot s^{-1}$. Note that only one unit (underwater modem or communications transducer) will be emitting sounds at a given time. The unit operates at frequencies outside the hearing range for fish and marbled murrelet, thus auditory injury and behavioral isopleths are not calculated; non-auditory injury (e.g., barotrauma) isopleths for MAMU are provided.

C.1.1 Effects to ESA Listed Diving Birds – Non-Auditory Injury

The following equation is used to determine the injury effect isopleth ranges for MAMU for mobile sound sources.

$$*EI = SF * \pi / (10^{TH/10}) * SV \qquad \text{Eq. 1}$$

EI is effect isopleth
SF is source factor = $10^{RMS\ SPL/10}$ * duty
cycle TH is SEL threshold

SV is source velocity in $m \cdot s^{-1}$

** This equation is like the one used for marine mammal permanent threshold shift (PTS) injury effect isopleths for mobile sound sources in the user spreadsheet tool that is part of NOAA (2018).*

The non-auditory injury effect threshold for MAMU is 208 dB SEL (the sources is outside of the hearing range, thus no auditory injury). The injury effect isopleths result from using this threshold and Equation 1 is 0 m.

C.1.2 Effects to Marine Mammals

For marine mammal injury (permanent threshold shift [PTS]) effects, we referenced NOAA (2018) and its ancillary user spreadsheet tool. The following parameters were used to fill in the user spreadsheet tool on Sheet D "MOBILE SOURCE: Non-Impulsive, Intermittent ("SAFE DISTANCE" METHODOLOGY)".

- Weighting factor adjustment:
- – 1.7 kHz for low-frequency cetaceans
- – 28 kHz for mid-frequency cetaceans
- – 48 kHz for high-frequency cetaceans
- – 6.2 kHz phocid pinnipeds

– 4.9 kHz for otariid pinnipeds

- Source level (RMS SPL): 178 dB
- Source velocity (meters/second): 0.25
- Pulse Duration (seconds): 0.001
- 1/Repetition rate (seconds): 0.01

The results of the spreadsheet calculations are in the table below (table template is copied from user spreadsheet).

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
SEL_{cum} Threshold	199	198	173	201	219
PTS Isopleth to threshold (meters)	0	0	3.7	0	0

The following equation is used to determine the behavior effect isopleths for marine mammals.

$$EI = 10^{\wedge} ((SPL - TH) / 15) * \qquad \text{Eq. 2}$$

- * Equation variable definitions are the same as the equation above for injury effects

The behavior threshold is 160 dB RMS and the resultant behavior effect isopleth is 15.8 m.

C.1.3 Summary of Effects

The injury effect isopleths for all marine mammal groups except the HF group is 0 m and thus there is no risk for injury. The HF group's injury isopleth extends to 3.7 m and considered negligible as the animal would have to be in that range from one of the sound source units for the entire 6 h activity. The SPL is low enough such that the injury isopleth for marbled murrelet is 0 m.

Based on the small SPL value, short duration of activities (30 h total), and short-range effect isopleths, this activity is considered Not Likely to Adversely Affect marine resources in the area.

C.2 Sub-Bottom Profiler

An EdgeTech Buried Object Scanning Sonar (BOSS), or similar,[1] will be towed subsurface from a vessel in Sequim Bay and near the entrance of Sequim Bay in the tidal channel near the PNNL-Sequim dock. The BOSS will be operated as a controlled sound source for a maximum of 6 h/d for a maximum of 5 d. The controlled sound from the system is to test the ability of detecting buried objects (e.g., inert unexploded ordnance [UXO]) in the seabed. The system will be operated from a towed platform that travels ~5 m off the seabed, is non-impulsive, has a beam directivity downward of 180 degrees, and in the frequency bandwidth of 3–30 kHz with an

[1] The Bluefin-21 synthetic aperture sonar is a similar sound source and would operate at approximately similar frequencies and source levels. There will be some minor variations but to avoid a lengthy attempt at an exhaustive list of scenarios it is included here to clarify other sound sources with different technology names that will have similar environmental effects.

RMS SPL of 195 dB re 1 µPa. The pulse duration is 0.004 s, and ping rate is 80 Hz (duty cycle of 32%). The towed platform will have a maximum velocity of 2 $m \cdot s^{-1}$. The unit operates at frequencies outside the hearing range for fish and marbled murrelet, thus auditory injury and behavioral isopleths are not calculated, but the non-auditory injury isopleth for marbled murrelet is calculated.

C.2.1 Effects to Diving Birds

The following equation is used to determine the injury effect isopleth ranges for marbled murrelet for mobile sound sources.

$$*EI = SF * \pi / (10^{TH/10}) * SV \qquad \text{Eq. 1}$$

EI is effect isopleth
SF is source factor = $10^{RMS\ SPL/10}$ * duty cycle
TH is SEL threshold
SV is source velocity in $m \cdot s^{-1}$

** This equation is like the one used for marine mammal PTS injury effect isopleths for mobile sound sources in the user spreadsheet tool that is part of NOAA (2018).*

The non-auditory injury effect threshold for marbled murrelet is 208 dB SEL (the sources is outside of the hearing range, thus no auditory injury). The injury effect isopleths result from using this threshold and Equation 1 is 0 m.

C.2.2 Effects to Marine Mammals

For marine mammal injury (Permanent Threshold Shift [PTS]) effects, we referenced NOAA (2018) and its ancillary user spreadsheet tool. The following parameters were used to fill in the user spreadsheet tool on Sheet D “MOBILE SOURCE: Non-Impulsive, Intermittent (“SAFE DISTANCE” METHODOLOGY)”.

- Weighting factor adjustment:
- – 1.7 kHz for low-frequency cetaceans
- – 28 kHz for mid-frequency cetaceans
- – 42 kHz for high-frequency cetaceans
- – 6.2 kHz phocid pinnipeds
- – 4.9 kHz for otariid pinnipeds
- Source level (RMS SPL): 195 dB
- Source Velocity (meters/second): 2
- Pulse Duration (seconds): 0.004
- 1/Repetition rate (seconds): 0.0125

The results of the spreadsheet calculations are in the table below (table template is copied from user spreadsheet).

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
SEL_{cum} Threshold	199	198	173	201	219
PTS Isopleth to threshold (meters)	0.2	0.3	76.3	0.1	0

The following equation is used to determine the behavior effect isopleths for fish.

$$EI = 10\^{} ((SPL - TH) / 15) * \qquad \text{Eq. 2}$$

** Equation variable definitions are the same as the equation above for injury effects*

The behavior threshold is 160 dB RMS and the resultant behavior effect isopleth is 215.4 m.

C.2.3 Summary of Effects

The injury effect isopleths for all marine mammal groups except the HF group is less than 1 m and considered negligible. The HF group's injury isopleth extends to 76.3 m and considered for possible effects though this is very unlikely as the animal would have to be in that range of the sound source for the entire 6 h activity. This range is easy to observe and monitor for endangered or threatened species. The SPL is low enough such that the injury isopleth for marbled murrelet is 0 m.

Based on the small SPL value, short duration of activities (30 h total), and short-range effect isopleths, this activity is considered Not Likely to Adversely Affect marine resources in the area.

C.3 Stationary J11 Sound Projector

A Navy-owned J11 sound projector (other similar sound sources could be used such as Ocean Sonics icTalk low-frequency or high-frequency projector, Lubell VC2C, or Benthowave spherical transducer)[2] will be suspended in a stationary manner 1–3 m below the water surface from the PNNL-Sequim dock and operated as a controlled sound source for a maximum of 6 h/d for a maximum of 5d. The production of controlled sounds from the J11 is to test drifting hydrophone platforms that measure sound output of marine renewable energy devices. The J11 is a non-impulsive and omnidirectional sound source and will be operated continuously (not intermittently) in the frequency band of 30 Hz–10 kHz with an RMS SPL of 158 dB re 1 µPa. The sound within the described bandwidth will vary in amplitude (never exceeding 158 dB re 1 µPa) and will be recordings of previously deployed operational tidal turbines.

C.3.1 Effects to Fish

C.3.1.1 Injury Effects

The following equation is used to determine the injury effect isopleth ranges for fish.

[2] The Benthowave spherical transducer is similar in that it is likely to be a stationary sound source, is omnidirectional, and would operate at approximately similar frequencies and source levels. There will be some minor variations but to avoid a lengthy attempt at an exhaustive list of scenarios it is included here to clarify other sound sources with different technology names that will have similar environmental effects.

$$EI = 10^{((SPL) + (10 \log_{10}(T_t) - TH) / 15)} \quad \text{Eq. 1}$$

EI is effect isopleth
SPL is root-mean-squared sound pressure level T_t is total time in seconds of the sound emissions TH is SEL threshold
15 is constant for sound attenuation (xLogR)

The injury effect threshold for fish less than 2 g is 183 dB SEL and for fish greater than 2 g is 187 dB SEL. The injury effect isopleths results from using these thresholds and equation 1 are:

- 16.7 m for fish <2 g
- 9.0 m for fish >2 g

C.3.1.2 Behavior Effects

The following equation is used to determine the behavior effect isopleths for fish.

$$EI = 10^{((SPL - TH) / 15)} \text{*} \quad \text{Eq. 2}$$

** Equation variable definitions are the same as the equation above for injury effects*

The behavior effect threshold for fish is 150 dB RMS. The effect isopleth result from using this threshold and equation 2 is 3.4 m.

C.3.1.3 Effects to Diving Birds

Equation 1 is used for determining the injury effect isopleths for diving birds. There is an auditory injury threshold of 202 dB SEL and a barotrauma injury threshold of 208 dB SEL. The injury effect isopleth results from these thresholds and equation 1 are:

- 0.9 m for auditory injury
- 0.4 m for barotrauma injury

Equation 2 is used for determining behavior effect isopleths for diving birds. The behavior threshold is 150 dB RMS and the resultant behavior effect isopleth is 3.4 m (note that behavior threshold is the same for fish and diving birds).

C.3.1.4 Effects to Marine Mammals

For marine mammal injury (PTS) effects, we referenced NOAA (2018) and its ancillary user spreadsheet tool. The following parameters were used to fill in the user spreadsheet tool on Sheet A “STATIONARY SOURCE: Non-Impulsive, Continuous”.

- Weighting factor adjustment:
  - 1.7 kHz for low-frequency cetaceans
  - 10 kHz for mid-frequency cetaceans
  - 10 kHz for high-frequency cetaceans
  - 10 kHz phocid pinnipeds

- 4.9 kHz for otariid pinnipeds

- Source level (RMS SPL): 158 dB
- Duration of sound production (h) within 24-h period: 6
- Propagation (xLogR): 15

The results of the spreadsheet calculations are in the table below (table template is copied from user spreadsheet).

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
SEL_{cum} Threshold	199	198	173	201	219
PTS Isopleth to threshold (meters)	1.4	1.1	32.5	1.0	0.1

Equation 2 is used for determining behavior effect isopleths for marine mammals. The behavior threshold is 120 dB RMS for continuous sound sources (160 dB RMS for others) and the resultant behavior effect isopleth is 341.5 m.

C.3.1.5 Summary of Effects

All fish injury isopleths are less than 20 m and the activity lasts for 6 hours. This time span and the fact there are no physical barriers would allow fish plenty of time to move away from the sound source past 20 m to avoid injury. The behavior isopleth for fish is only 3.4 m and like the injury effect isopleth ranges, fish can easily move away from the area to avoid the sound for the 6 h activity duration for each of the 5 d.

The injury effect isopleths for diving birds are less than 1.0 m and are considered negligible. The behavior isopleth is 3.4 m and is also considered negligible as a bird would have to be submerged within that range for the entire 6 h activity duration which is unlikely.

The injury effect isopleths for all marine mammal groups except the HF group are less than 1.5 m and considered negligible. The HF group's injury isopleth extends to 32.5 m. To mitigate possible effects to individuals in this group, all activity staff will be responsible for observing for cetaceans in the area and a shutdown of the J11 will be conducted if the cetacean(s) is within the injury effect isopleth or appears to be traveling toward the J11 location.

Based on the small SPL value, short duration of activities (30 h), and short-range effect isopleths, this activity is considered Not Likely to Adversely Affect marine resources in the area.

C.4 Underwater Positioning System; Kongsberg µPAP

A Kongsberg (there are several other vendors that supply similar technologies [WaterLinked] and would have similar sound emissions and effects) underwater positioning system (includes a surface unit and underwater unit that both emit sound) will be operated in Sequim Bay and around the entrance channel of Sequim Bay as a controlled sound source for a maximum of 6 h/d for a maximum of 5 d. The production of controlled sounds from the system is to track divers and other objects underwater in real time. The system is a non-impulsive, omni-directional sound source that will be operated intermittently in the frequency band of 22–30 kHz with a maximum RMS SPL of 189 dB re 1 µPa. The pulse duration is 0.031 s and maximum ping rate of 1 Hz (duty cycle of 3%). Both the underwater modem and communications transducer will be mobile and operating at the same time and moving no faster than 0.25 $m \cdot s^{-1}$. Note that only one unit (underwater modem or communications transducer) will be emitting sounds at a given time. Each unit must communicate with the other with a return transmission, so the total maximum ping rate is 2 Hz (once per second per unit) and maximum duty cycle of 6%. The unit operates at frequencies outside the hearing range for fish and marbled murrelet, thus auditory injury and behavioral isopleths are not calculated; the non-auditory injury isopleth for marbled murrelet is calculated.

C.4.1 Effects to Diving Birds

The following equation is used to determine the injury effect isopleth ranges for marbled murrelet for mobile sound sources.

$$*EI = SF * \pi / (10^{TH/10}) * SV \qquad \text{Eq. 1}$$

EI is effect isopleth
SF is source factor = $10^{RMS\ SPL/10}$ * duty
cycle TH is SEL threshold
SV is source velocity in $m \cdot s^{-1}$

** This equation is like the one used for marine mammal PTS injury effect isopleths for mobile sound sources in the user spreadsheet tool that is part of NOAA (2018).*

The non-auditory injury effect threshold for marbled murrelet is 208 dB SEL (the sources is outside of the hearing range, thus no auditory injury). The injury effect isopleths result from using this threshold and Equation 1 is 0 m.

C.4.2 Effects to Marine Mammals

For marine mammal injury (PTS) effects, we referenced NOAA (2018) and its ancillary user spreadsheet tool. The following parameters were used to fill in the user spreadsheet tool on Sheet D “MOBILE SOURCE: Non-Impulsive, Intermittent (“SAFE DISTANCE” METHODOLOGY)”.

- Weighting factor adjustment:
  – 1.7 kHz for low-frequency cetaceans
  – 30 kHz for mid-frequency cetaceans
  – 30 kHz for high-frequency cetaceans
  – 6.2 kHz phocid pinnipeds
  – 4.9 kHz for otariid pinnipeds
- Source level (RMS SPL): 189 dB
- Source Velocity (meters/second): 0.25
- Pulse Duration (seconds): 0.031
- 1/Repetition rate (seconds): 0.5

The results of the spreadsheet calculations are in the table below (table template is copied from user spreadsheet).

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
SEL_{cum} Threshold	199	198	173	201	219
PTS Isopleth to threshold (meters)	0.1	0.1	29.7	0	0

The following equation is used to determine the behavior effect isopleths for fish.

$$EI = 10\text{\^{}}\ ((SPL - TH) / 15)\ * \qquad \text{Eq. 2}$$

** Equation variable definitions are the same as the equation above for injury effects.*

The behavior threshold is 160 dB RMS and the resultant behavior effect isopleth is 85.8 m.

C.4.3 Summary of Effects

The injury effect isopleths for all marine mammal groups except the HF group is less than 1 m and considered negligible. The HF group's injury isopleth extends to 29.7 m and considered negligible as the animal would have to be in that range from one of the sound source units for the entire 6 h activity. The SPL is low enough such that the injury isopleth for marbled murrelet is 0 m.

Based on the small SPL value, short duration of activities (30 h total), and short-range effect isopleths, this activity is considered Not Likely to Adversely Affect marine resources in the area.

C.5 Stationary 38 kHz Fisheries Echosounder

A fisheries echosounder, or similar,[3] will be operated with a transducer as a controlled sound source in a stationary manner 2-5 m underwater attached to a piling at the PNNL-Sequim dock aiming horizontally into the water column for a maximum of 6 h/d for a maximum of 5 d. The production of controlled sounds will be to test the sensor's ability to detect large artificial targets moving through the water column at the entrance of Sequim Bay. The echosounder transducer will be operated as a non-impulsive, intermittent, and directional (10 degree half-power beam angle) sound source operated at the frequency of 38 kHz with and RMS SPL of 215 dB re 1 µPa. The pulse duration will 0.000512 s with a ping rate of 2 Hz (duty cycle 0.1%). Omnidirectional sound sources create isopleths that are the same in a full 360 degree arc. Because of the narrow beam angle of the sound emission, only an arc created from a 10 degree origin will make up effect isopleth arcs (EIA) (Figure C.1) as described and referred to below. The unit operates at frequencies outside the hearing range for fish and marbled murrelet, thus auditory injury and behavioral isopleths are not calculated; the non-auditory injury isopleth for marbled murrelet is calculated.

[3] The Benthowave piston transducer is a similar sound source and would operate at approximately similar frequencies and source levels. There will be some minor variations but to avoid a lengthy attempt at an exhaustive list of scenarios it is included here to clarify other sound sources with different technology names that will have similar environmental effects.

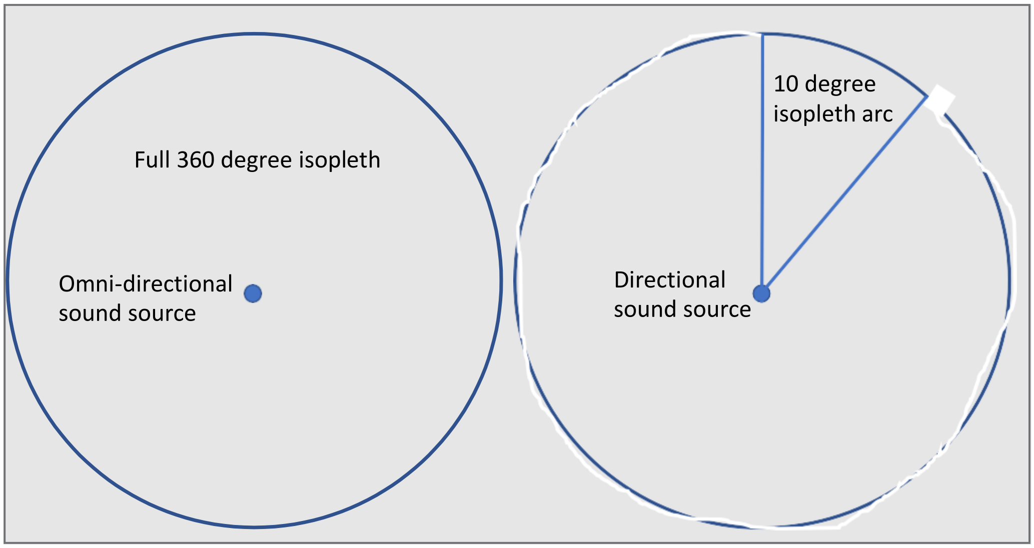

Figure C.1. An omnidirectional sound source creates a full 360-degree effect isopleth (left). A directional sound source, like the described echosounder transducer, creates an EIA (right).

C.5.1 Effects to Diving Birds

The following equation is used to determine the injury EIA ranges for marbled murrelet.

$$EIA = 10\wedge\ ((SPL) + (10\ \log_{10}(T_t) - TH) / 15 \qquad \text{Eq. 1}$$

EIA is effect isopleth arc
SPL is root-mean-squared sound pressure level T_t is total time in seconds of the sound emissions TH is SEL threshold
15 is constant for sound attenuation (xLogR)

The non-auditory injury effect threshold for marbled murrelet is 208 dB SEL. The injury EIA results from using this threshold and Equation 1 is 23.1m.

C.5.2 Effects to Marine Mammals

For marine mammal injury (PTS) effects, we referenced NOAA (2018) and its ancillary user spreadsheet tool. The following parameters were used to fill in the user spreadsheet tool on Sheet B “STATIONARY SOURCE: Non-Impulsive, Intermittent”.

- Weighting factor adjustment:
- – 1.7 kHz for low-frequency cetaceans
- – 38 kHz for mid-frequency cetaceans
- – 38 kHz for high-frequency cetaceans
- – 6.2 kHz phocid pinnipeds
- – 4.9 kHz for otariid pinnipeds

- Source level (RMS SPL): 158 dB
- Duration of sound production (h) within 24-h period: 6
- Pulse Duration (seconds): 0.000512
- 1/Repetition rate (seconds): 0.5
- Propagation (xLogR): 15

The results of the spreadsheet calculations are in the table below (table template is copied from user spreadsheet).

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
SEL_{cum} Threshold	199	198	173	201	219
PTS Isopleth arcs to threshold (meters)	91.9	104.8	4,971.3	67.6	4.3

The following equation is used to determine the behavior effect isopleths for fish.

$$EI = 10^{\wedge} ((SPL - TH) / 15) * \quad \text{Eq. 2}$$

- * Equation variable definitions are the same as the equation above for injury effects

The behavior threshold is 160 dB RMS and the resultant behavior EIA is 4641.6 m.

C.5.3 Summary of Effects

The non-auditory injury EIA for diving birds is approximately 23 m and is likely negligible because an individual would have to be submerged within the ensonified area for the entire 6 h of activity for injury to occur. If a diving event occurs, it is assumed the bird would sense it and depart the area avoiding injury.

The injury EIA for otariid pinnipeds is less than 5 m and it is assumed an individual would leave the area to avoid injury. The LF, MF, and Phocid groups are all within reasonable ranges for a PNNL PSO to spot and therefore this will be a mitigation measure for this group. If an individual is spotted within the range of 150 m within the EIA and remains for more than 5 minutes, the echosounder will be shutdown to allow the animal to exit the area. The EIA for the HF group extends beyond 4 km. The aim of the echosounder transducer 10-degree beam will be toward a shoreline that is less than 1 km away. This will allow a PNNL PSO to watch for animals in this group entering the EIA. If they reside there for more than 5 minutes the echosounder will be shut down to allow the animal to exit the area.

C.6 Turbine

The following description is for a generic turbine based on previously installed units and current research projects developing devices. The turbine could be bottom or surface oriented and be a vertical or horizontal axis device. The sound from operation will come mostly from the rotating blades and internal drive-train components. Testing of a turbine could be for as short as 5 d and up to 1 y. Operation of the turbine will occur when current speeds reach the cut-in speed of the device, assumed in this application to be 0.5 $m \cdot s^{-1}$. This would lead to an operation time varying between 40% to 60%. Maximum source levels measured to date for turbines are approximately 175 dB re 1 µPa, but the scale of devices that could be tested in Sequim Bay channel, due to size restrictions, will be much lower. The likely maximum source level for devices that would be tested would be 150 dB re 1 µPa and even more likely, the levels would be below 125 dB re 1 µPa. The sound emitted from turbines is broadband (typically 10 Hz–100 kHz) and to create the most conservative isopleth effect distances, the default weighting factor adjustments are used in the calculations for marine mammal estimates.

C.6.1 Effects to Fish

Effects to fish are separated by two criteria: injury and behavior effects.

C.6.1.1 Injury Effects

The following equation is used to determine the injury effect isopleth ranges for fish.

$$EI = 10^{\wedge} ((SPL) + (10 \log_{10}(T_t) - TH) / 15 \qquad \text{Eq. 1}$$

EI is effect isopleth
SPL is root-mean-squared sound pressure
level T_t is total time in seconds of the sound
emissions TH is SEL threshold
15 is constant for sound attenuation (xLogR)

The injury effect threshold for fish less than 2 g is 183 dB SEL and for fish greater than 2 g is 187 dB SEL. The injury effect isopleths results from using these thresholds and equation 1 are:

- 8.8 m for fish <2 g
- 4.7 m for fish >2 g

C.6.1.2 Behavior Effects

The following equation is used to determine the behavior effect isopleths for fish.

$$EI = 10^{\wedge} ((SPL – TH) / 15) * \qquad \text{Eq. 2}$$

** Equation variable definitions are the same as the equation above for injury effects*

The behavior effect threshold for fish is 150 dB RMS. The effect isopleth result from using this threshold and equation 2 is 1.0 m.

C.6.2 Effects to Diving Birds

Equation 1 is used for determining the injury effect isopleths for diving birds. There is an auditory injury threshold of 202 dB SEL and a barotrauma injury threshold of 208 dB SEL. The injury effect isopleth results from these thresholds and equation 1 are:

- 0.5 m for auditory injury
- 0.2 m for barotrauma injury

Equation 2 is used for determining behavior effect isopleths for diving birds. The behavior threshold is 150 dB RMS and the resultant behavior effect isopleth is 1.0 m (note that behavior threshold is the same for fish and diving birds).

C.6.3 Effects to Marine Mammals

For marine mammal injury (PTS) effects, we referenced NOAA (2018) and its ancillary user spreadsheet tool. The following parameters were used to fill in the user spreadsheet tool on Sheet A "STATIONARY SOURCE: Non-Impulsive, Continuous".

- Weighting factor adjustment:
- – 1.7 kHz for low-frequency cetaceans
- – 28 kHz for mid-frequency cetaceans
- – 42 kHz for high-frequency cetaceans
- – 6.2 kHz phocid pinnipeds
- – 4.9 kHz for otariid pinnipeds
- Source level (RMS SPL): 158 dB
- Duration of sound production (h) within 24-h period: 6
- Propagation (xLogR): 15

The results of the spreadsheet calculations are in the table below (table template is copied from user spreadsheet).

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
SEL_{cum} Threshold	199	198	173	201	219
PTS Isopleth to threshold (meters)	0.8	0.9	40.7	0.6	0

Equation 2 is used for determining behavior effect isopleths for marine mammals. The behavior threshold is 120 dB RMS for continuous sound sources (160 dB RMS for others) and the resultant behavior effect isopleth is 100 m.

C.6.4 Summary of Effects

All fish injury isopleths are less than 10 m and the activity lasts for 6 h/d. This time span and the fact there are no physical barriers would allow fish plenty of time to move away from the sound source past 10 m to avoid injury. The behavior isopleth for fish is only 1.0 m and considered negligible.

The injury effect isopleths for diving birds are less than 1.0 m and are considered negligible. The behavior isopleth is 1.0 m and considered negligible.

The injury effect isopleths for all marine mammal groups except the HF group are less than 1.0 m and considered negligible. The HF group's injury isopleth extends to 40.7 m. There are no barriers in or around the activity site and thus any animal in the HF group can easily avoid the area preventing injury. The behavior effect isopleth is 100 m and like the injury isopleth provides enough area around the device for an animal to avoid the area.

Based on the small SPL value, short duration of activities (30 h), and short-range effect isopleths, this activity is considered Not Likely to Adversely Affect marine resources in the area.

C.7 Appendix C References

NOAA (National Oceanic and Atmospheric Administration). 2018. 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, 2023, at https://www.fisheries.noaa.gov/action/user-manual-optional-spreadsheet-tool-2018-acoustic-technical-guidance.

Appendix D – Discretionary Tidal Turbine Above Water Marbled Murrelet (MAMU) Monitoring Plan

Guidelines are lacking on how best to use both well-established and novel survey methods to assess seabird use of tidal flow areas (Langston et al. 2012). Thus, in addition to abiding by criteria described in Sections 5.1 and 5.2, Appendix D further details information on how to adequately conduct discretionary above water MAMU monitoring for the currently proposed general deployment area for tidal turbines (Figure 2.6). The survey area would be that depicted in Figure D.1, or any other general area selected for tidal turbine deployments. During tidal turbine research driven surveys, the focus of surveys are MAMU monitoring; however, any other monitoring specific to other federally protected species could be conducted simultaneously by the same PSO.

The Discretionary Tidal Turbine Above Water MAMU Monitoring Plan is <u>not</u> mandatory for a specific tidal turbine deployment (mandatory requirements for such are covered in Section 5). PNNL may choose to monitor, which could occur in anticipation of and would be independent of sponsor-supported tidal turbine research. Appendix D is considered optional at this time, based on the PNNL adoption of underwater monitoring with an AMP or similar integrated platform (Section 5.4).

D.1 Tidal Stages

At Sequim Bay high and low tides occur twice in any given 24-hr period. Four tidal stages surveyed will include low, high, rising (flood), and falling (ebb). Low and high tide periods are generally classified as the 1 hour period before and after a low or high tide (Haynes et al. 2008) and typically encompass the slack tide stage. These tidal stages will be considered as part of monitoring plan design.

D.2 Survey Times

Daytime surveys during the breeding season (April – August [Ralph et al. 1995] but for purposes of monitoring would also include September) would take place during various times of day, categorized as follows: (1) dawn; (2) morning, (3) afternoon, and (4) dusk (Haynes et al. 2008). Daytime surveys during the non-breeding season (October – March) would take place as follows: (1) morning, (2) noon, and (3) afternoon. Nighttime surveys would also be conducted during the breeding and non-breeding season.

D.3 Survey Frequency

Survey frequency is based on adequately covering the tidal stages and times of day indicated above. Based on the tidal stage and duration information provided above under *Tidal Stages*, high and low tides comprise about one-third of each 24-hr period or about 8 hrs. The remainder of each 24-hr period, about 16 hours, comprises rising and falling tides. An example scheduling of daytime surveys to occur each time of day each Friday of each week from April through September 2022 and from October 2022 through March 2023 (using Washington State Tides and Currents Pro software) resulted in unequal representation of tidal stages, i.e., a disproportionately greater number of rising and falling tide surveys and relatively few high and low tide surveys during each season, and some combinations of time of day by tidal stage sparsely represented (1 survey) or not represented at all (0 surveys) during both the breeding and non-breeding season. Therefore, a planned sampling schedule must consider both tidal predictions and time of day to adequately characterize use of the deployment area by marbled murrelets during the breeding season and non-breeding season.

There are 16 tidal-stage by time-of-day combinations during the breeding season (4 times of day and 4 tidal stages) and 12 tidal-stage by time-of-day combinations during the non-breeding season (2 times of day and 4 tidal stages). The four tidal stages each occur at different times during the 24-hr clock throughout the year. Based on a preliminary review of the times when tide stages which occured in 2022, it is noteworthy that some of the above tidal-stage by time-of-day combinations are disproportionately limited in number and tend to occur in only some months (e.g., dawn and dusk high and low tides). Thus, providing complete survey coverage of all tidal-stage by time-of-day combinations within any given month is not feasible. Consequently, providing complete survey coverage for the four tidal stages at the required times of day is presented on a monitoring-season basis.

Though the number of surveys is subject to change, the current example addresses 2 surveys per monitoring season, time of day and tidal stage. Note that surveys would be conducted during each month, but the 6-month monitoring season is anticipated to allow enough flexibility to adequately cover the following number of surveys for each tidal-stage by time-of-day combination. Thirty-two surveys and 24 surveys would be required to cover each tidal-stage by time-of-day combination 2 times during the breeding season and 2 times during the non-breeding monitoring season, respectively (Table D.1). Daytime surveys will be scheduled in advance to occur during the tidal stages using predicted tide cycles.

Table D.1. Targeted number of daytime surveys by time of day and tidal stage to be completed within the breeding and non-breeding monitoring seasons.

Monitoring Season	Time of Day	Tidal Stage				Total
		High	Low	Rise	Fall	
Breeding (April–September)	Dawn	2	2	2	2	8
	Morning	2	2	2	2	8
	Afternoon	2	2	2	2	8
	Dusk	2	2	2	2	8
	Total	8	8	8	8	32
Non-Breeding (October–March)	Morning	2	2	2	2	8
	Noon	2	2	2	2	8
	Afternoon	2	2	2	2	8
	Total	6	6	6	6	24
Annual Total						**56**

In addition, nighttime monitoring surveys would be conducted but will not be restricted to a particular time of night. The four tidal stages will each be covered 2 times during the breeding season and 2 times during the non-breeding monitoring season (Table D.2). Nighttime surveys will be scheduled in advance using predicted tide cycles.

Table D.2. Number of nighttime surveys by tidal stage and monitoring season.

Monitoring Season	Tidal Stage				Total
	High	Low	Rise	Fall	
Breeding	2	2	2	2	8
Non-Breeding	2	2	2	2	8
Total					**16**

D.4 Survey Area

Adequate coverage of the currently proposed general deployment area for tidal turbines depicted in Figure 2.6 would require six approximate polygons delineated to cover the survey area (**Error! Reference source not found.**), the width of each polygon being based roughly on t he distance of maximum observer visibility (50 m) from either side of the survey vessel (Section 5.2.2). The approximate path of the survey vessel would bisect these polygons (**Error! R eference source not found.**). If a different general deployment area for tidal turbines is selected, this would change to appropriately capture that area.

Figure D.1. Approximate tentative vessel path (blue lines) and observation/data recording polygons (6 red polygons) for marbled murrelet surveys in the example deployment area for tidal turbines. The spit located just north of Travis Spit is Gibson Spit.

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APPENDIX B

NATIONAL MARINE FISHERIES SERVICE (NMFS) PROGRAMMATIC BIOLOGICAL OPINION

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

TABLE OF CONTENTS

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.

[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.

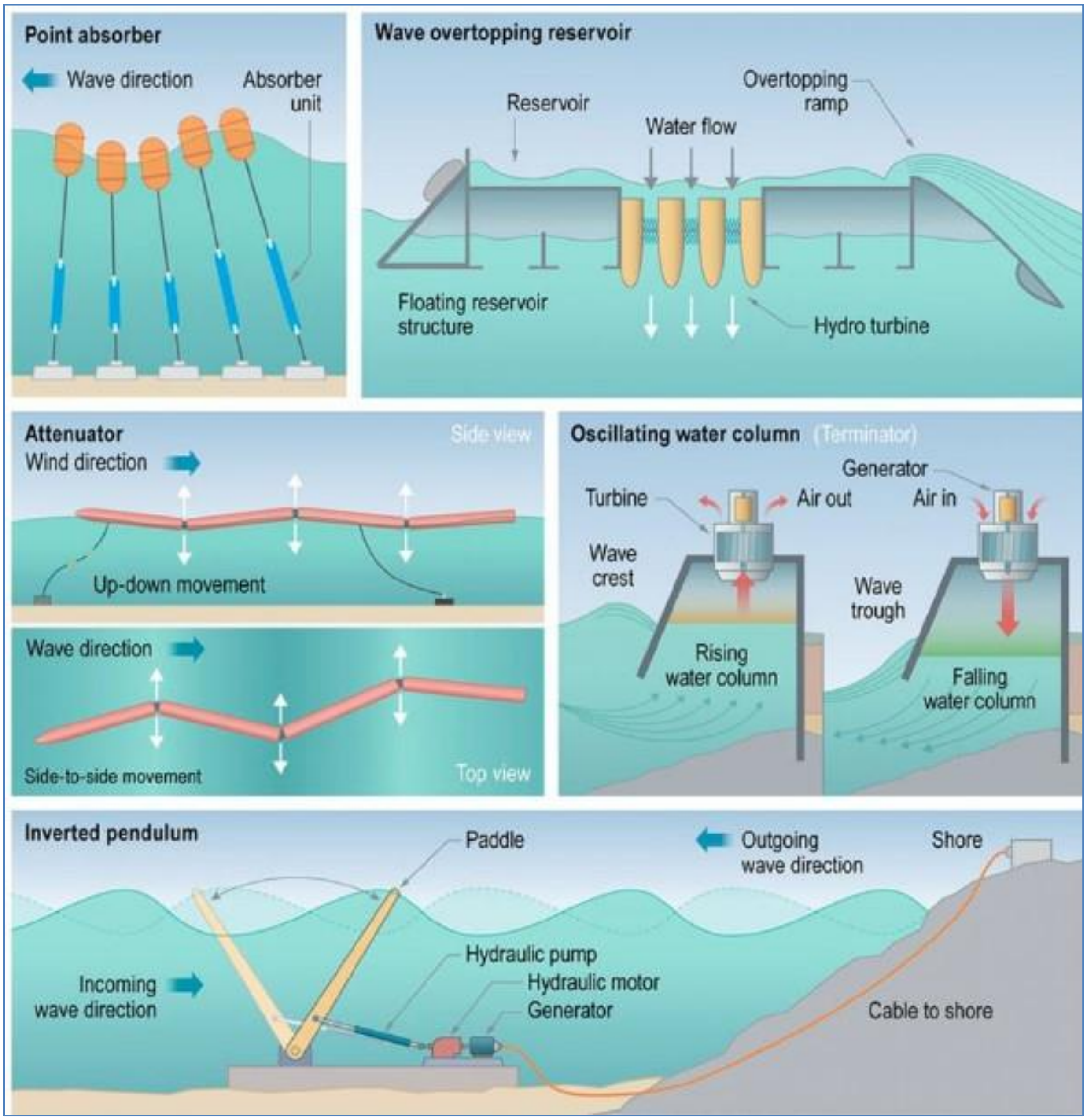


Figure 1. Examples of types of marine energy devices and movement style (Augustine et al. 2012).

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).

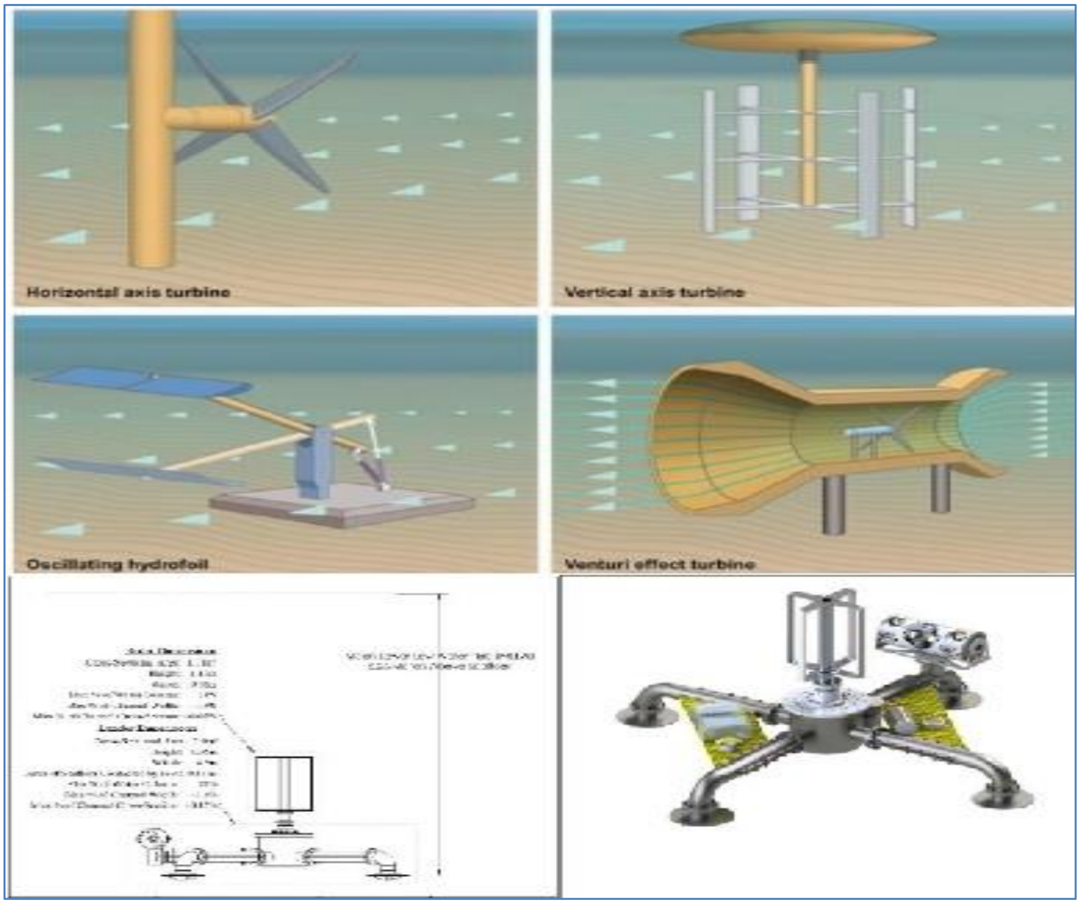
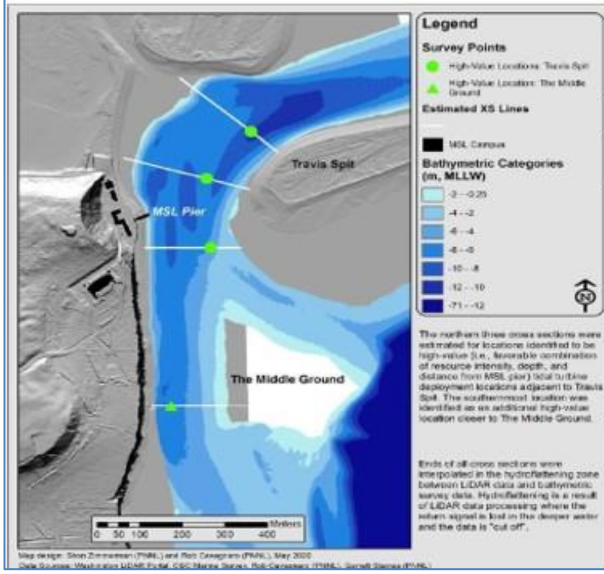


Figure 2. Tidal Turbine Examples

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.

[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.

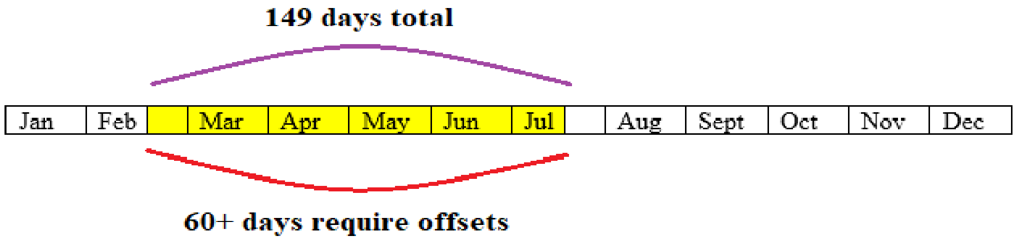


Figure 4. Non leap year offset requirement example

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.

<u>Abundance, Productivity, and Trends.</u> 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.

Limiting Factors and Threats. 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.

Spatial Structure and Diversity. 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.

Abundance and Productivity. 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.

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[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 HUC5 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 will be present, 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.

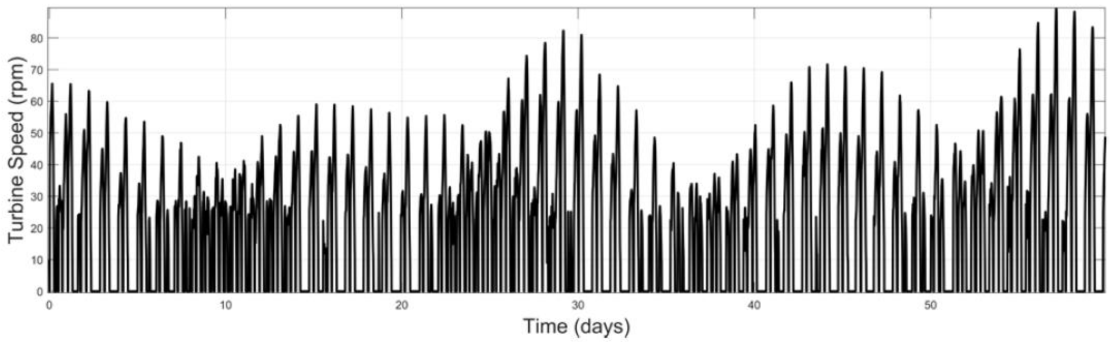

Figure 7. Two-Month Simulation of Rotation Rate of an 86-cm Diameter Vertical-Axis (DOE PBA)

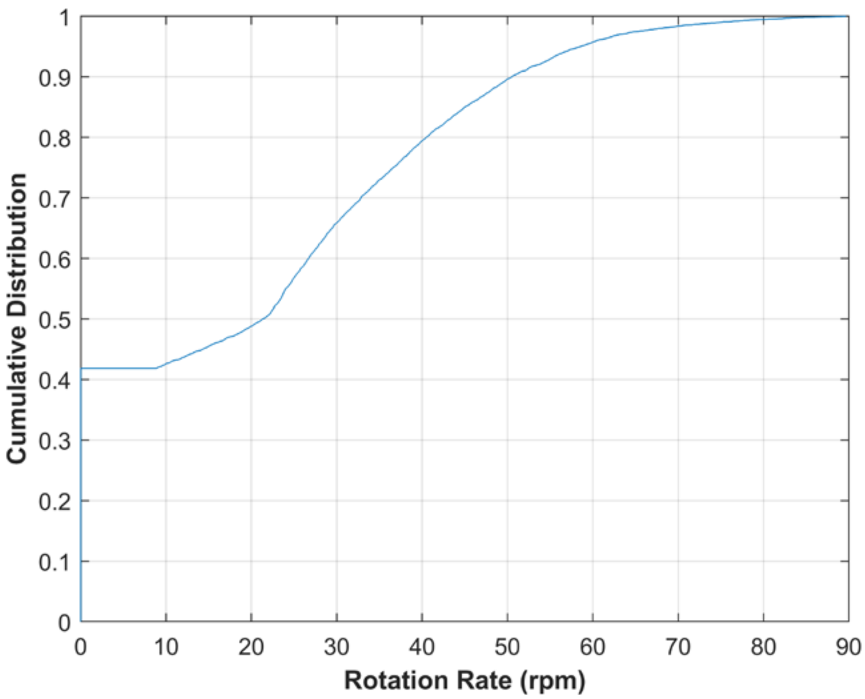

Figure 8. Example Cumulative Distribution Function of Turbine Rotation Rate (DOE PBA)

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.

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

Rockfish - 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.

Rockfish and green sturgeon - 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.

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

SRKW - 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.

Sunflower sea stars 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.

Fishes -
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

<u>Extent of take from water quality impact activities (suspended sediment/turbidity, low DO, dyes)</u>

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.

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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: ☐

To be filled out by PNNL:				
Date:	Responsible PM/Task Lead:			
PNNL Reference #:				
Project Title:				
To be filled out by Services:				
NMFS: WCRO-2020-02569-		FWS:		
Biologist:		Approved date:		
Project Information:				
Activity: Check *all* that apply	** 1a☐ b☐ c☐	2 ☐	** 3a☐ b ☐	4a☐ b ☐
	*5a☐ b☐ c☐	6 ☐	7 ☐	*8 ☐
	*9a☐ b☐	*10a☐ b☐	11a☐ b☐	** 12a☐ b☐
	*** 13 ☐	Lat:	Long:	
Any Overarching Criteria Not Met?				
General Construction Measures Taken:	1 ☐ 2 ☐ 3 ☐ 4 ☐ 5			
EFH CR's:	1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐			
If NOT following EFH CR, why?				
Project Start Date and Duration: (See calculator summary page)	Start; End: Days: Days outside work window:			
Offsets *Potentially required for Activities 1, 3, 12, & 13	Final Calculator date: _____________ Balance: ______________ ☐ Submit documentation that all required credits/offsets were purchased prior to the impacting project's construction start date			
Monitoring Plans *Required for Activities 9, 10, & 13	The following reports are required: ☐ Marine Mammal Monitoring Plan ☐ MAMU Monitoring Plan			

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

APPENDIX C

U.S. FISH AND WILDLIFE SERVICE (USFWS) PROGRAMMATIC BIOLOGICAL OPINION

United States Department of the Interior

FISH AND WILDLIFE SERVICE

Washington Ecological Services
1009 College St. SE, Suite 215
Lacey, Washington 98503

In Reply Refer To:
FWS/R1/2024-0008431

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

Dear Ms. Turner:

Subject: Marine Research and Equipment Testing, Pacific Northwest National Laboratory Sequim, Sequim Bay, and Strait of Juan de Fuca, Washington

This letter transmits the U.S. Fish and Wildlife Service's (Service) Biological Opinion (Opinion) addressing the Department of Energy's (DOE) proposed program of Marine Research and Equipment Testing at Pacific Northwest National Laboratory – Sequim (PNNL), located in Clallam County, Washington, and its effects on the marbled murrelet (*Brachyramphus marmoratus*). Formal consultation on the proposed action was requested by the DOE, Pacific Northwest Site Office, on August 24, 2023, and was conducted in accordance with section 7 of the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq.*) (ESA).

The enclosed Opinion is based on information provided in the August 24, 2023, Programmatic Biological Assessment (PBA; DOE Document No. 23-PNSO-0210), previous letter correspondence provided by DOE in support of consultation ('Response to Service Letter'; DOE Document No. 22-PNSO-0116, received March 14, 2022), meetings and telephone conversations, site visits and field investigations, and other sources of information cited in the Opinion. A complete record of this consultation is on file at the Service's Washington Fish and Wildlife Office in Lacey, Washington.

An electronic copy of this Opinion will be available to the public approximately 14 days after it is finalized and signed. A list of Opinions completed by the **(**Service**)** since October 1, 2017, can be found on the Environmental Conservation Online System (ECOS) website at https://ecos.fws.gov/ecp/report/biological-opinion.html.

The DOE's PBA also included a request for Service concurrence with "not likely to adversely affect" determinations for certain listed resources. The enclosed document includes a section separate from the Opinion that addresses your concurrence requests. We included a concurrence for the bull trout (*Salvelinus confluentus*), short-tailed albatross (*Phoebastria albatrus*), and designated bull trout critical habitat. The rationale for these concurrences is included in the concurrence section.

If you have any questions regarding the enclosed Opinion, our response to your concurrence requests, or our shared responsibilities under the ESA, please contact staff biologist Mitch Dennis (mitchell_dennis@fws.gov), or Molly Good (molly_good@fws.gov), Assistant Field Supervisor (Coastal Lowland Aquatic Marine Zone Team).

Sincerely,

MOLLY GOOD

Digitally signed by MOLLY GOOD
Date: 2024.08.21 07:20:30 -07'00'

For Brad Thompson, State Supervisor
Washington Fish and Wildlife Office

Enclosure(s)

cc:
DOE, PNSO, Operations, Richland, WA (T. McDermott)
DOE, PNSO, Operations, Richland, WA (H. Newsome)
PNNL, Sequim, WA (C. Duberstein)
PNNL, Sequim, WA (I. Bociu)

Endangered Species Act - Section 7 Consultation

BIOLOGICAL OPINION

U.S. Fish and Wildlife Service Reference:
2024-0008431

Marine Research and Equipment Testing at Pacific Northwest National Laboratory

Clallam County, Washington

Federal Action Agency:

Department of Energy

Consultation Conducted By:

U.S. Fish and Wildlife Service
Washington Fish and Wildlife Office
Lacey, Washington

MOLLY GOOD

Digitally signed by MOLLY GOOD
Date: 2024.08.21 07:20:51 -07'00'

For Brad Thompson, State Supervisor
Washington Fish and Wildlife Office

Date

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FIGURES

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ACRONYMS AND ABBREVIATIONS

AC	alternating current
ACZA	ammoniacal copper zinc arsenate
ADCP	acoustic doppler current profiler
AEC	acoustic effects calculator
ASB	autonomous smart buoys
ASV	autonomous surface vehicles
AUV	autonomous underwater vehicle
BMP	best management practices
CCA	chromated copper arsenate
CFR	Code of Federal Regulations
Service	U.S. Fish and Wildlife Service
City	City of Sequim
cm	centimeter
cm^2	square centimeters
County	Clallam County
cy	cubic yards
dB	decibel
DC	direct current
DOE	Department of Energy
DVL	doppler velocity log
EMF	electromagnetic field
ERP	environmental research permitting
ESA	Endangered Species Act of 1973, as amended (16 U.S.C. l531 *et seq.*)
FAA	Federal Aviation Administration
FMO	foraging, migration, and overwintering
FR	Federal Register
ft	feet
ft^2	square feet
GHG	greenhouse gas
GPS	global positioning system
ha	hectare
IPCC	Intergovernmental Panel on Climate Change
km	kilometers
km^2	square kilometers
kW	kilowatts
LAA	likely to adversely affect
LiDAR	light detection and ranging
m	meter
MHHW	mean higher high-water line
MLLW	mean lower low-water
MPE	maximum permissible exposure
m/s	meters per second
mT	milliTesla
murrelet	marbled murrelet

Navy	U.S. Navy
NLAA	not likely to adversely affect
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOHD	nominal ocular hazard distance
NWFPEM	Northwest Forest Plan's Effectiveness Monitoring Program
Opinion	biological opinion
PBA	programmatic biological assessment
PBFs	physical or biological features
PCEs	primary constituent elements
PDC	project design criteria
PDO	Pacific Decadal Oscillation
PEOS	peak efficiency operating speed
PFFP	portable free fall penetrometer
PM	project manager
PNSO	Pacific Northwest Site Office
PNNL	Pacific Northwest National Laboratory
ppb	parts per billion
Project	marine research and equipment testing at Pacific Northwest National Laboratory Project
PSO	protected species observer
PVC	polyvinyl chloride
rpm	revolutions per minute
RPM	reasonable and prudent measures
RU	Coastal Recovery Unit
SAP	surface acoustic pingers
SAV	submerged aquatic vegetation
Service	U.S. Fish and Wildlife Service
Services	U.S. Fish and Wildlife Service and National Marine Fisheries Service
SJF	Strait of Juan de Fuca
SME	subject matter expert
SPI/PV	sediment-profile imaging and plan view
sq ft	square feet
T	Tesla
UAS	unmanned aerial systems
UMSLI	unobtrusive multi-static serial LiDAR imager
US	United States
USCG	United States Coast Guard
WT	water tracing
WDFW	Washington Department of Fish and Wildlife

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1 INTRODUCTION

This document represents the U.S. Fish and Wildlife Service's (Service) Biological Opinion (Opinion) and concurrence, based on our review of the Department of Energy's (DOE) proposed program of Marine Research and Equipment Testing at Pacific Northwest National Laboratory (PNNL), located in Sequim, Sequim Bay, and the Strait of Juan de Fuca (SJF), Clallam County, Washington, in accordance with section 7 of the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq*.) (ESA). The Opinion addresses foreseeable, limited adverse effects to the marbled murrelet (*Brachyramphus marmoratus*), and includes a concurrence section that addresses effects to the bull trout (*Salvelinus confluentus*), short-tailed albatross (*Phoebastria albatrus*), and designated bull trout critical habitat.

The DOE made "no effect" determinations for additional listed species and designated critical habitat that are known to occur in Clallam County. These "no effect" determinations rest with the action agency (i.e., the DOE). The Service has no regulatory or statutory authority for concurring with "no effect" determinations, and no consultation with the Service is required. We recommend that the DOE document their analyses on effects to listed species and maintain that documentation as part of their project file.

The enclosed Opinion is based on information provided in the August 24, 2023, Programmatic Biological Assessment (PBA; DOE Document No. 23-PNSO-0210), previous letter correspondence provided by DOE in support of consultation ('Response to Service Letter'; DOE Document No. 22-PNSO-0116, received March 14, 2022), meetings and telephone conversations, site visits and field investigations, and other sources of information cited in the Opinion. A complete record of this consultation is on file at the Service's Washington Fish and Wildlife Office in Lacey, Washington.

2 CONSULTATION HISTORY

The following is a summary of important events associated with this consultation:

- The Service previously consulted with the DOE to address implementation of the Scientific Research Plan and associated activities at PNNL (01EWFW00-2016-I-0176). A five-year term of coverage was initially envisioned. Four subsequent letters administratively extended the term of coverage (letters issued February 22, 2021; February 24, 2022; January 4, 2023; and October 24, 2023).
- On November 4, 2020, the DOE submitted a Biological Assessment (BA) (01EWFW00-2021-I-0226) and a request for informal consultation. The request addressed additional research, associated activities, and a new (and longer) term of coverage.
- On October 29, 2021, the Service provided comments and recommendations to the DOE; the Service communicated concerns regarding possible adverse effects and incidental take. On March 14, 2022, the DOE responded ('Response to USFWS Letter'; DOE Document No. 22-PNSO-0116).
- The DOE, staff from PNNL, and Service held a series of virtual meetings to discuss the program of research activities at Sequim, Sequim Bay, and the SJF, program

implementation, and avoidance and minimization measures. Meetings occurred in October 2021, November 2021, December 2021, January 2023 through August 2023, October 2023, and January 2024.

- A site visit was conducted on May 2, 2022. The visit to the PNNL facilities in Sequim consisted of a presentation of activities and a tour of the facilities.
- On August 24, 2023, the DOE submitted a revised programmatic BA and request for formal consultation. Additional information was requested and received on December 15, 2023, and February 9 and 13, 2024.
- A copy of the draft Programmatic Opinion was provided to the DOE and PNNL for review and comment on February 16, 2024; a second, revised copy of the draft Programmatic Opinion was provided to the DOE and PNNL for review and comment on July 17, 2024.
- Comments for the draft Programmatic Opinion were provided by the DOE and PNNL on July 30, 2024.

3 CONCURRENCE

The DOE proposes to conduct and perform a broad program of research activities at PNNL (Sequim, Sequim Bay, and the SJF). Specific fields of research focus include development and testing of technologies and systems to monitor changes in the marine environment, marine and coastal resources, environmental chemistry, water resources and modeling, ecotoxicology, biotechnology, materials science, renewable energy development, overwater and underwater surveillance and detection technologies, and national security. Research activities are located at the PNNL campus in Sequim, in Sequim Bay, and the adjacent portions of the SJF (i.e., between Dungeness Spit and Protection Island) (Figure 1).

Figure 1. Action area, including Sequim Bay and Strait of Juan de Fuca (from Sequim Bay north to Dungeness Spit and east to Protection Island).

Research activities include placement of instruments on the water surface, in the water column, and substrate or benthos; sampling of environmental media; deployment and testing of detection and monitoring technologies based on acoustics and LiDAR; operations of autonomous vehicles for sample collection and monitoring; and deployment, testing, evaluation, and monitoring of pilot-scale hydrokinetic devices. Activities are grouped by category (see Section 4.1 in the body of the Opinion). Some research activities fall into multiple categories (for example, tidal turbine research includes or uses vessel operations, light emitting devices, seabed installations, etc.). The 14 categories are:

- Surface Platforms and Buoys (Section 4.1.2)
- Dock Installations (Section 4.1.3)
- Seabed Installations (Section 4.1.4)

- Vessel Use and Operations (Section 0)
- Autonomous Vehicle Surveys and Operations (Section 4.1.6)
- Benthic Surveys (Section 4.1.7)
- Water Column Sampling (Section 4.1.8)
- Dye and Particulate Releases (Section)
- Seagrass, Macroalgae, and Intertidal Research (Section 4.1.10)
- Light Emitting Devices and Operations (Section 0)
- Acoustic Devices and Operations (Section 4.1.12)
- Operations Producing Electromagnetic Fields (EMF) (Section 4.1.13)
- Community and Research Scale Marine Energy Devices (Section 4.1.14)
- Tidal Turbine Research (Section 4.1.15)

ESA coverage for the program will use implementation procedures described in the body of the Opinion. When a new project or activities are proposed, the DOE will provide notice to the Service. Depending upon the possible impacts and effects, the Service may be simply notified, or the project/activities may require a reply and verification by the Service. For projects (activities or parts thereof) that will or may result in measurable adverse exposures or effects, verification may include identification of project design criteria (PDC) and/or conservation measures that must be implemented. If specific projects (activities or parts thereof) are not consistent with and covered by the completed formal consultation and Opinion, the Service will work with the DOE to identify information needs and discuss procedural steps and timelines in support of individual ESA section 7 consultation.

Sufficient information has been provided to determine the effects of the proposed action, and to conclude whether it would adversely affect the bull trout (*Salvelinus confluentus*), designated critical habitat for the bull trout, or the short-tailed albatross (*Phoebastria albatrus*). This concurrence section is based on information provided by the action agency, best available science, and complete and successful implementation of the conservation measures included by the action agency.

3.1 Bull Trout

The action area includes suitable nearshore marine habitats and supports bull trout from the Coastal Recovery Unit (USFWS 2015). The Coastal Recovery Unit is located in western Oregon and Washington, and includes Olympic Peninsula, Puget Sound, and lower Columbia River basins. The Olympic Peninsula and Puget Sound basins and their associated marine waters (Puget Sound, Hood Canal, SJF, and Pacific coastal waters), are critical to supporting bull trout in the Coastal Recovery Unit, including the unique anadromous life history form.

The bull trout that are present and occur in the action area most likely belong to and originate from the lower Dungeness River-Gray Wolf River bull trout core area (USFWS 2015). This local bull trout population(s) is considered depressed because of declining abundance; likely influenced by road density, sedimentation, urbanization, poaching, and competition and hybridization with introduced brook trout (*Salvelinus fontinalis*) (64 FR 58910).

Within and across the Coastal Recovery Unit, foraging, migrating, and overwintering habitat (FMO, including nearshore marine FMO) is often shared by bull trout from multiple core areas/populations. Sequim Bay and adjacent portions of the SJF provide FMO habitats that may support bull trout from additional core areas and populations. FMO habitats contribute to successful overwintering, survival, and dispersal among core areas, and are important for genetic mixing and long-term population resiliency; especially for the anadromous and fluvial life history forms (USFWS 2015; USFWS 2017).

Bull trout often forage on salmon fry and eggs, and therefore even smaller, independent tributaries located outside of core areas provide important freshwater foraging habitats. Independent tributaries on the Olympic Peninsula are not believed to support spawning populations of bull trout (USFWS 2004). Bull trout migrate through nearshore marine waters, to feed where seasonally abundant prey are available, including at the mouth and within smaller, independent tributaries.

According to WDFW's SalmonScape (https://apps.wdfw.wa.gov/salmonscape/map.html; checked on February 14, 2024), bull trout have been documented at one location within the action area (Bell Creek, adjacent to the mouth/outlet of Sequim Bay). Bell Creek is located east of the Dungeness River and empties into the SJF north of Travis Spit, the outlet of Sequim Bay, and the PNNL campus. Also, according to SalmonScape, bull trout have not been documented in Dean, Jimmycomelately, Johnson, or any other tributaries to Sequim Bay.

Drift cell processes maintain accretionary landforms, including Dungeness Spit and various other spits and small embayments associated with Washington Harbor and Sequim Bay (USFWS 2015). Sediment processes (erosion, transport, and deposition) play an important role in nearshore ecosystem function, including forming suitable habitats for marine forage fish and marine forage fish spawning (Parks et al. 2013). Marine forage fish are an important prey resource for bull trout, birds, and mammals. In coastal areas of western Washington, subadult and adult bull trout feed on Pacific herring (*Clupea pallasii*), Pacific sand lance (*Ammodytes hexapterus*), and surf smelt (*Hypomesus pretiosus*) (USFWS 2004; USFWS 2017). Spawning areas for these marine forage fish species occur in Sequim Bay, including in the vicinity of the PNNL campus (e.g., sand lance spawning sites are located north (100 m) and south (50 m) of the PNNL pier). Sand lance spawn at high tide in shallow water on sand-gravel beaches, from November through February (Essington et al. 2018); juvenile sand lance rear in nearshore marine waters during summer (Penttila 2007). Surf smelt spawn during summer on high intertidal beaches of sand and gravel (Penttila 2007); juvenile surf smelt linger in spawning areas and feed in shallow waters (Penttila 2007). Sand lance, surf smelt, and herring are common in the nearshore waters of Sequim Bay. We assume that bull trout opportunistically forage on these marine forage fish concentrations.

The Service concludes, it is unlikely that bull trout will be exposed to or measurably affected by implementation of the PNNL program of research activities. We expect that bull trout use

Sequim Bay infrequently and in low numbers, and they use and transit through the Sequim Bay inlet only occasionally or rarely. Implementation of the program of research activities will have limited impacts to the intertidal and subtidal bed of Sequim Bay and the SJF, the benthos, submerged aquatic vegetation, and water quality; most of these impacts will be temporary, low intensity, and limited in duration.

The Service concludes, it is extremely unlikely that individual bull trout will be entrained, physically injured, or killed by research activities, or the effects of these activities in the environment; physical injury and mortality are considered extremely unlikely and therefore discountable. The Service concludes that the proposed action will not prevent bull trout from successfully foraging and migrating in the action area, will not significantly disrupt normal bull trout behaviors (i.e., the ability to successfully feed, move, and/or shelter), and the foreseeable effects of the proposed action will not measurably degrade or impair bull trout habitat or habitat functions (including prey production) at the scale of the action area. The Service concludes that implementation of the PNNL program of research activities will have an insignificant effect on bull trout.

3.2 Short-Tailed Albatross

The short-tailed albatross is a large pelagic bird that nests on isolated windswept offshore islands, with restricted human access. Short-tailed albatross mostly nest on islands near Japan, with the only known nesting in the United States occurring around Hawaii. North Pacific marine foraging habitats used by short-tailed albatross are characterized by regions of upwelling and high productivity and expansive, deep water beyond the continental shelf (65 FR 46643).

Historically, short-tailed albatross occurred in and were observed annually in Washington's offshore waters. However, since 1907 there have been few observations, and the species is mostly absent (Carter and Sealy 2014). During the 19th century, short-tailed albatross were widely harvested for their feathers, for the production of fertilizer, and as food. Short-tailed albatross populations dropped by approximately 90 percent, and they appear now mostly limited to Pacific waters surrounding nesting sites on islands near Japan (Carter and Sealy 2014).

The SJF is considered part of the short-tailed albatross's range (USFWS 2019b). However, presence and/or use of the action area by the species is assumed to be a rare, infrequent event. We assume that very low numbers may occasionally use some portion of the action area; most likely, the open, offshore waters of the SJF.

The Service concludes, it is extremely unlikely that short-tailed albatross will be exposed to or measurably affected by implementation of the PNNL program of research activities. Exposures causing (or potentially causing) a significant disruption of normal short-tailed albatross behaviors (i.e., feeding, moving, and/or sheltering) are considered extremely unlikely, and therefore discountable. Implementation of the program of research activities will have limited impacts to the intertidal and subtidal bed of Sequim Bay and the SJF, the benthos, submerged aquatic vegetation, and water quality; most of these impacts will be temporary, low intensity, and limited in duration. The Service concludes, the proposed action will not measurably degrade or impair habitat or habitat functions that are important to the short-tailed albatross (including prey production) at the scale of the action area. Short-tailed albatross will not be prevented from successfully feeding, moving, and sheltering in the action area, and all of the reasonably foreseeable potential exposures and effects are considered either insignificant or discountable.

3.3 Designated Bull Trout Critical Habitat

In nearshore marine areas, the inshore extent of designated bull trout critical habitat is the mean higher high-water line (MHHW), including the uppermost reach of the saltwater wedge within tidally influenced, freshwater heads of estuaries. Critical habitat extends offshore to a depth of 10 m (33 ft) relative to the mean lower low-water line (MLLW) (75 FR 63935; October 18, 2010).

Designated bull trout critical habitat includes: (1) freshwater spawning and early rearing habitats; (2) freshwater FMO habitat; and (3) nearshore marine FMO habitat. Within the action area, designated bull trout critical habitat includes nearshore portions of Sequim Bay, nearshore portions of the SJF, and tidally influenced, freshwater heads of estuaries (e.g., the mouths of Bell Creek, Dean Creek, and Jimmycomelately Creek) (Figure 2). Designated bull trout critical habitat generally encompasses one or more bull trout core areas and includes FMO located outside of core areas that is important to the survival and recovery of bull trout (USFWS 2017).

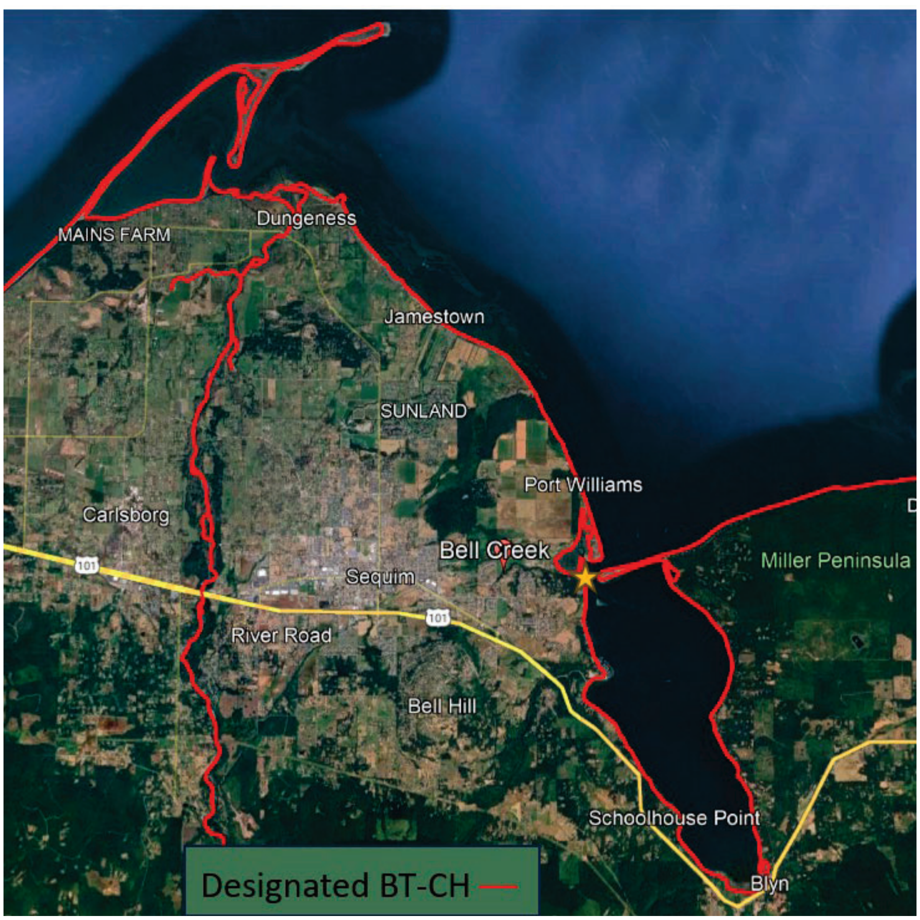

Figure 2. Designated nearshore marine critical habitat for bull trout.

The final revised rule designating bull trout critical habitat (75 FR 63898; October 18, 2010) identifies nine Primary Constituent Elements (PCEs) essential for the conservation of the species. The 2010 designation uses the term PCE. The new critical habitat regulations (81 FR 7214) replace this term with physical or biological features (PBFs). This shift in terminology does not change the approach used in conducting our analyses, whether the original designation identified PCEs, PBFs, or essential features.

The following PCEs are present in the action area:

PCE 2: *Migration habitats with minimal physical, biological, or water quality impediments between spawning, rearing, overwintering, and freshwater and marine foraging habitats, including but not limited to permanent, partial, intermittent, or seasonal barriers*.

The proposed program of research activities will result in measurable impacts to the intertidal and subtidal bed of Sequim Bay and the SJF, the benthos, submerged aquatic vegetation, and water quality. However, these impacts will be localized, limited in physical extent, and low intensity; many of the impacts will also be temporary and limited in duration.

Placement of materials and equipment (e.g., sensors, cables, probes, floats, platforms, marine energy devices, tidal turbines) on and over the seabed will have measurable and unavoidable impacts to migratory habitat. And the proposed research and activities may result in temporary impacts to the sound and visual environment. These effects to the sound and visual environment will be temporary and limited in physical extent and duration.

With adoption and successful implementation of the conservation measures, individual PDCs (Sections 4.1.2 through 4.1.15), and overarching (program level) PDCs (Section 4.2.1), the PNNL program of research activities and resulting impacts will not significantly degrade or impair the current function of PCE #2. All of the foreseeable impacts and effects, including those to the sound and visual environment, will be limited in physical extent, intensity, and duration, and are not likely to measurably impair the current function of nearshore migratory habitat. The proposed action will not cause or contribute to losses of submerged aquatic vegetation or other nearshore marine physical habitat that is important to bull trout.

The Service concludes that the proposed action will not permanently degrade PCE #2 or prevent nearshore migratory habitat in the action area from functioning as intended. The Service expects no measurable adverse effects to PCE #2.

PCE 3: *An abundant food base, including terrestrial organisms of riparian origin, aquatic macroinvertebrates, and forage fish*.

Within the action area, the current function of PCE #3 is moderately impaired. Salmonid and marine forage fish prey resources are below historic, long-term peaks of production. However, year-to-year and geographic variability is significant and not easy to generalize with recognizable trends.

The proposed program of research activities will result in measurable impacts to the intertidal and subtidal bed of Sequim Bay and the SJF, the benthos, submerged aquatic vegetation, and water quality. However, these impacts will be localized, limited in physical extent, and low intensity; many of the impacts will also be temporary and limited in duration. Placement of materials and equipment (e.g., sensors, cables, probes, floats, platforms, marine energy devices, tidal turbines) on and over the seabed may have limited but unavoidable impacts to bull trout prey resources (e.g., limited impacts to marine forage fish spawning substrates, eggs, and/or spawn).

With successful implementation of the conservation measures and PDCs, the PNNL program of research activities and resulting impacts will not significantly degrade or impair the current function of PCE #3. The Service expects that the proposed action will not cause or contribute to measurable losses of salmonid or marine forage fish prey production (or availability) at the scale of the action area. The Service expects no measurable adverse effects to PCE #3.

PCE 4: *Complex river, stream, lake, reservoir, and marine shoreline aquatic environments, and processes that establish and maintain these aquatic environments, with features such as large wood, side channels, pools, undercut banks and unembedded substrates, to provide a variety of depths, gradients, velocities, and structure*.

Within the action area, the current function of PCE #4 is mildly impaired and still functions well. However, at locations where armored and hardened shorelines, marine and estuarine fill, and/or overwater structures are more pervasive, this PCE is moderately impaired.

The proposed program of research activities will result in measurable impacts to the intertidal and subtidal bed of Sequim Bay and the SJF, the benthos, submerged aquatic vegetation, and water quality. However, these impacts will be localized, limited in physical extent, and low intensity; many of the impacts will also be temporary and limited in duration. Placement of materials and equipment (e.g., sensors, cables, probes, floats, platforms, marine energy devices, tidal turbines) on and over the seabed will have limited but unavoidable impacts to marine shoreline aquatic environments, processes, and habitat complexity.

With adoption and successful implementation of the conservation measures, individual PDCs (Sections 4.1.2 through 4.1.15), and overarching (program level) PDCs (Section 4.2.1), the PNNL program of research activities and resulting impacts will not significantly degrade or impair the current function of PCE #4. The Service concludes that the proposed action will not permanently degrade PCE #4 or prevent marine shoreline aquatic environments in the action area from functioning as intended. The proposed action will not cause or contribute to losses of submerged aquatic vegetation or other nearshore marine physical habitat that is important to bull trout, and will not have measurable effects to processes that establish and maintain marine aquatic environments or habitats. The Service expects no measurable adverse effects to PCE #4.

PCE 8: *Sufficient water quality and quantity such that normal reproduction, growth, and survival are not inhibited*.

Within the action area, the current function of PCE #8 is mildly impaired and still functions well. The proposed program of research activities will result in measurable impacts to water quality; these impacts will be localized, limited in physical extent and duration, and low intensity. The proposed action does not include continuous sources of discharge, and no persistent or long-term effects to water quantity or quality are expected or foreseeable. With successful implementation of the conservation measures and PDCs, the PNNL program of research activities will not significantly degrade or impair the current function of PCE #8. The Service expects no measurable adverse effects to PCE #8.

4 BIOLOGICAL OPINION

4.1 DESCRIPTION OF THE PROPOSED ACTION

A federal action means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by federal agencies in the United States or upon the high seas (50 CFR 402.02).

4.1.1 Overview of the Marine Research and Testing Program

PNNL is managed and operated by Battelle on behalf of the DOE Pacific Northwest Site Office (PNSO). The Sequim laboratory and field sites provide capabilities for future energy research, climate change effects analyses, wetland and coastal ecosystem restoration, and other environmental research involving marine resources. While DOE does conduct some of its own research, most of the work involves outside researchers and agencies that contract with and make use of the PNNL facility.

ESA coverage for the program of research and equipment testing will use the framework and implementation procedures described below. When a new project or activities are proposed, the DOE will provide notice to the Service. Depending upon the possible impacts and effects, the Service may be simply notified, or the project/activities may require a reply and verification by the Service. Specific activities requiring verification may also be subject to compensatory mitigation (i.e., those activities described in Sections 4.1.2, 4.1.4.1, 4.1.14, and 4.1.15). The DOE's proposed action includes compensatory mitigation for a subset of deployments between February 16 and July 15 (DOE-PNSO 2023, pp. 17, 18, 20, 38, 43, 59, 60, 62), to offset the impacts and effects of these deployments. All other activities will not be subject to compensatory mitigation.

Notification is required for projects (activities or parts thereof) that are not likely to have or result in measurable adverse exposures or effects (NLAA); the Service will be notified before these projects/activities proceed. For projects (activities or parts thereof) that will or may result in measurable adverse exposures or effects (LAA), the Service will be notified, the Service will confirm that the project/activities are consistent with and covered by the completed formal consultation and Opinion, and the Service will reply to DOE with a verification.

The Service will review and provide verification(s) within 30 days; some reviews and verifications will require and may be granted up to 90 days (e.g., tidal turbine research). For projects (activities or parts thereof) that will or may result in measurable adverse exposures or effects (LAA), verification may include identification of project design criteria (PDC) and/or conservation measures that must be implemented. If specific projects (activities or parts thereof) are not consistent with and covered by the completed formal consultation and Opinion, the Service will work with the DOE to identify information needs and discuss procedural steps and timelines in support of individual ESA section 7 consultation.

Activities are grouped by category. Some research activities fall into multiple categories (for example, tidal turbine research includes or uses vessel operations, light emitting devices, seabed installations, etc.). The 14 activity categories are described below; the fuller descriptions appearing in the DOE's PBA are incorporated here by reference in their entirety.

4.1.2 Surface Platforms and Buoys

Buoys provide buoyancy in water and may or may not include sensors, instruments, and/or moorings. Most buoys will be less than 8 square feet (sq ft) in size; some buoys may be up to 100 sq ft in size, to support deployment of larger sensors and/or instruments. Buoys larger than 100 sq ft will be evaluated as platforms. [Note: Community/research scale marine energy devices (Section 4.1.14) which inherently function as buoys (i.e., shape, structure, operation) will be addressed/notified as buoys. All other community/research scale marine energy devices will be addressed as such (see Section 4.1.14).]

Solid platforms are in-water structures (e.g., buoys over 100 sq ft) with no (or negligible) open space or configuration to allow light penetration below. Solid platforms will not exceed 400 sq ft. Grated surface platforms are in-water structures with floats (e.g., encapsulated foam) that provide a generally flat, walkable surface up to 400 sq ft. For each grated surface platform, up to 50 percent of the total surface may be solid (e.g., metal or wood sheets/planks) and half the area of the grated surface platform must include materials with 60 percent open space (i.e., to allow for light penetration to the water column).

Platforms and buoys generally float at the surface; some floats or devices (sensors, instruments) may be suspended at mid-water column (with surface markings as needed). Platforms and buoys are generally temporary and deployed for one day to a year or more, and removed when the project or activity is over. In some cases, the platforms, buoys, string of buoys, or other structure may be designed to float freely during the research or testing. Multiple anchors and mooring lines may be installed to keep structures in position.

Project Design Criteria 4.1.2

The following PDC apply to all the activities described within Section 4.1.2. The overarching (program level) PDC described in Section 4.1 also apply:

- 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 DOE documents the functional grating percentages above are being met in structure design, achieving the same light penetration to the water column as the percentages above, or the structure is notified/verified as a solid surface platform.

- Structure designs that include non-biofouling light-penetrating materials will be preferred.
- Structure materials (e.g., plexiglass) that initially allows light penetration but are subject to eventual biofouling will only be used for short-term deployments. Deployment duration will depend on biofouling rate and loss or reduction of light penetration. Once functional grating percentages are not met, the structure will be removed or cleaned to fulfill functional grating requirements.
- Platforms will be constructed of corrosion resistant, non-toxic materials such as encapsulated polyethylene foam, aluminum, fiberglass, or wood treated with non-toxic protection such as ammoniacal copper zinc arsenate.
- Floating platforms and buoys will be anchored using diver-installed helical anchors (preferred), concrete or corrosion resistant metal anchors.
- Anchors will be chosen to minimize seabed disturbance. If necessary, midline floats will be added to keep mooring lines from scouring the bottom- or creating-line entanglement.
- A minimum distance of 10 ft will be maintained between floating platforms and buoys, with a maximum of 15 buoys, 5 grated platforms, or 3 solid platforms deployed at one time.
- Infrastructure to support or suspend equipment may be needed in the form of buoys and floating platforms, with an average of 0 to 7 and maximum of 25 deployments per year.
- Deployments between February 16 and July 15, for 60 days or more, will require compensatory mitigation using the modified PNNL Puget Sound Nearshore Habitat Conservation Calculator and conservation credit resources (NOAA NMFS 2023).

Table 1. Reporting requirements for buoy and platform types; deployment timeframes.

Duration	**Buoy (max 100 sq ft)**	**Grated Platform (max 400 sq ft [20ft x 20ft])**	**Solid (Non-Grated) Platform (max 400sq ft [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, <u>and</u> Outside Work Window[1]	Verification and Mitigation	Verification and Mitigation	Verification and Mitigation

[1] "outside work window" includes deployments from February 16 to July 15.

4.1.3 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 is required to support some activities. Deployment of instruments (e.g., light sensors, water quality sensors, coupons for biofouling studies, etc.) supports data collection and testing and pretesting of instruments prior to deployment at other locations. Attachment or mounting is achieved by hand with or without diver assistance, using materials such as cable ties, hose clamps, webbing, or straps. Installation and operation of scientific equipment from the pier and/or floating dock is temporary (usually days to months), with the exception of a few continuous monitoring activities (e.g., water quality multi-parameter instrument).

Project Design Criteria 4.1.3

The following PDC apply to all the activities described within Section 4.1.3. The overarching (program level) PDC described in Section 4.2.1 also apply:

- Installations are limited to PNNL-Sequim pier, ramp, or float (i.e., floating dock) locations that will extend into the water column.
- Instruments will be installed by hand and will not disturb the benthos.
- The maximum surface area per device will be 6 sq ft with a range of 0 to 20 deployments per year and a maximum of 40 deployments per year, with no more than 20 deployed at any given time.
- The maximum dimensions of 6 sq ft per instrument will inherently limit fully solid surfaces and will be limited to sensor supporting structures (i.e., cage to hold multiple sensors).
- All deployments from the pier, ramp, floating dock, pilings, or adjacent shoreline require notification only.

Table 2. Reporting requirements for dock installations; deployment timeframes.

Duration	Dock Installations
1-14 Days	Notification
15-45 Days	Notification
Greater than 45 Days	Notification
Greater than 60 Days, and Outside Work Window	Notification

4.1.4 Seabed Installations

Seabed installations (Sequim Bay and/or SJF) will include a variety of structures, from inert targets for detection (e.g., scuba tanks), to larger benthic landers housing multiple instruments.

4.1.4.1 Equipment and Sensors

Examples of equipment, sensors, and instruments that will 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

Deployments will be temporary (one day to two years). The maximum footprint for any single seabed installation will be approximately 50 sq ft, excluding associated cable(s).

Docking systems for AUVs are used to charge devices between missions. These systems are installed on the seabed, at the PNNL-Sequim pier, or attached to buoys or platforms (and suspended at the water surface or mid-water column). Power sources and delivery include cable(s) to shore, marine energy devices, solar panels, or batteries. Navigation of the AUV is achieved with ultra-short baseline positioning, long baseline positioning, or active acoustics.

Project Design Criteria 4.1.4.1

The following PDC apply to all the activities described within Section 4.1.4.1. The overarching (program level) PDC described in Section 4.2.1 also apply:

- Equipment and instruments are anchored to the seabed with diver-installed screw or helical anchors or tethered to concrete or corrosion resistant metal moorings. Surface water marking of underwater equipment locations may be required, based on the relief or profile of the device extending vertically from the seabed into the water column.
- [Note: Seabed installations for purposes of Seagrass Macroalgae and Intertidal Research will follow/apply relevant Section 4.1.4.1, Section 4.1.10, and the overarching PDCs.]
- Deployments will be temporary.
- Various equipment and prototypes will be installed (Sequim Bay and SJF), with a range of 0-15 deployments per year, a maximum of 35 per year, and no more than 15 deployments at any given time (across both Sequim Bay and SJF).
- Seabed installations will not exceed 50 sq ft, excluding cable(s).
- Deployments between February 16 and July 15, for 60 days or more, will require compensatory mitigation using the modified PNNL Puget Sound Nearshore Habitat Conservation Calculator and conservation credit resources (NOAA NMFS 2023).

Table 3. Reporting requirements for seabed installations (equipment/sensors); deployment timeframes.

Duration	Seabed installations
1-14 Days	Notification
15-45 Days	Verification
Greater than 45 Days	Verification
Greater than 60 Days, and Outside Work Window[1]	Verification And Mitigation

[1] "outside work window" includes deployments from February 16 to July 15.

4.1.4.2 Subsurface Probes, Markers, and Targets

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

Some activities may be aimed at developing technologies to detect objects such as placards, inert unexploded ordinance, or other objects, on or buried in the substrate. To test these technologies, various inert targets (such as scuba tanks, crab pots, aluminum cylinders, other metallic objects with high acoustic reflectivity for system reference [e.g., "Lincoln Hats," etc.]) will be placed on the substrate surface or buried up to 5 ft in the substrate. Target locations will be recorded with high accuracy underwater global positioning system (GPS) or acoustic tags. Targets will typically remain one to six months, but in some cases may be deployed for a year or more.

Project Design Criteria 4.1.4.2

The following PDC apply to all the activities described within Section 4.1.4.2. The overarching (program level) PDC described in Section 4.2.1 also apply:
Burial within the substrate will be performed by divers using hand tools or with the aid of a water jet.

Probes, markers, and/or targets will be spaced at least 1.5 ft apart.
A yearly range of 0 to 80 deployments, with a maximum of 150 deployed at any given time.
No probes, markers or targets will remain in place for more than 2 years.

Verification is required for all deployment durations regardless of the number of probes, markers, and/or targets (Table 4).

Table 4. Reporting requirements for seabed installation (probes, markers, and targets); deployment timeframes.

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

4.1.5 Vessel Operations

Vessel operation support activities are 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. Vessels range in type/size, from kayaks or canoes, up to 50 ft or 80 ft fully equipped research ships. Routine vessel operations do not require notification or verification.

Project Design Criteria 4.1.5

The following PDC apply to all the activities described within Section 0. The overarching (program level) PDC described in Section 4.2.1 also apply:

- Vessels operate according to maritime regulations, standard safety, and environmental practices; operations follow ESA/MMPA harassment/approach regulations; and maintain spill prevention plans.
- There are no limits on numbers of vessels or trips.

Table 5. Reporting requirements for vessel use; deployment timeframes.

Duration	Vessel Use
1-14 Days	N/A
15-45 Days	N/A
Greater than 45 Days	N/A
Greater than 60 Days, and Outside Work Window	N/A

4.1.6 Autonomous Vehicle Surveys and Operations

AUVs, which include remotely operated and fully autonomous vehicles, and autonomous surface vehicles (ASVs), may be deployed from shore, vessels, platforms, or underwater charging stations and will be electronically tracked during operations. AUVs are mobile, pre-programmed, or remote-controlled platforms that carry a wide variety of instruments over a range of different depths. AUV underwater charging stations will be tested and operated. ASVs are surface vessels without an operator onboard which carry or deploy a wide variety of instruments and sensors. AUVs/ASVs may will be used for surveying and mapping, environmental monitoring tasks based on the sensor payload, and to deliver components from the surface to a specified location or underwater docking platform.

AUVs and ASVs use acoustic navigation (DiveNet system), a propeller and fins for steering and diving, use GPS for navigation and tracking from the surface, and communicate to shore via acoustic signals. A variety of equipment may be operated by the AUVs/ASVs, 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.

Unmanned aerial systems (UAS) are flying platforms that require a remote pilot. UASs will be deployed from the shoreline, floating platforms, or vessels. The systems will deploy various sensors such as LiDAR for bathymetry measurements, video, hyperspectral and RGB photography, and physical sensors.

Project Design Criteria 4.1.6

The following PDC apply to all the activities described within Section 4.1.6. The overarching (program level) PDC described in Section 4.2.1 also apply:

- ASVs will include standard automatic identification systems.
- A range of 0 to 10 AUVs/ASVs with a maximum of 30 could be deployed within a given year, with a maximum of 10 being deployed at any given time.
- Systems will be under observation during deployments.
- Marine grade or appropriately encased drones will be used.
- A range of 0 to 60 UAS with a maximum of 150 deployments will occur within a given year, with a maximum of 10 being deployed at any given time.
- All pilots will hold or obtain a pilot's license before operating a drone, as per FAA regulations.
- As per 14 CFR § 107.3, small, unmanned aircraft are limited to 55 pounds on takeoff, including payload or attached devices to the aircraft.
- Flights will comply with the 14 CFR § 107.51 (Operating Limitations for Small Unmanned Aircraft) 400 ft elevation limit over the water surface. If operations must exceed the elevation limit, DOE will seek an FAA exemption(s).
- NMFS guidance for avoiding marine wildlife will be followed (NMFS 2023).

Flights within 200 yds of Protection Island, and within the boundary drawn around Dungeness Spit (Figure 10), are prohibited (PNNL 2023).

Table 6. Reporting requirements for AUVs, ASVs, and UASs; deployment timeframes.

Duration	Autonomous Aquatic Vehicles (AUVs, ASVs and UAS)
Not Applicable	Notification

4.1.7 Benthic Surveys

Habitat and aquatic species surveys will include but not be limited to diver surveys, underwater video, or sonar. Surveys and sampling may be one-time analyses for targeted sampling or could occur multiple times at a location in a monitoring capacity. Survey targets include sediments, submerged aquatic vegetation, macroalgae/kelp, invertebrates, fish, and marine mammals.

4.1.7.1 Benthic Sediment Sampling Surveys

Sediment sampling involves collecting substrate by mechanical or manual methods (i.e., 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. The longest bore coring device will be a gravity corer with a sample size of 3 m long with a 10 cm diameter. Most sampling devices will be deployed from a research vessel or platform. Sampling can also be conducted in other ways (e.g., divers may collect small samples underwater using trowels or similar hand tools).

Project Design Criteria 4.1.7.1

The following PDC apply to all the activities described within Section 4.1.7.1. The overarching (program level) PDC described in Section 4.2.1 also apply:

- A typical range of 0 to 12 surveys requiring sediment collection could take place within a year, with an annual maximum of no more than 30 surveys.
- Sediment samples will be spaced at least 27 yds apart, or 10 yds apart if devices are limited to 1 sq ft or less of surface sediment disturbance.
- A maximum volumetric limit of 1 cubic yard (cy) per survey and 30 cy per year across the action area.
- Sediment sampling surveys are typically of short duration (< 7 days); notification or verification are not duration dependent. Sediment collection surveys are notification only.

Table 7. Reporting requirements for sediment collection surveys.

Duration	Sediment Collection Surveys
Not Applicable	Notification

4.1.7.2 Benthic Characterization Surveys (No Sediment Sampling)

Benthic characterization may be conducted through a variety of means. Only activities that come in direct contact with the benthos are included in this section.

The sediment-profile imaging and plan view (SPI/PV) imaging system consists of a camera attached to a metal frame that is lowered by a vessel to map benthic habitats. Once the frame reaches the seabed, an internal camera prism assembly is lowered to penetrate the sediment and 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 500 cm^2.

From a vessel, a portable free fall penetrometer (PFFP) will be deployed to assess sediment shear strength and pore pressure in the upper meter of the seafloor surface. The device also measures accelerations and ambient pressure. A representative PFFP that may be used is the BlueDrop by BlueCDesigns, which 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 less than 1 m depth in soft mud and less than 0.3 m depth in sands and gravels. It can be deployed from a variety of 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.

Seabed characterization may also be performed using fully autonomous amphibious bottom crawlers such as the Otter or SeaOx Surf Zone Crawlers (Figure 3). These crawlers can operate to depths of 100 m through high current and up onto land. The Otter is 45 kg with maximum dimensions of 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. Crawlers may tow cameras and/or a Flex EMI sled that uses an electromagnetic induction array to detect objects on the seabed.

Figure 3. C-2 Innovations SeaOx with tow sled.

Project Design Criteria 4.1.7.2

The following PDC apply to all the activities described within Section 4.1.7.2. The overarching (program level) PDC described in Section 4.2.1 also apply:

- Non-intrusive benthic characterization surveys equipment (e.g., benthic crawlers) will be spaced at least 3 ft apart and will require notification only.
- Intrusive sediment characterization events (e.g., PFFP) will be spaced 80 ft apart and will not sample within the same area within the same year.
- Benthic research for purposes of "Seagrass Macroalgae and Intertidal Research" will follow relevant Section 4.1.7.2, Section 4.1.10, and overarching PDC.
- Substrate crawlers will 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); species-specific forage fish spawning areas near the Sequim Campus are depicted in PBA, Figure 9; operations conducted outside of the

Tidal Reference Area 10 work windows must first document the absence of forage fish in the project area (valid for 2 weeks, as stipulated by WDFW).

- Benthic characterization surveys (without sediment sampling) are typically of short duration (<7 days); notification or verification are not duration dependent.

Table 8. Reporting requirements for benthic characterization surveys.

Description	Benthic Characterization Surveys
Non-intrusive surveys and intrusive events with distances > 80 ft apart	Notification
Intrusive characterization events ≤ 80 ft apart	Verification

4.1.8 Water Column Sampling: Plankton, Invertebrates and Additional Parameters

Plankton and invertebrate species sampling may occur as one-time collections or multiple times (in either one or multiple locations) in a monitoring capacity. Sampling may involve hand collection by divers, diver held sampling devices, or by research vessel, platform, buoy, AUV, or previously deployed research equipment. Invertebrates and plankton sampled from the water column or water surface will be collected using appropriately sized (screened) gear (e.g., Neuston net, sweep netting).

Water column sampling for additional parameters may include marine microbes, nutrients, minerals, or other targeted abiotic substances; collection 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.

Project Design Criteria 4.1.8

The following PDC apply to all the activities described within Section 4.1.8. The overarching (program level) PDC described in Section 4.2.1 also apply:

- Vertebrates will be returned to the water if incidentally captured.
- An average of 0 to 15 water, plankton, and invertebrate sampling events will be conducted each year, with an annual maximum of no more than 30.

Table 9. Reporting requirements for water column sampling; deployment timeframes.

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

4.1.9 Dye and Particulate Releases

Florescent dye tracers have been used to study dispersion and transport in many aqueous environments (Clark et al. 2014). Optical fluorometer measurement techniques can be combined with dye release protocols to accurately measure in situ. This in situ 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 activities, materials and methods may include dyes such as Rhodamine water tracing (WT) dye (<20 ppb), and detection instruments such as a Cyclops turbidity sensor co-located 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.

Project Design Criteria 4.1.9

The following PDC apply to all the activities described within Section . The overarching (program level) PDC described in Section 4.2.1 also apply:

- Rhodamine water tracing (WT) dye will be below a 20ppb concentration.
- Follow manufacturers use guidelines and limit to minimum concentrations needed for application.
- Measurement devices will not exceed dimensions listed within existing PDC.

Table 10. Reporting requirements for dye and particulate release; deployment timeframes.

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

4.1.10 Seagrass, Macroalgae, and Intertidal Research

Research and survey activities in and around submerged aquatic vegetation 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. Divers perform underwater experiments on eelgrass and macroalgae, as well as associated water and substrate, to understand sediment-nutrient dynamics.

Examples of research activities include transplanting eelgrass shoots and rhizomes, installation of equipment and sensors, and deployment of equipment for data collection in and around these habitats. Eelgrass, macroalgae, water, and associated sediment samples may be collected from shore during low tide, by divers, or via research vessels in deeper water. Specimens will be analyzed in the laboratory for metabolites, biomass, carbon, 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. Equipment installations 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 will be secured using garden stakes or staples, t-posts, PVC piping, rebar, cinder blocks, or similar. Sediment cores (approximately 7 ft deep and 4 in diameter) will be collected, and groundwater wells (approximately 2 in diameter) will be inserted into the space cleared by the sediment coring process. Small groundwater wells will be fit with sensors to collect data relevant to water-soil-nutrient processes. For greenhouse gas measurements, PVC collars will be inserted into the sediment to interface with flux chambers. Sediment cores will be collected at select locations for marsh habitat carbon sequestration research. Periodic surveys of elevation and vegetation cover will collect sediment and vegetation samples. Push point samplers (i.e., hollow metal rods) will be used to collect porewater samples for chemical analyses.

Project Design Criteria 4.1.10

The following PDC apply to all the activities described within Section 4.1.10. The overarching (program level) PDC described in Section 4.2.1 also apply:

- A total of up to 215 ft^2 (20 m^2) of submerged aquatic vegetation may be disturbed (including collection) per year; approximately 108 ft^2 (10 m^2) in Sequim Bay and approximately 108 ft^2 (10 m^2) in the SJF.
- Sampling will not collect more than 10 percent of the eelgrass in any given collection area (e.g., 1.08 ft^2 out of 10.8 ft^2 (0.1 m^2 out of 1 m^2).
- Transplants and/or submerged aquatic vegetation (SAV) specimens will be collected by hand in shallow water or with a small research vessel at deep-water habitats.
- The number of plants removed, and locations will be recorded with a GPS or alternative means (e.g., mapping).
- Sampling and monitoring will not significantly alter the habitats that are being investigated.
- "Seabed installations" and "Benthic Characterization Surveys" for purposes of "Seagrass, Macroalgae and Intertidal Research" will implement relevant general and specific PDCs. Deployments will be temporary, for the duration of the project (one day to two years); equipment and cables will be removed when the activity is complete.
- For greenhouse gas measurements in the Tidal Marsh Area (PBA, Figure 12), PVC collars will be no more than 1 ft diameter inserted 4 in into the sediment in order to interface with flux chambers.
- Sediment cores will be limited to 2 cu ft in volume and 4 in diameter.

- Push point samplers (hollow metal rods) will be limited to no more than 1 in diameter and 1 cu ft of total volume disturbance.

Table 11. Reporting requirements for seagrass, macroalgae, and intertidal research.

Duration	Seagrass, Macroalgae and Intertidal Research
Not Applicable	Notification

4.1.11 Light Emitting Devices and Operations

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 debris and organisms in the vicinity of hydrokinetic devices or other equipment, for bathymetry studies, and for surface applications (i.e., wind measurements and habitat assessments). Underwater detection systems may use either a red laser, green laser, or both. An example system is the Unobtrusive Multi-static Serial LiDAR Imager (UMSLI) and other systems developed by Florida Atlantic University (Figure 4).

Figure 4. Versions of the UMSLI developed by Florida Atlantic University; approximately 81 cm (32 in.) tall, 107 cm (42 in.) wide.

The UMSLI system incorporates both red and green lasers with specifications described below (Table 12). The red laser system is ‘eye-safe’ for both humans and marine animals and is functional out to approximately 10 m, depending on water clarity; it is used for fine scale tracking and object identification. The green laser system is not ‘eye-safe’ for humans or marine animals at near distances but is functional to approximately 20 m from the source. It is used to detect animals approaching the system, then automatically turns off once the animal or object is 10 m from the source.

Table 12. Specifications of the UMSLI green and red laser systems.

	Green	Red
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 nJ
Beam distribution	Gaussian	Gaussian

	Green	Red
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 aircraft or UAV. Examples of aerial bathymetry systems are the Leica Chiroptera 4X that can penetrate to a depth of 25 m, or the Leica Hawkeye 4X that penetrates to depths of 50 m. These are all certified for safe human use as a commercial product.

LiDAR systems may also be used above the surface of the water. These can be used for wind measurements, habitat assessments, or target detection. For wind applications, an upward looking LiDAR will be placed either on the ground or on a platform/buoy. An example of this is the WINDCUBE LiDAR. These have a range up to 200 m and are safety compliant to Class 1M IEC/EN 60825-1. For habitat assessments or target detection, a LiDAR will be flown in an aircraft or drone/UAV, pointing downwards. This could use a system similar to the Phoenix miniRANGER-UAV. This is an eye-safe (Class 1) LiDAR at 905 nm, with a range of 250 m at 60 percent reflectivity.

Project Design Criteria 4.1.11

The following PDC apply to all the activities described within Section 0. The overarching (program level) PDC described in Section 4.2.1 also apply:

- Spotlights and strobes for monitoring, photography, etc., will be intermittent and not continuous.
- Continuous lighting used to prevent biofouling, typically associated with sensors, will be shrouded, and will not interfere with the surrounding water column.
- Any observed effects on fish/marine mammals resulting from ‘eye-safe’ lasers and LiDAR sources will be reported.
- Non-‘eye-safe’ laser (e.g., green laser) operations will use/implement Protected Species Observers (PSOs).
- Operations of non-‘eye-safe’ lasers will be paused and/or discontinued if a protected species (e.g., marine mammals, marbled murrelets) is located within 50 m.
- Non-‘eye-safe’ devices with automated shutdown capability will be enabled during deployment.

- PSOs will scan areas prior to and during use of aerial non-‘eye-safe’ LiDAR and discontinue operations if pinnipeds or marbled murrelets are in the survey area.
- PSOs will report observed effects on protected species (i.e., marbled murrelet, fish/marine mammals).

Table 13. Reporting requirements for light emitting devices; deployment timeframes.

Duration	‘Eye-Safe’ Light Emitting Devices	Non-‘Eye-Safe’ Light Emitting Devices
1-14 Days	Notification	Verification
15-45 Days (Weeks)	Notification	Verification
Beyond 45 Days	Verification	Verification
Greater than 60 Days, and Outside Work Window	Verification	Verification

4.1.12 Acoustic Devices and Operations

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, or underwater infrastructure (e.g., marine renewable energy devices, rotating underwater turbines). Equipment such as echosounders and sub-bottom profilers are used for detection of organisms 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. Deployment configurations include tethered to pier, installed on the substrate, moored/suspended in the water column, bundled with other instrumentation, towed by vessel or AUV, carried by divers, or on free-floating drift buoys. Table 14 provides examples of the variety of sound emitting devices that may be used and that are within hearing range of marine mammals and fish; Table 14 includes physical parameters of the generated sounds. Some of these devices operate at sound pressure levels that exceed established effects thresholds.

Additional acoustic technologies may be used or deployed. These include single and multibeam echosounders, sonars, and acoustic cameras (Table 15). 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. Non-impulsive sound emitting devices, frequencies, source levels, and duty cycles.

Device[1]	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 sub-bottom profiler[2,3]	3–30 kHz	195	32%
APL Custom Transmitter[3]	3–30 kHz	180	32%
Benthos ATM 900 underwater modem[2]	22–27 kHz	178	0.001s ping at 100Hz (10%)
Kongsberg Underwater Positioning System[2]	2230 kHz	189	0.031 s ping at 2 Hz (6%)
Stationary 38 kHz echosounder[2, 4]	38 kHz	215	~ 0.1%
Navy J11 projector[2]	30 Hz –10 kHz	158	continuous sound
Bluefin-21 SAS Sonar[5]	4–24 kHz	200	50%
Benthowave spherical transducer[6]	20–200 kHz	180–200	Up to 50%
Benthowave piston transducer[7]	3.5–100 kHz	180–220	Up to 50%

[1]all devices are considered non-impulsive sound sources

[2]Detailed Analysis provided in PBA (2023, pp. C.1-C.14).

[3]Device is aimed downward from approximately 5 m above the substrate

[4]Directional beam w/ 10° arc, not omnidirectional

[5]Similar to eBOSS sub-bottom profiler

[6]Similar to Navy J11

[7]Similar to Stationary 38 kHz echosounder

Table 15. Examples of acoustic devices and parameters that will not exceed harassment levels.

Device	Operation Frequencies	Source Level (dB re 1 µPa at 1 m)
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 (ADCP)	300 kHz–6 MHz	*NA due to operation frequency outside hearing range*

Project Design Criteria 4.1.12

The overarching (program level) PDC described in Section 4.1 apply to all activities. The following additional PDC apply to devices operating at frequencies within the hearing ranges of protected species, and for sound pressure levels above relevant effects thresholds:

- Sound pressure levels above thresholds operating at frequencies within the hearing range of protected species will be mapped as effect isopleths.
- Effect isopleths (distance from the sound source to where the sound pressure level attenuates to below the reference effect threshold) for sound emissions will be determined with an Acoustic Effects Calculator.
- One or more PSOs will make and report observations for any sound-emitting instrument with effect isopleths greater than 5 m. Operations will be paused or discontinued if an individual is observed within the distance where effects could occur.
- DOE proposes time limits for sound sources with injury isopleths greater than 20 m, or behavioral isopleths greater than 50 m (see below).
- For potential marine mammal injury and behavioral effects (NOAA-NMFS jurisdiction), PSOs will 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 – reinitiate consultation

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.

- The maximum distance at which marbled murrelets can reliably be detected (even under good visibility conditions [Beaufort sea state of 2 or less]) is 50 m (USFWS 2013). Thus, for potential marbled murrelet injury effects from sound pressure levels above thresholds, the number of PSOs will be based on the area that can be reliably observed with each PSO spaced at 50 m, as follows:

– PSOs will survey a maximum distance of 50 m.

- For marbled murrelet behavior effects, use PSOs to extent practicable, given that behavior effect isopleths are greater than injury effect isopleths and the consequences of behavioral changes are less than those of injury, as follows:

– 0-5 m – Vessel staff are observers

– 5-50 m – 1 designated PSO

– 50-250 m – 2 designated PSO with binoculars

– >250 m – 3 designated PSO with binoculars.

- Discontinue operations when any marine mammal or marbled murrelet is observed in the surveyed area.
- 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.
- DOE proposes time limits for sound sources with injury isopleths greater than 20 m, or behavioral isopleths greater than 50 m (see below).
- Time limits for 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/calendar year (maximum consecutive months of activity is 4)
– Total allowable hours of sound emission activity per year is 480.

Table 16. Reporting requirements for acoustic device operations; deployment timeframes.

Duration	Acoustic Emissions with No Potential to Effect (marine mammals, fish, and murrelet)[a]	Acoustic Emissions Within Hearing Range (marine mammals, fish, and murrelet)[b]
1-14 Days	Notification	Verification
15-45 Days (Weeks)	Notification	Verification
Greater than 45 Days	Notification	Verification
Greater than 60 Days, and Outside Work Window	Notification	Verification

[a] Devices operating at frequencies outside the hearing ranges of protected species, or devices operating at frequencies within the hearing ranges of protected species but at sound pressure levels below the applicable effect thresholds.
[b] Devices operating at frequencies within the hearing ranges of protected species and at sound pressure levels above the applicable effect thresholds.

4.1.13 Operations Producing Electromagnetic Fields (EMF)

Devices and cables which may emit electromagnetic fields are described below.

4.1.13.1 EMF Devices

EMF devices used in research will produce variable levels of EMF up to 1.25 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 or in the water column and may include either alternating current (AC) or direct current (DC) configurations. Cables and devices generating EMF will not typically be buried, but will rest on the seabed, be suspended in the water column, or float at the surface.

Project Design Criteria 4.1.13.1

The following PDC apply to all the activities described within Section 4.1.13.1. The overarching (program level) PDC described in Section 4.2.1 also apply:

- Devices with automated shutdown capability will be enabled during deployment.
- DOE will report any observed effects on protected species (i.e., marbled murrelet, fish/marine mammals).

Table 17. Reporting requirements for electromagnetic device operations; deployment timeframes.

Duration	EMF Operations
14 Days	Notification
45 Days (Weeks)	Notification
Greater than 45 Days	Notification
Greater than 60 Days, and Outside Work Window	Verification

4.1.13.2 Cables

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 are inherent to various deployment types, not limited to seabed installations, may power/charge devices, and/or provide data transfer and communications. Divers and/or vessels will run cables from points on the existing pier/floating dock or other shoreline locations into the water, from shoreline facilities, and out to the deployed devices/equipment. Divers will attach cables to the substrate with small hand-installed helical anchors to avoid scour; in some cases, small concrete blocks or similar anchoring devices may be used. Alternatively, partial burial of cables will be considered for longer deployments. If a specific site is identified for multiple projects/activities that requires several cables or repeated cable installations, a conduit may be installed on or within the substrate to allow installation and removal of cables and avoid repeated disturbance of the substrate. Cable installation elsewhere may be required for devices including hydrophones, water quality sensors, underwater cameras, and navigation aids. Installations will be temporary for the duration of the project/activities (one day to two years).

Project Design Criteria 4.1.13.2

The following PDC apply to all the activities described within Section 4.1.13.2. The overarching (program level) PDC described in Section 4.2.1 also apply:

- Cables may be anchored to the seabed using diver-installed screw or helical anchors, small concrete blocks, or corrosion resistant metal mooring.
- Any singular cable diameter will not exceed 1 ft.
- A maximum of 40 cables will be deployed in research areas at any given time.
- Cables will be either housed together or spaced appropriately to avoid entanglement and clutter.
- Cable installations for purposes of "Seagrass Macroalgae and Intertidal Research" will follow relevant PDC from Section 4.1.4.2, Section 4.1.10, and overarching (program level) PDC.
- Deployments will be temporary for the duration of the project/activities.

Table 18. Reporting requirements for seabed installations of sensors, equipment, and cables; deployment timeframes.

Duration	Cables
1-14 Days	Notification
15-45 Days	Notification
Greater than 45 Days	Notification
Greater than 60 Days and Outside Work Window[1]	Verification

[1] "outside work window" includes deployments from February 16 to July 15.

4.1.14 Community and Research Scale Marine Energy Devices

Marine energy devices are structures which can harness energy from ocean waves, currents, tides, salinity gradients and temperature changes, and convert the energy into power. Research activities involving marine energy devices are generally focused on applications that seek to understand design and performance, and/or development of approaches for understanding the interaction of devices and prototypes with the environment. At the community and research scale, the power produced by these devices is not typically delivered to the U.S. power grid, and is limited (e.g., hundreds of kW of power generation). Deployments may occur in both Sequim Bay and SJF and may power microgrids.

Wave energy converters (WECs) tend to have fewer moving parts than tidal turbines. These devices capture kinetic energy by moving up and down or by rocking with the waves. Devices may include, but are not limited to: point absorbers, wave overtopping reservoirs, attenuators, oscillating water columns, inverted pendulums, submerged pressure differential devices, and rotating mass devices (Figure 5). 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. Attenuators use 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. Any devices which are classified as buoys (see Section 4.1.2), will be viewed independently from this section and will not be subject to the PDC in Section 4.1.14.

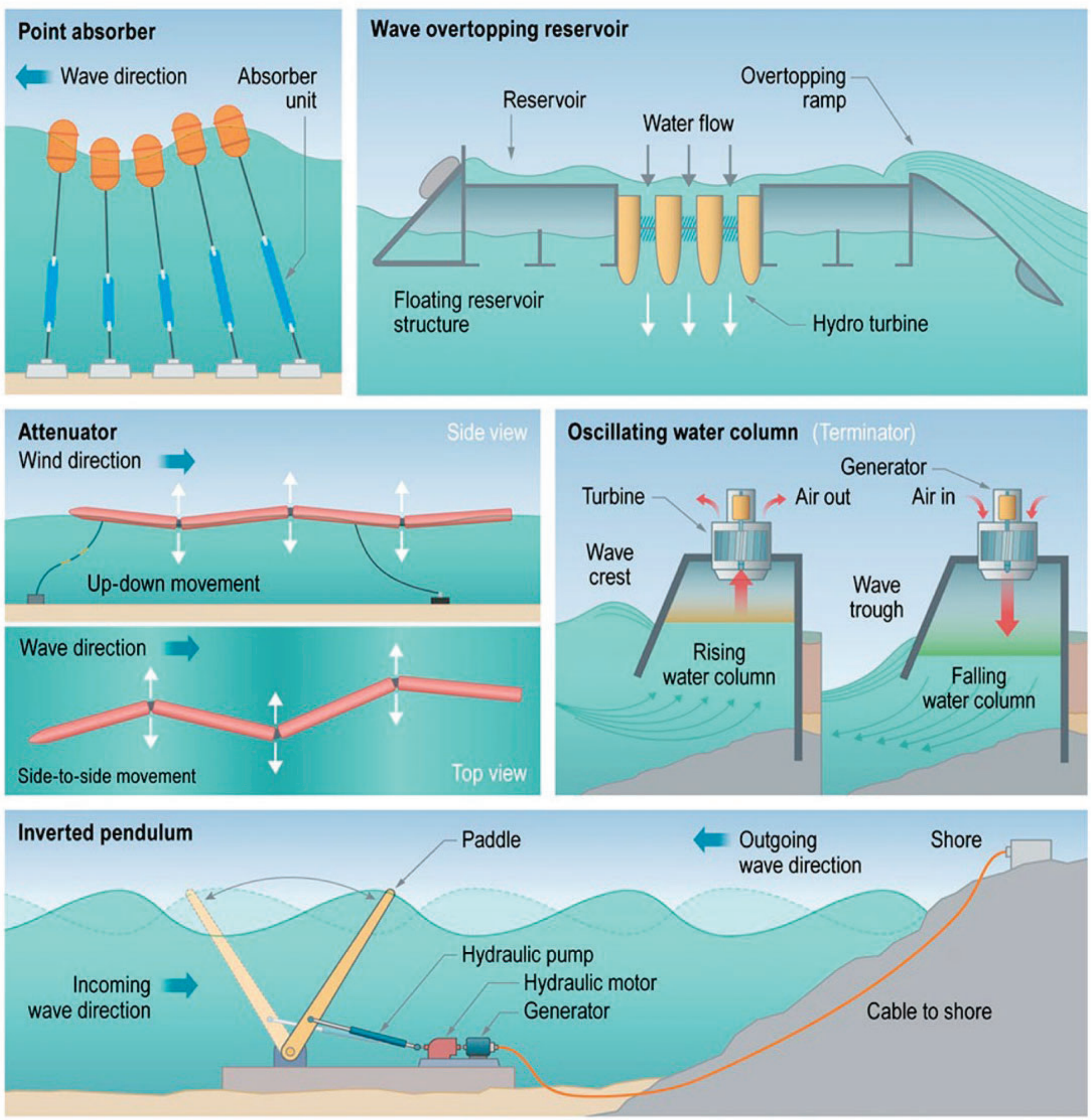

Figure 5. Example marine energy devices and WECs (Augustine et al. 2012).

Project Design Criteria 4.1.14

The following PDCs apply to all the activities described within Section 4.1.14. The overarching (program level) PDC described in Section 4.2.1 also apply:

- Community and research scale marine energy devices will include best management practices (BMPs) to prevent and minimize impacts to species (i.e., screens around moving parts); a list is detailed below:

– Any combination of the below BMPs may be used and implemented; adoption of BMPs will be documented and reported.

- Screens will be installed and will be of mesh size sufficient to prevent the entrainment of protected species (all life stages).
- Divers will confirm anchoring on unconsolidated habitat.
- Generators/turbines and/or exposed rotating parts will be housed in a manner to prevent impingement or areas of entrapment.
- Exposed rotating parts will operate at a speed of 10 m/s or less.
- Wave overtopping reservoirs will be designed so as to allow for a minimum of 50 percent water exchange between surface water and reservoir water.
- Any new and/or novel products/technologies will be documented, including how deployments will avoid impacts to protected species.
- PSOs will make and report observations during operations. If protected species are seen within 50 m of a device, stop work and continue operation 30 minutes after the protected species have left the survey area.

- Projects/activities unable to adopt BMPs, will require verification regardless of duration.
- A range of 5 to 7 deployments, with a maximum of 150 deployments, will occur in any given year.
- Devices will be anchored using diver-installed helical anchors (preferred), or concrete or corrosion resistant metal anchors.
- Anchors will be chosen to minimize seabed disturbance. If necessary, midline floats will be added to keep mooring lines from scouring the bottom- and prevent-line entanglement.
- Deployments between February 16 and July 15, for 60 days or more, will require compensatory mitigation using the modified PNNL Puget Sound Nearshore Habitat Conservation Calculator and conservation credit resources (NOAA NMFS 2023).

Table 19. Reporting requirements for community and research scale marine energy devices; deployment timeframes.

Duration	Community and Research Scale Marine Energy Devices (With BMPs)	Community and Research Scale Marine Energy Devices
14 Days	Notification	Verification
45 Days (Weeks)	Notification	Verification
Beyond 45 Days	Verification	Verification
Beyond 60 Days Outside Work Window[1]	Verification and Mitigation	Verification and Mitigation

[1] "outside work window" includes deployments from February 16 to July 15.

4.1.15 Tidal Turbine Research

The proposed tidal turbine research is designed to support future marine energy development and may include deployment of various turbine types (and numbers) under various operational scenarios. Various types of turbine devices will be considered, deployed, tested, and monitored, including horizontal axis (axial-flow) and vertical axis (crossflow) turbines (Figure 6 and Figure 7). Either type of turbine can be mounted on the bottom substrate or attached to a floating platform.

Other types of turbines, such as oscillating hydrofoils, venturi effect devices, Archimedes screws, and tidal kites may also be considered, deployed, tested, and monitored. PNNL will not install tidal turbines for the purpose of connecting to the US power grid but will install various types of tidal turbines for research purposes. Research will focus on testing turbine concepts to improve efficiency or performance, microgrid research, and monitoring technologies to measure and assess the environmental impacts of tidal turbine devices.

Tidal turbine placement locations are based upon two factors: 1) locations deep enough to provide enough clearance to allow for vessels to pass over the turbines (as determined by the U.S. Coast Guard [USCG]); and 2) locations that provide sufficient tidal current speed and proximity to PNNL-Sequim facilities. The maximum dimensions of tidal turbines that are technically feasible to deploy at a site includes the clearance distance between the top of the 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 the USCG, to allow sufficient clearance for vessels passing overhead.

Based upon these criteria, four locations for tidal turbine deployments have been identified and will be prioritized. Estimates of the maximum potential size for tidal turbines at each of the four representative locations were made based on the available water depth and clearance considerations (Table 21 and Table 22). The four representative locations are situated near the inlet to Sequim Bay – three near Travis Spit and one near The Middle Ground (Figure 8). Water depths, tidal flow speeds, and proximity to shoreside infrastructure make these locations suitable for testing small- to medium-scale tidal turbines (Table 20). The ratio of turbine cross-sectional area to total channel cross-section at low water is used to provide a measure of the scale of these devices, and to determine the largest technically feasible device. This percentage for each site and turbine form factor is provided in Table 21 and Table 22.

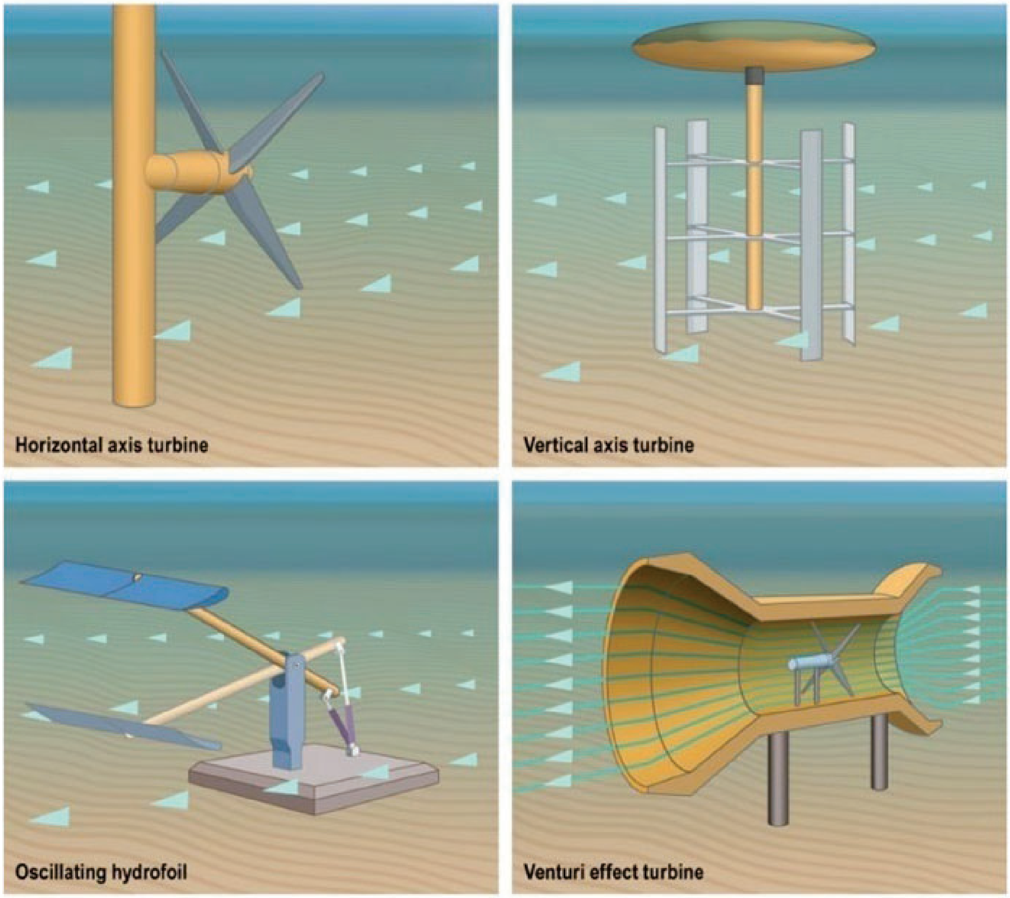

Figure 6. Example tidal turbines (Augustine et al. 2012).

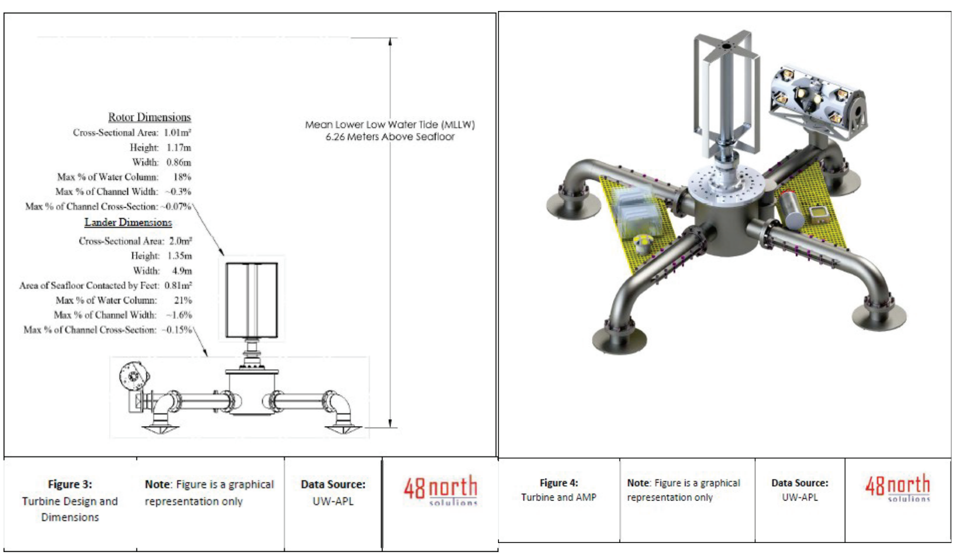

Figure 7. Example vertical axis/shaft, substrate-mounted tidal turbine (APL, University of Washington).

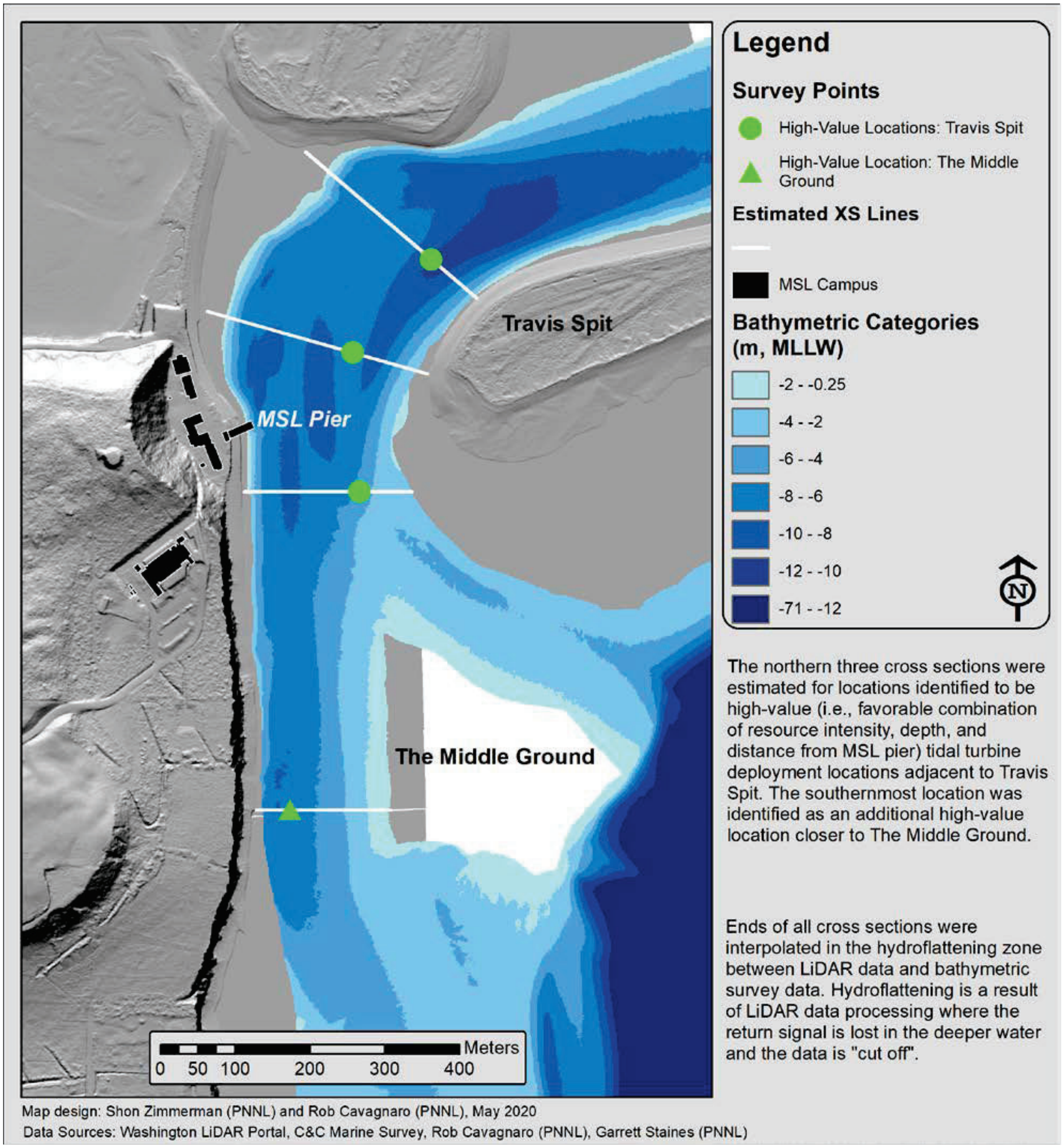

Figure 8. Locations of four representative high-value turbine locations; Sequim Bay inlet channel.

Table 20. Characteristics of four ***representative*** high-value tidal turbine locations.

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

Table 21. Maximum size, power, and speed of ***horizontal-axis*** tidal turbines at four locations.

Site	Max Turbine Diameter (m)	Max Area (m^2)	Max % of 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 22. Maximum size, power, and speed of ***vertical-axis*** tidal turbines at four locations.

Site	Max Turbine Height (m)	Max Turbine diameter (m)	Max Area (m^2)	% of 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

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 with reference to 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 when tip-speed ratios are 5 or higher. Tidal turbines operate at peak performance between tip-speed ratios of 1.5 and 5. For reference, at a flow speed of 2 m/s (about 4.5 mph), an 86 cm diameter turbine's blade will have an absolute tangential speed of 4 m/s (9 mph) at a tip-speed ratio of 2.

Regarding operations, 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) is not a realistic mode of operation. Peak operating efficiency is essential to realistic testing for commercial energy production applications. Optimizing energy production is also a target of research, where tidal turbines will operate over a range of speeds to determine peak operating efficiency. Braking unnecessarily increases electrical and/or mechanical fatigue for components, reduces longevity, and may in certain cases create unsafe circumstances (i.e., potential catastrophic failure).

The DOE intends to conduct research based upon real-world deployment scenarios. While these efforts are focused on research and development, it is essential to emulate conditions relevant to real-world deployment scenarios, including monitoring for impacts to the environment and evaluating novel developer designs. Currently and historically, substrate-base mounted horizontal-axis turbines are the most common design, accounting for over 70 percent of global research and development (Isaksson et al. 2020).

The DOE does not intend or propose to limit the turbine types, numbers, or operations. A commitment to limit turbine type, numbers, or operations may unnecessarily limit the ability to conduct needed research based on emerging market needs, and concurrently limit development of monitoring technologies.

Instead, the DOE will use an adaptive approach, will deploy up to one additional tidal turbine at a time, which over time may include up to five turbines deployed concurrently, with a maximum of 10 turbines deployed in any given year. Any subsequent larger deployments will rely on future adaptive management between DOE and the Services. The current proposed action includes deployment of one tidal turbine at a time, an adaptive approach to subsequent tidal turbine deployments, and exchanges of information with the Services (including monitoring results) during and prior to subsequent turbine deployments.

Project Design Criteria 4.1.15

The following PDC apply to all the activities described within Section 4.1.15. The overarching (program level) PDC described in Section 4.2.1 also apply:

- An adaptive approach will be implemented, with a total of one tidal turbine deployed at a time in the first year. More turbines may be deployed afterward (up to five tidal turbines deployed concurrently; up to 10 tidal turbines deployed in any given calendar year), depending on further collaboration with the Services.
- Underwater monitoring as detailed in Section 4.2.4 will be implemented, including notification/reporting if a target (i.e., seabird, marine mammal, fish) is detected within 1 m. In the event of blade strike, post-processing analysis of adaptable monitoring package (AMP) data will determine if the target was debris, if the target

was an organism, and (if an organism) the species and disposition or condition of the target. The Services will be contacted within 48 hours to determine course of action.

- Turbines and associated structures placed on the seafloor will be installed in a controlled manner to minimize turbidity.
- Divers will confirm placement of turbines avoids rocky outcrops.
- PSOs will make and report observations during installation and decommissioning. If protected species are seen within 50 m of the device, operations will be paused or discontinued until the individuals have left the survey area.
- Deployments between February 16 and July 15, for 60 days or more, will require compensatory mitigation using the modified PNNL Puget Sound Nearshore Habitat Conservation Calculator and conservation credit resources (NOAA NMFS 2023).

Table 23. Reporting requirements for tidal turbine research; deployment timeframes.

Duration	Tidal Turbine Research
14 days	verification
45 days (weeks)	verification
Beyond 45 days	verification
Beyond 60 Days Outside Work Window	Verification and Mitigation

[1] "outside work window" includes deployments from February 16 to July 15.

4.2 Conservation Measures

4.2.1 Project Design Criteria

Project Design Criteria (PDCs) for specific research activities are outlined in the previous sections. PDCs are required of all activities. If/when the DOE cannot or will not implement specific PDCs, the DOE must identify these as minor deviations or minor modifications (i.e., when making notifications and/or requesting verifications).

An individual research project may fit under multiple activity types (e.g., an AUV may collect sediment samples and use an acoustic modem for communication and navigation; an instrument package deployed on the seabed may use LiDAR and include electrical cables). If a project falls under multiple activity types, all PDCs for those activity types will be implemented, including verification or notification requirements. Activities that do not include all relevant PDCs, and that would result in additional adverse effects and/or incidental take (i.e., activities that are not consistent with and covered by the completed formal consultation and Opinion), will require individual consultation.

All projects and activities are subject to and will include implementation of the following overarching (program level) PDCs:

1. All devices and associated structures will be removed at project completion.

2. No significant alteration of the shoreline will result from activities, including deployment of structures/devices.

3. No deployments will occur in SAV, with exception of Seagrass Macroalgae and Intertidal Research, Seabed Installations, and Benthic Characterization Surveys for the explicit purpose of SAV.

4. Anchors will be installed so as to avoid scour (e.g., use of midline floats and/or tensile materials to prevent looping and/or drag during slack tidal conditions).

5. Projects/activities 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 treated with non-toxic protection). Any inorganic arsenical pressure-treated wood (chromated copper arsenate (CCA) or ammoniacal copper zinc arsenate (ACZA)) will be sealed with a wrapping or a polyurea barrier.

7. Any activities in contact with the seabed surface will move sunflower sea stars (*Pycnopodia helianthoides*) by hand if they are encountered in the area of disturbance (if they do not move freely).

8. All work will comply with all federal, state, and local regulations, including 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, exposures, or effects to an individual of any protected species, the PNNL Biological Resources Subject Matter Expert (SME) will notify the Services.

10. The DOE will submit a notification or verification to the Service (as described below) for all activities.

When the DOE has determined that the project or activities meet all relevant, specific, and overarching (program level) PDC, the DOE will proceed with either a notification or verification to the Service. The DOE will inform the Service of an activity prior to its start. Notifications do not require a response from the Service.

Verification requests will be sent to the Service and will demonstrate that the DOE is applying and will implement all relevant and appropriate PDCs. Timeframes and responsibilities for these functions are further outlined below. Specific activities requiring verification may also be subject to compensatory mitigation (i.e., those activities described in Sections 4.1.2, 4.1.4.1, 4.1.14, and 4.1.15). The DOE's proposed action includes compensatory mitigation for a subset of deployments between February 16 and July 15 (DOE-PNSO 2023, pp. 17, 18, 20, 38, 43, 59, 60, 62), to offset the impacts and effects of these deployments. All other activities will not be subject to compensatory mitigation.

Projects will be reviewed in the proposal and funded stages to determine if the scope and life cycle of work are within those described in Section 4.1. Projects will also be evaluated for incorporation of the relevant PDCs.

For projects (activities or parts thereof) that will or may result in measurable adverse exposures or effects (LAA), the Service will be notified, the Service will confirm that the project/activities are consistent with and covered by the completed formal consultation and Opinion, and the Service will reply to DOE with a verification. The Service will review and provide verification(s) within 30 days; some reviews and verifications will require and may be granted up to 90 days (e.g., tidal turbine research). For projects (activities or parts thereof) that will or may result in measurable adverse exposures or effects (LAA), verification may include identification of PDCs and/or conservation measures that must be implemented.

For any activities requiring adaptive management during deployment (e.g., tidal turbine research), a longer verification period (up to 90 days) will be granted. The DOE may contact the Service during the 30-day or 90-day verification periods.

The DOE will track, monitor, and report outcomes for all projects. The DOE will provide annual project summaries to the Service; these will document yearly deployments, projects, impacts, and effects.

Internal DOE/PNNL best practices will include but are not limited to:

1. Project tracking and permitting.

2. Each project scope will be reviewed and identified for suitable fit.

3. As appropriate, a summary of habitats and species that may be affected by the project will include an assessment of impacts.

4. Project scope review will identify PDC and any additional conservation measures that are needed to minimize or avoid adverse effects.

5. Other permits required for project scope will be assigned, including any additional requirements described by the issuing agencies.

6. All project review and permitting materials will be maintained in an online file system.

7. An annual report will be provided to the Service by the anniversary of the issuance date of the programmatic Opinion.

8. Project outcomes and data that provide additional insight and can inform implementation will be provided to the Service.

9. Prior to initiating work, field personnel will receive training or briefings, as applicable, regarding the potential presence of threatened or endangered species that may be

encountered, their physical characteristics, preferred habitats, how they can be identified, actions to be taken if sighted, and avoidance measures to be followed as detailed in the PDCs and conservation measures. This training or briefing will be prepared and offered by PNNL or external experts, the environmental research permitting lead, and/or biological resources staff.

4.2.2 Guidelines for Protected Species Observers

PSOs will provide support to a variety of projects/activities. PSOs will make and report in-person, field observations, to assess species presence and inform implementation of avoidance and minimization measures (including 'stop-work' pauses, or discontinuation of activities). Requirements include:

- PSOs will be deemed qualified to monitor using documentation in Section 4.2.2.1 and as part of their role will provide data forms using the template listed in Section 4.2.2.2.
- PSOs will be positioned and make observations as described in Section 4.1 (i.e., specific to each activity type).
- For deployments requiring marbled murrelet observations/marbled murrelet PSOs, additional specific requirements are described below (see Above Water Marbled Murrelet Monitoring; Section 4.2.3).

4.2.2.1 Protected Species Observer Qualifications

PSOs must have on-water experience observing and identifying ESA-listed species, sufficient for recording presence/absence of individuals belonging to broad and specific taxonomic groups. The following is a list of required qualifications:

1. Visual acuity in both eyes (correction is permissible) sufficient to discern moving targets at the water's surface, with ability to estimate target size and distance. Use of binoculars or spotting scope may be necessary to correctly identify the target.

2. Advanced education in biological science, wildlife management, mammalogy, or related fields (Bachelor's degree or higher is preferred), or equivalent traditional knowledge.

3. Experience and ability to conduct field observations and collect data according to assigned protocols (this may include academic experience).

4. Experience or training in the field identification of marine mammals (cetaceans and pinnipeds) and ESA-listed species (including marbled murrelet, specifically).

5. Sufficient training, orientation, or experience with vessel operation and on-water research activities to provide for personal safety during observations.

6. Writing skills sufficient to prepare a report of observations. Reports should include information, such as the number, type, and location of marine mammals or ESA-listed species observed; the behavior of marine mammals, marbled murrelets, or other species

in the area of potential sound effects during construction; dates and times when observations and in-water construction activities were conducted; dates and times when in-water construction activities were suspended because of marine mammals, marbled murrelets, etc.

7. Ability to communicate orally, by radio or in person, with project personnel to provide real time information on marine mammals or ESA-listed species observed in the area, as needed.

The PNNL Biological Resources SME will be responsible for determining those staff that qualify as PSOs for observing during research activities. Note that a single staff may function as the PSO for both marine mammals and ESA-listed species if qualified for both. The list of potential PSOs will be provided to the Environmental Research Permitting (ERP) SME and Biological Resources SME for documentation purposes in the project permitting file. The Designated Observer Qualifications Form, with any reporting requirements, will be added to the project file. A short summary will be prepared by each PSO after activities are complete (project, date, time, location, species observed, notes on behavioral response, etc.), even if no observations are noted. Summaries will be collated from all PSOs and provided to the ERP SME and Biological Resources SME. This will assure that end-of-quarter or end-of-year reporting requirements are fulfilled.

4.2.2.2 PSO Data Recording

PSO data are recorded for all projects as outlined in the individual PDCs (Sections 4.1.2 through 4.1.15) and overarching (program level) PDCs (Section 4.2.1) using the form provided in the PBA (PBA, p. 5-4).

4.2.3 Above Water Marbled Murrelet Monitoring

The following sections describe marbled murrelet monitoring to be conducted as part of (1) temporary, localized, above water monitoring for marbled murrelet during activities requiring a marbled murrelet PSO (e.g., some light emitting activities, some sound emitting activities, monitoring during tidal turbine installation and decommissioning), and (2) discretionary (optional) above water marbled murrelet monitoring for tidal turbine operations (see 0).

4.2.3.1 Marbled Murrelet Species Information

Marbled murrelets occur in low densities throughout the action area including the deployment areas. Additionally, these densities vary throughout the year and vary by location depending upon foraging opportunities (Speich and Wahl 1995). This variability emphasizes the need to identify the factors that influence marbled murrelet use of the area, and the need to focus monitoring when those factors occur, in order to efficiently and adequately characterize interactions, potential exposures, and effects.

Factors that may influence potential marbled murrelet use of the deployment areas include:

- Time of day
- Prey presence
- Tidal stage
- Season (of the year, and breeding versus non-breeding)
- Water depth and distance from shore

Although literature indicates the above factors are variable in their ability to predict marbled murrelet use of any given area across time, spatial scale, and location, it is worthwhile describing them briefly for their potential relevance to use of deployment areas. Such information can be used to enable improved detection of marbled murrelet by PSOs.

Little is known about marbled murrelet spatial distribution and behavior at night. Several authors have found that marbled murrelets feed near shorelines or narrow channels during the day and move to deeper waters at night (Haynes et al. 2008). Speckman et al. (2000) found higher abundance of marbled murrelets during high or falling morning tides, especially in shallow areas where Pacific sand lance were abundant. This information indicates that use of the research areas may be more likely to occur during the day, and particularly during the morning, than at night.

One of the major influences on seabird occurrence is the distribution and availability of prey. Although seabirds are expected to show a strong response to their prey, this is often not the case at small scales. At larger scales, seabirds occupy the same general regions as their prey. As the scale becomes finer, the spatial associations between seabirds and prey become weak or highly variable and are dependent on prey patch size and prey abundance (Haynes et al. 2008). For example, the tidal turbine deployment area(s) is approximately 800 m in length and of variable width (200-400 m) (Figure 8), comprising an area of approximately 0.24 km^2, which is considered fine-scale habitat where prey occurrence may not correlate with seabird occurrence.

Marbled murrelet prey include marine forage fish and some aquatic invertebrates (Pastran et al. 2021, Ralph et al. 1995). Spawning areas for marine forage fish are present in Sequim Bay, including in the vicinity of the PNNL campus (e.g., sand lance spawning sites are located north (100 m) and south (50 m) of the PNNL pier) (Figure 9). Sand lance spawn at high tide in shallow water on sand-gravel beaches, from November through February (Essington et al. 2018); juvenile sand lance rear in nearshore marine waters during summer (Penttila 2007). Surf smelt spawn during summer on high intertidal beaches of sand and gravel (Penttila 2007); juvenile surf smelt linger in spawning areas and feed in shallow waters (Penttila 2007). Sand lance, surf smelt, and herring are common in the nearshore waters of Sequim Bay. Spawning areas for Pacific herring, Pacific sand lance, and surf smelt occur in or near the proposed tidal turbine deployment area(s).

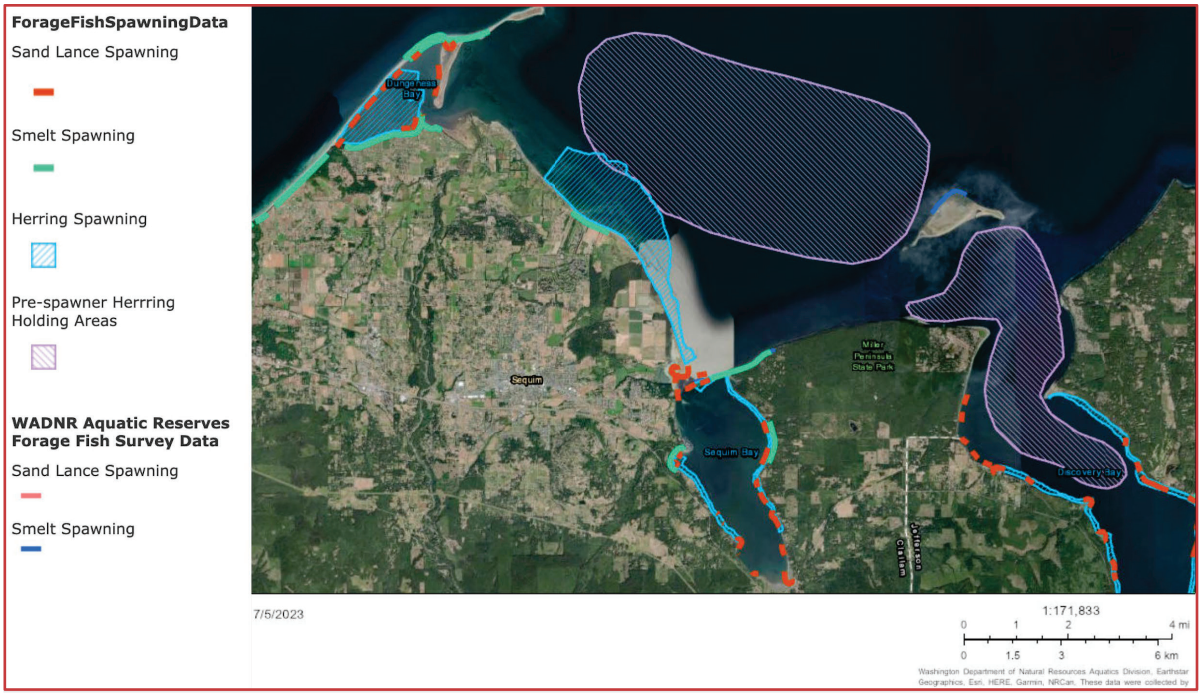

Figure 9. Sand lance, surf smelt, and herring spawning areas near the PNNL-Sequim campus (WDNR and WDFW 2023).

The tidal cycle may make prey more available by concentrating prey and providing favorable foraging conditions. Tidal stage was found to be related to marbled murrelet densities, with marbled murrelets in southeast Alaska more abundant in surveys at slack tide compared to rising/falling tide (Haynes et al. 2008), and at high or falling morning tides, especially in shallow areas where Pacific sand lance were abundant (Speckman et al. 2000). Information on how seabirds behave within tidal stream environments (micro-habitat, <1 km), above all, is needed (Isaksson et al. 2020).

Marbled murrelets forage by pursuit diving in relatively shallow waters, usually between 20 m and 80 m in depth. The species has also been observed diving in waters less than 1 m and more than 100 m deep (Strachan et al. 1995). Although the majority of birds are found as pairs or as singles in a band from 300 m to 2000 m offshore (Strachan et al. 1995), the above information on water depth, distance from shore as related to time of day, areas of tidal mixing, and prey abundance indicate potential use of sites in Sequim Bay and the SJF. This information will be considered in the design of any monitoring protocols for marbled murrelets to increase chances of detection.

4.2.3.2 Survey Area

Locations of activities in Sequim Bay and the SJF will be surveyed/monitored for marbled murrelet by the PSO(s). PSOs may monitor up to (but not more than) 50 m from the deployment location or activity, based on visibility limitations under suitable conditions. PSOs monitoring for marbled murrelet within 50 m may also monitor incidentally for other protected species (e.g., marine mammals) within and beyond the 50 m.

Detectability of marbled murrelets is highly dependent on sea state and weather conditions that affect visibility. No monitoring will be conducted when visibility is significantly limited, such as during heavy rain, fog, glare, or in a Beaufort sea state (USFWS 2013) greater than 2. Under suitable sea state and weather conditions, maximum observer distance is 50 m using binoculars or spotlight. A single PSO may cover and observe over an approximate 50 m distance of open water within a 180-degree arc of the observer's position (USFWS 2013). Observers should calibrate the 50 m distance using a buoy towed behind the survey vessel (Haynes et al. 2008).

4.2.3.3 Labor and Equipment

The size and shape of an activity's area of potential effect will determine the number of requisite PSOs. PSOs will carry and use binoculars, spotting scopes (optional), two-way radios (or cell phones), range finders, logbooks, and identification guides. Daytime surveys will require use of binoculars; nighttime surveys will require use of spotlights (Haynes et al. 2008). PSOs will communicate in order minimize missed detections and reduce the possibility of double counting.

4.2.3.4 Boat Speed

If moving (for transects), boat speed should be no less than 5 knots and no greater than 10 knots. PSO/observer coverage should not be compromised; therefore, the observer's ability to scan will dictate the speed of the boat (USFWS 2013).

4.2.4 Underwater Tidal Turbine Monitoring

The DOE proposes to use the best available industry instruments and technologies to evaluate and reduce the risk of species collisions with tidal turbines as identified in the most recent *State of the Science Report* (Copping and Hemery 2020). Target species for monitoring include marine mammals, seabirds (including marbled murrelets), and fish. 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 (including marbled murrelets) use high-flow environments.
- Detecting collisions.

While many monitoring instruments and technologies are available, there is no 'one method fits all' solution (Isaksson et al. 2020). For example, information on how seabirds behave within a distance several times the diameter of a tidal turbine (generally not to exceed 10 m) is needed (Isaksson et al. 2020) and may require specific survey methods. The DOE will use and apply the best available marine renewable energy monitoring instruments, such as multibeam sonar or stereo optical camera (see Chapter 10 of *2020 State of the Science Report* [Copping and Hemery 2020]), either singly or in configurations of multiple instruments (with a system for data collection), depending on the purpose and configuration of the turbine deployment.

The DOE proposes to deploy, at a minimum, an integrated monitoring system for the duration of tidal turbine deployments, with the same basic function achieved by the adaptable monitoring package (AMP) for monitoring by the Navy and University of Washington (UW) (Navy 2020; Letter of Concurrence – U.S. Department of the Navy, Marine Energy Converter Field Demonstration Project, Sequim Bay, Washington, Ref. No. FWS/R1/2022-0047787, June 1, 2022), or as applied by Bassett (2022). Representative test deployments of the UW AMP with alternate configurations and operational strategies are described in Polagye et al. (2020) and include those tested in Sequim Bay in conjunction with PNNL. Data collected during Sequim Bay testing were used to train a machine learning model, and classify targets detected on the multibeam sonar as either seals, diving birds, fish schools, or small targets (which may be individual fish or floating debris) (Cotter and Polagye 2020). In post-processing, 89 percent of biological targets were accurately grouped into these four categories. DOE's proposed action for tidal turbines is broader than that of the Navy (2020), with additional possible turbine type and number, operating parameters (e.g., tip-speed ratio), depth, location, and deployment duration. The DOE will use and implement underwater equipment systems that allow for near-field monitoring and can be adapted to address specific information.

The AMP, a customizable commercially available instrumentation platform, can support integration of a variety of sensors. The AMP will include: one hydrophone, one multi-beam sonar, and two stereo optical cameras equipped with artificial illumination (four lights). One of the main advantages of the AMP is that it is a cabled system – meaning that it has an external power source and data are relayed to the user in real time. All devices operate continuously, with the exception of artificial illumination, which will illuminate the water if a target of interest is detected. Data from AMP sensors can be collected on a duty cycle, or data acquisition can be triggered by real-time detection of targets (Cotter et al. 2017, Cotter and Polagye 2020). The DOE will prioritize the latter, to adequately detect and describe protected species interactions, and reduce data volumes while focusing on targets of interest. The AMP does not include an acoustic doppler current profiler (ADCP). However, as an external addition, an ADCP will most likely be deployed by projects throughout the during deployments of turbines.

At the first detection of a target of interest (e.g., seabirds, marine mammals, and/or fish) within a 1 m radius of any turbine, the Service 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 events are observed with the multibeam sonar at night or if it is determined that artificial illumination will aid in species identification (e.g., due to clarity conditions). The first target interaction observed that is designated/identified as a blade strike will be reported to the Service and the turbine will be shut down until further notice. The DOE proposes to conduct near-field underwater monitoring during each week of any given year while a turbine is deployed, in order to document and record possible seasonal variation in near-field underwater habitat use.

4.3 Action Area

The action area is defined as 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). In delineating the action area, we evaluated the farthest reaching physical, chemical, and biotic effects of the action on the environment. The action area for this proposed federal action is based on the geographic extent of proposed activities, as depicted in Figure 10, Figure 11, Figure 12, and Figure 13.

The DOE proposes to conduct and perform a broad program of research activities at PNNL (Sequim, Sequim Bay, and SJF). Specific fields of research focus include development and testing of technologies and systems to monitor changes in the marine environment, marine and coastal resources, environmental chemistry, water resources and modeling, ecotoxicology, biotechnology, materials science, renewable energy development, overwater and underwater surveillance and detection technologies, and national security. Research activities are located at the PNNL campus in Sequim, in Sequim Bay, and the adjacent portions of the SJF (i.e., between Dungeness Spit and Protection Island) (Figure 1).

Research activities include placement of instruments on the water surface, in the water column, and substrate or benthos; sampling of environmental media; deployment and testing of detection and monitoring technologies based on acoustics and LiDAR; operations of autonomous vehicles for sample collection and monitoring; and deployment, testing, evaluation, and monitoring of pilot-scale hydrokinetic devices. Activities will take place in: Sequim Bay, the SJF, Battelle/DOE owned Sequim parcels, and the Tidal Marsh Area.

4.3.1 Sequim Bay Research Area

Sequim Bay is a 2,024-hectare (ha) salt-water body connected to the SJF by a relatively narrow channel (200 m wide at MLLW) between Travis Spit and the PNNL-Sequim campus pier and floating dock (Figure 10). Tidal exchange at the location results in moderate tidal currents (up to 1.5 m/s) with up to a 2.7 m tidal exchange at the channel connection with the strait. The bay has a maximum depth of approximately 30.4 m at MLLW. The bay is bordered by residential properties, the PNNL-Sequim campus, and includes a small boat marina (John Wayne Marina). Recreational and commercial vessel traffic is common throughout Sequim Bay.

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 primarily located in a fringe around and along the shoreline. Sequim Bay is not currently listed as a 303(d) impaired waterbody, but it has been designated as such in the past, and surrounding areas currently have some designation(s).

The area proposed for PNNL research includes all of Sequim Bay, from the connection to the SJF to the approximate 2 m depth (MLLW) to the south (Figure 10), waterward of MLLW except for Battelle or DOE-owned land and tidelands (Figure 11). Research activities will also use Battelle or DOE-owned land adjacent to the shoreline and tidelands (e.g., marsh, wetlands) for purposes described in Section 4.1 (Figure 11).

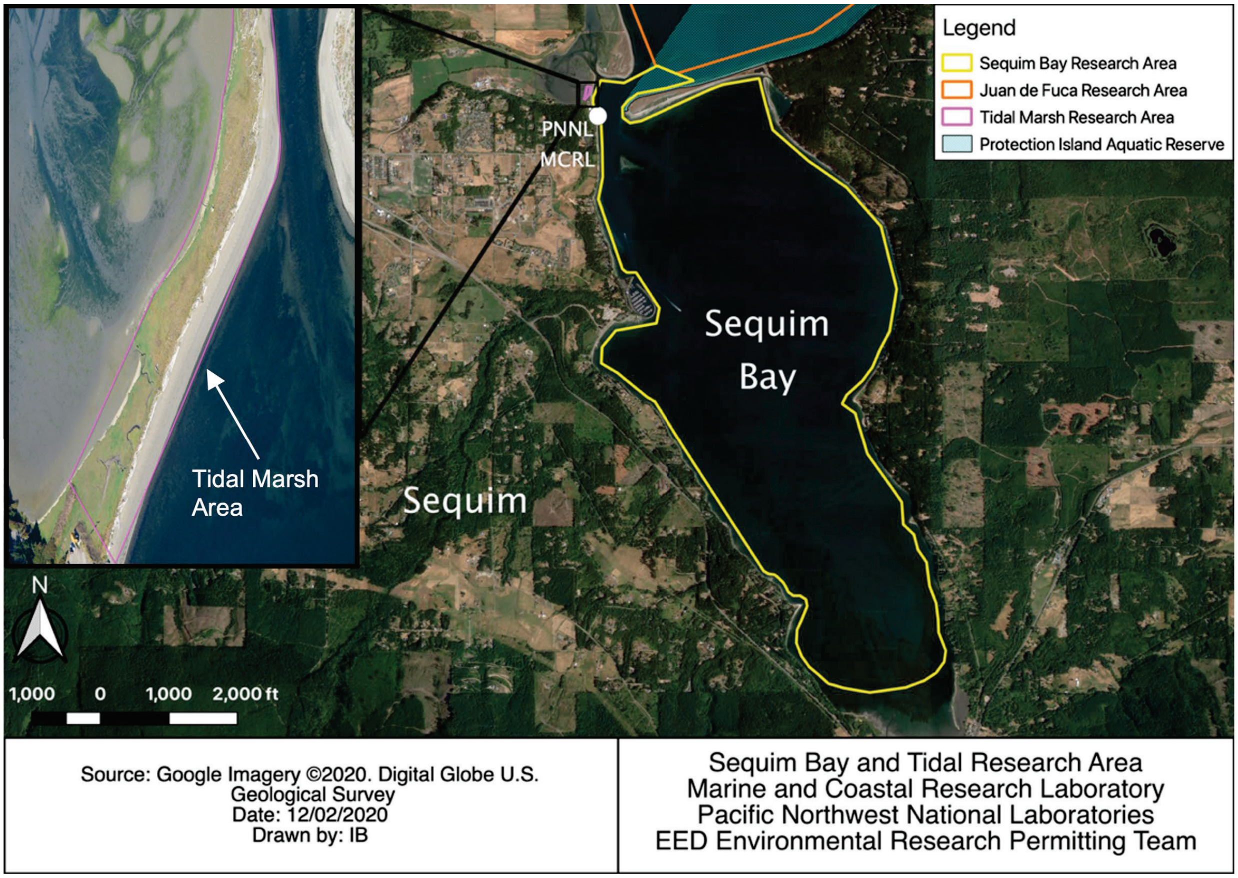

Figure 10. Sequim Bay Research Area and Tidal Marsh Area.

Figure 11. PNNL-Sequim Tidelands and Marsh.

4.3.2 Sequim Bay Research Area – Tidal Marsh Area

The Tidal Marsh Area (Figure 11 and Figure 12) consists of tidelands and shoreline below and above MHW along Bugge Spit. 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*).

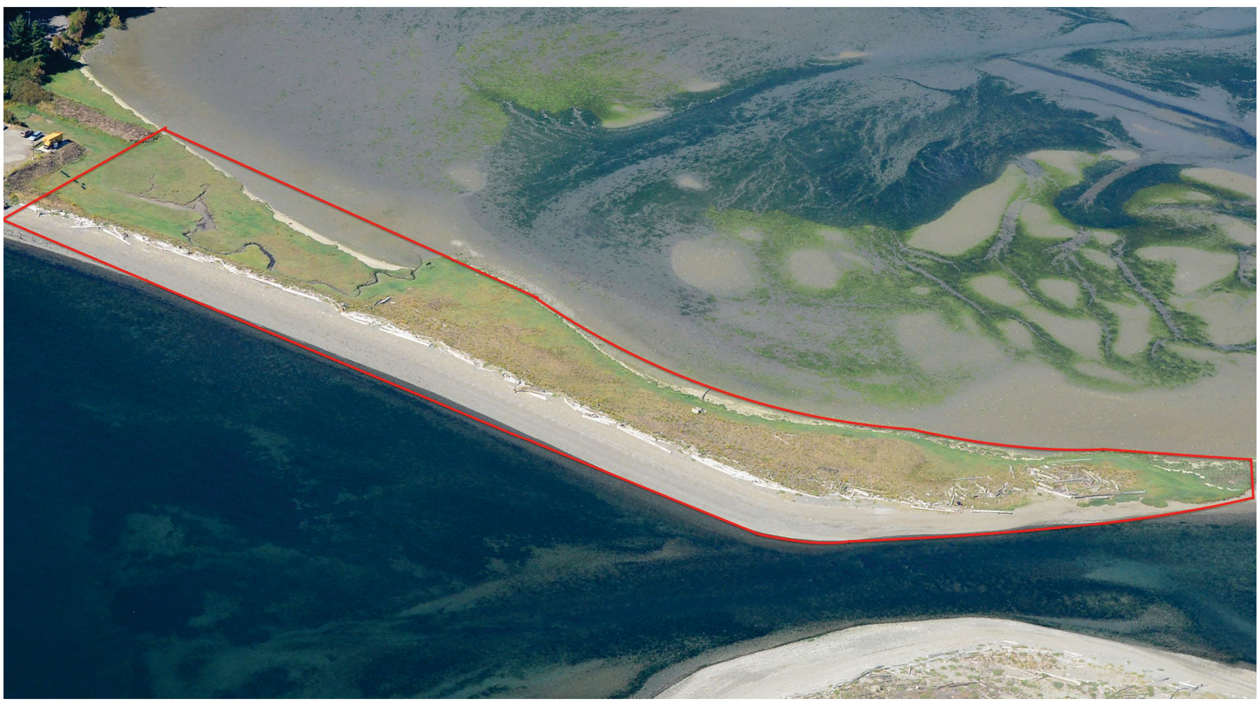

Figure 12. Approximate boundary of the Tidal Marsh Area along Bugge Spit; the full extent is the Battelle/DOE owned parcels.

4.3.3 Strait of Juan de Fuca Research Area

The proposed research area in the SJF is a semi-triangular area as shown in Figure 13. 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 (Figure 13), comprising a total area of approximately 7,250 ha. Water depth is mostly 10 to 50 m, reaching to greater than 70 m deep to the northern and south and west of Protection Island. Currents are relatively mild/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).

National Wildlife Refuges are located at both Dungeness Spit and Protection Island. PNNL research would not occur within the boundaries of either of these refuges. There is also a larger

Washington Department of Natural Resources (WDNR) Protection Island Aquatic Reserve surrounding Protection Island (Figure 13). Some research activities could occur within the WDNR 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.

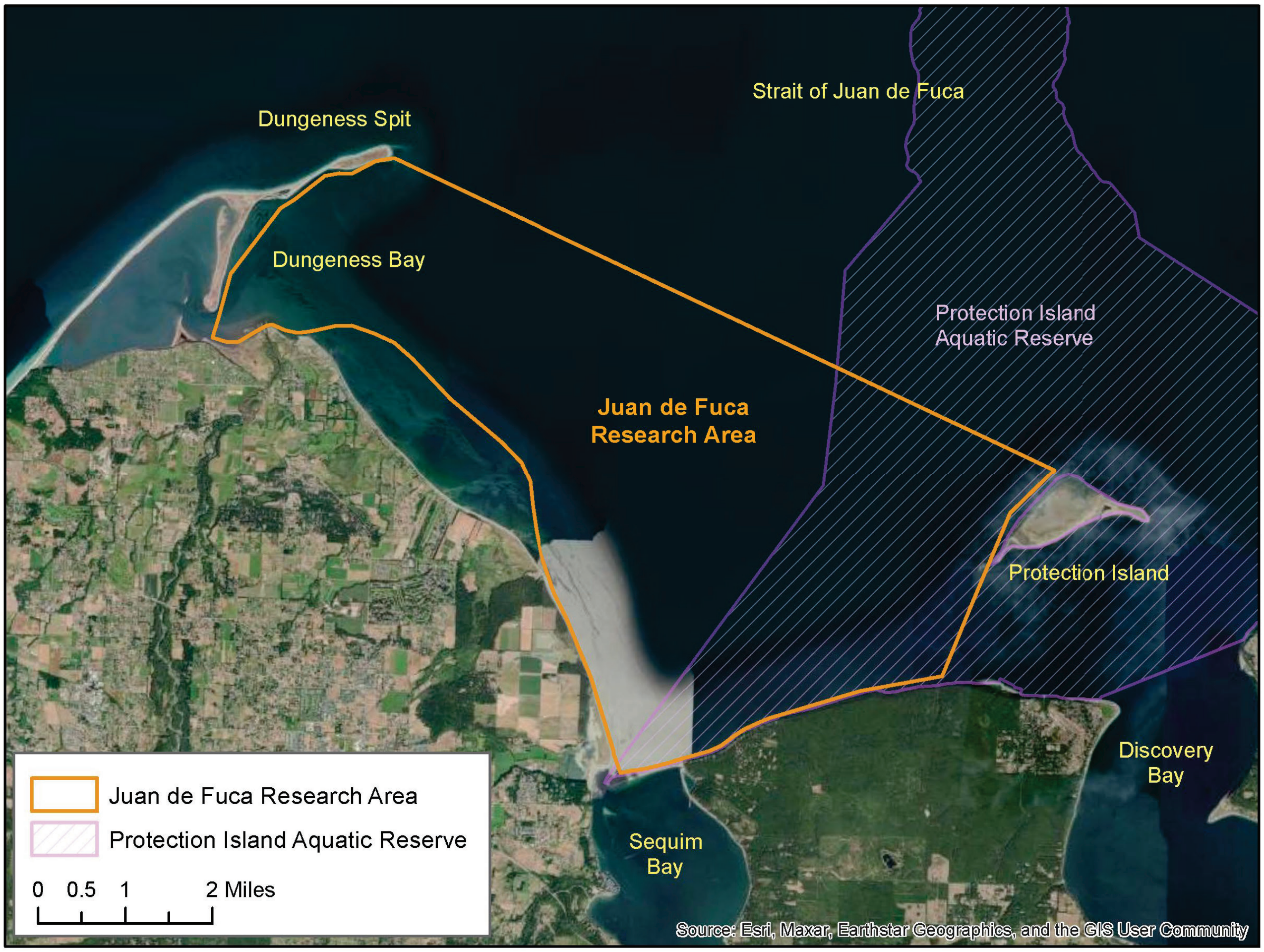

Figure 13. Strait of Juan de Fuca Research Area; boundaries of Protection Island Aquatic Reserve.

5 ANALYTICAL FRAMEWORK FOR THE JEOPARDY DETERMINATION

5.1 Jeopardy Determination

In accordance with our regulations (see 50 CFR 402.02, 402.14(g)), the jeopardy determination in this Opinion relies on the following four components:

The *Status of the Species* evaluates the species' current range-wide condition relative to its reproduction, numbers, and distribution; the factors responsible for that condition; its survival and recovery needs; and explains if the species' current range-wide population retains sufficient abundance, distribution, and diversity to persist, and retains the potential for recovery (see Endangered Species Consultation Handbook, March 1998).

The *Environmental Baseline* section of this Opinion evaluates the past and current condition of the species in the action area relative to its reproduction, numbers, and distribution absent the effects of the proposed action; including the anticipated condition of the species contemporaneous to the term of the proposed action; the factors responsible for that condition; and the relationship of the action area to the survival and recovery of the species.

The *Effects of the Action* section of this Opinion evaluates all consequences to the species that are reasonably certain to be caused by the proposed action (i.e., the consequences would not occur but for the proposed action and are reasonably certain to occur), and how those consequences are likely to influence the survival and recovery of the species.

The *Cumulative Effects* section of this Opinion evaluates the effects of future State, Tribal, or private actions/activities, not involving Federal activities, that are reasonably certain to occur within the action area subject to consultation, on the species and its habitat, and how those effects are likely to influence the survival and recovery of the species.

In accordance with policy and regulation, the jeopardy determination is made by formulating the Service's opinion as to whether the proposed Federal action, including its consequences, taken together with the status of the species, environmental baseline, and cumulative effects, reasonably would be expected to reduce appreciably the likelihood of both the survival and recovery of the species in the wild by reducing the reproduction, numbers, or distribution of that species.

6 STATUS OF THE SPECIES: Marbled Murrelet

For a detailed account of marbled murrelet biology, life history, threats, demography, and conservation needs, refer to Appendix A: Status of the Species: Marbled Murrelet.

7 ENVIRONMENTAL BASELINE: Marbled Murrelet

Regulations implementing the ESA (50 CFR 402.02) define the environmental baseline as 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 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process. The impacts to listed species or designated critical habitat from Federal agency activities or existing Federal agency facilities that are not within the agency's discretion to modify are part of the environmental baseline.

7.1 Current Condition of the Marbled Murrelet in the Action Area

7.1.1 Marbled Murrelet Population and Distribution in the Action Area

The action area includes marine waters and inland territories of Puget Sound and the SJF. The proposed action occurs within Conservation Zone 1 as defined in the Marbled Murrelet Recovery Plan (USFWS 1997). Conservation Zone 1 extends south from the U.S.-Canadian border along the east shore of Puget Sound to the southern end of Puget Sound, then turning westward along the north shore of the Olympic Peninsula to Koitlah Point, just northeast of Cape Flattery. Conservation Zone 1 includes all of Puget Sound and most waters of the SJF, extending inland a distance of 50 miles from eastern Puget Sound and including the northern and eastern section of the Olympic Peninsula.

The Service considers the Northwest Forest Plan's Effectiveness Monitoring Program (NWFPEM) to be the best available information describing the population status and trends of marbled murrelets in Puget Sound. Surveys conducted as part of the NWFPEM resulted in a population estimate of 3,797 marbled murrelets (95 percent confidence interval [CI] of 2,781-4,829) in Conservation Zone 1 in 2022, the last year for which an estimate is available (Table 24, McIver et al. 2023, p. 17). Since 2001, the estimated population size for Conservation Zone 1 has ranged from a low of 2,822 marbled murrelets in 2014, to a high of 9,758 in 2002 (McIver et al. 2023, p. 11-17). Between 2001 and 2022, the estimated average marbled murrelet density in Conservation Zone 1 has ranged from 0.81 to 2.79 marbled murrelets per km^2 (McIver et al. 2023, p. 11-17). Overall, however, the marbled murrelet population in Conservation Zone 1 has been significantly declining over the history of NWFPEM ($p<0.001$), decreasing at 4.6 percent per year (McIver et al. 2023, p. 3).

Table 24. NWFPEM marbled murrelet population estimates and densities in Conservation Zone 1 (McIver et al. 2023, p. 11-17).

Year	Population Estimate	Confidence Intervals		Density (birds/km^2)
		Lower 95%	Upper 95%	
2001	8,936	5,740	11,896	2.55
2002	9,758	5,954	14,149	2.79
2003	8,495	5,795	11,211	2.43
2004	5,465	2,921	7,527	1.56
2005	7,956	4,900	11,288	2.28
2006	5,899	4,211	8,242	1.69
2007	6,985	4,148	10,639	2.00
2008	4,699	3,000	6,314	1.34
2009	5,623	3,786	8,497	1.61
2010	4,393	2,719	6,207	1.26
2011	7,187	4,807	9,595	2.06
2012	8,442	5,090	12,006	2.41
2013	4,395	2,298	6,954	1.26
2014	2,822	1,688	3,836	0.81
2015	4,290	2,783	6,492	1.23
2016	4,614	2,298	7,571	1.32
2017	-	-	-	-
2018	3,843	1,937	6,901	1.10
2019	-	-	-	-
2020	3,143	2,030	4,585	0.90
2021	-	-	-	-
2022	3,797	2,781	4,829	1.09

Within Conservation Zone 1, which encompasses all of Puget Sound and the SJF, marbled murrelets tend to forage in well-defined areas during the breeding season. They are found in the highest densities in the nearshore waters of the San Juan Islands, Rosario Strait, the SJF, Admiralty Inlet, and Hood Canal. They are more sparsely distributed elsewhere in Puget Sound, with smaller numbers observed during different seasons within the Nisqually Reach, Possession Sound, Skagit Bay, Bellingham Bay, and along the eastern shores of Georgia Strait. In the most southern end of Puget Sound, they occur in extremely low numbers. During the non-breeding season, they typically disperse and are found farther from shore (Strachan et al. 1995).

In fall and winter, marbled murrelets from British Columbia and from Conservation Zone 2 move into more sheltered waters in Puget Sound and the Strait of Georgia, which contributes to increased numbers of marbled murrelets in Puget Sound during those seasons (Burger 1995). In Sequim and Discovery Bays, marbled murrelets reach peak abundance during the fall (2.54 birds/km^2) and winter (0.92 birds/km^2) (Speich and Wahl 1995, pp. 314-315). Since most marbled murrelet abundance surveys occur during the spring and summer, the status of those densities is unknown.

7.1.1.1 Sequim Bay Region

Avian surveys have been conducted annually during spring (typically in May) from 2013 through 2019 on PNNL-Sequim campus (including the waterfront and nearshore marine environment in Sequim Bay and the forested uplands), and the marbled murrelet was not recorded (Duncan et al. 2019, pp. B.3-B.5). These general avian surveys took place during daytime, not at dawn or dusk during the species' peak inland activity and were not conducted with the same rigor as surveys that specifically target the marbled murrelet (Evans Mack et al. 2003). Because marbled murrelets are difficult to detect, even when specifically targeted (61 FR 26256), these surveys only suggest the species may not use upland forests at the PNNL-Sequim campus but are by no means conclusive.

Christmas Bird Counts (CBC) have also been conducted within a 15 mi radius centered just northeast of the City of Sequim since 1975 (Sequim-Dungeness CBC survey) (OPAS 2019; Boekelheide 2019). Individual CBC surveys conducted at the PNNL-Sequim campus from 2010 to 2017 (Buenau 2019), and at the lagoon north of campus (which are part of the larger Sequim-Dungeness CBC survey area) (Boekelheide 2019), have not recorded marbled murrelets. However, other individual CBC surveys within the Sequim-Dungeness CBC survey area have reported marbled murrelets in low numbers (OPAS 2019), including in west Sequim Bay (south of the PNNL-Sequim campus) and east Sequim Bay (Boekelheide 2019).

Marbled murrelets have also been sighted year-round near John Wayne Marina (located approximately 1 mi south of the PNNL-Sequim campus on the west side of Sequim Bay), but the specific locations of these sightings and whether the individuals were on the water or in flight are not reported (ebird 2022). Webster et al. (2018) conducted seabird surveys for a five-week period during June and July 2018, between the southwest corner of Travis Spit, the PNNL-Sequim dock, and Gibson Spit located to the north (which comprises the northern portion of the proposed deployment area). Observation periods were 30 minutes each during daytime hours, scheduled to occur during tidal exchanges, both flood and ebb, and during times of slack current. No marbled murrelets were observed. Washington Department of Fish and Wildlife (WDFW) has conducted aerial surveys for marbled murrelet in the eastern part of the SJF in December through February from 1996 through 2023 (Figure 14) with densities ranging from 0.32 birds/km^2 (2003) to 3.41 birds/km^2 (2010). None of the above-referenced surveys are adequate (spatially or temporally) to characterize marbled murrelet use of the open waters of Sequim Bay, and specifically use of the proposed tidal turbine deployment area in Sequim Bay channel.

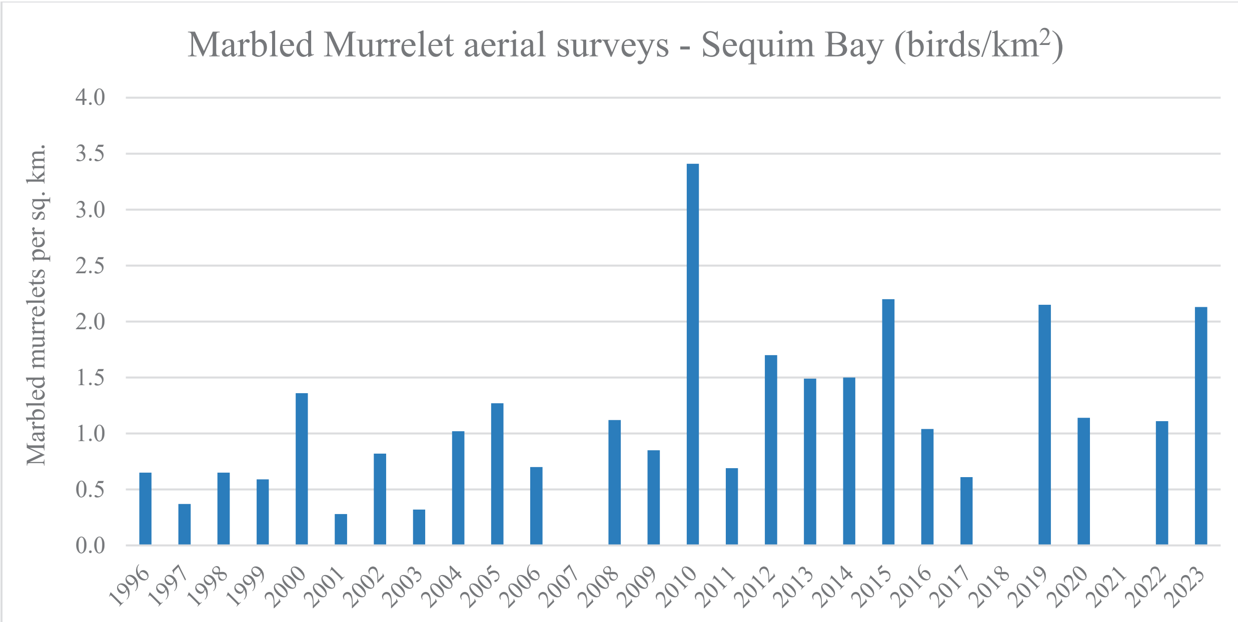

Figure 14. Marbled murrelet densities (birds/km^2) for Sequim Bay, Washington (December-February, 1996-2023) (https://gispublic.dfw.wa.gov/WinterSeabird/).

The description provided by Ralph et al. (1995) is generalized but still informative. Surveys were conducted in the late 1980s/early 1990s to quantify the general, seasonal distribution and abundance of all marine waterbird species in Puget Sound, which includes the inland marine areas of Washington. Winter surveys were from light aircraft and summer surveys were from small boats and light aircraft. Marbled murrelets reached peak abundance in Sequim and Discovery Bays during the fall period, with a density of 2.5 birds/km^2 based on surveys (n = 13) of open water greater than 20 m deep. No locations of similar habitat in Puget Sound had as high a density during any season of the year. Densities reported for Sequim and Discovery Bays during surveys conducted during spring (n = 17), summer (n = 2), and winter (n = 18) were 0.0, 0.33, and 0.92 birds/km^2. The winter density was also the highest of any location of similar habitat in Puget Sound during that season. The proportion of individual censuses where marbled murrelets were present was generally around 20 percent in each season, with the exception of summer when the species was observed on 50 percent of surveys, but the summer sample size was very small (n = 2) (Ralph et al. 1995). Thus, given the limitations of these data (not current and not covering Sequim Bay specifically), detectability and/or occurrence of marbled murrelets in the open waters of Sequim Bay may be sporadic. Further, marbled murrelets may use shallow marine areas close to freshwater streams (Pastran et al. 2021), as well as areas of tidal mixing where prey concentrate (Ralph et al. 1995). The Sequim Bay inlet channel is one such area, but this area was not reported by Ralph et al. (1995).

7.1.2 Previously Consulted-Upon Effects

Within Puget Sound, Hood Canal, and the SJF, the Service has consulted on the effects of many projects, including:

- Fisheries
- Harbor expansions
- Shoreline armoring
- Ferry terminal upgrades
- Aquaculture activities
- Discharges from wastewater treatment plants
- Construction and replacements of piers, ramps, and floats
- Bridge, road, and port maintenance projects and upgrades

The adverse exposures and effects to marbled murrelets resulting from many of these projects are similar and have often included exposure to increased sound pressure levels from pile driving, water quality impacts and exposures (e.g., elevated turbidity and water column contaminant concentrations), and impacts to marine forage fish spawning habitats and/or prey resources.

7.2 Climate Change

7.2.1 Global Climate Change

Our analyses under the ESA include consideration of ongoing and projected changes in climate. The term "climate" refers to the mean and variability of weather conditions over time, with 30 years being a typical period for such measurements, although shorter or longer periods also may be used (IPCC 2014a, pp. 119-120). The term "climate change" thus refers to a change in the mean or variability of one or more measures of climate (e.g., temperature or precipitation) that persists for an extended period, typically decades or longer, whether the change is due to natural variability, human activity, or both (IPCC 2014a, p. 119).

Measurements spanning several decades demonstrate that changes in climate are occurring, and that the rate of change since the 1950s is unprecedented (IPCC 2014a, p. 40). Examples include warming of the atmosphere and the oceans, melting of glaciers and sea ice, and substantial increases in precipitation in some regions of the world with decreases in other regions (e.g., IPCC 2014a, pp. 40-42; Solomon et al. 2007, pp. 35-54, 82-85). Analyses presented by the Intergovernmental Panel on Climate Change (IPCC) show that most of the observed increase in global average temperature since the mid-20th century cannot be explained by natural variability in climate, and is "extremely likely" (defined by the IPCC as 95 percent or higher probability) due to the observed increase in greenhouse gas (GHG) concentrations in the atmosphere as a result of human activities, particularly carbon dioxide emissions from use of fossil fuels (IPCC 2014a, pp. 47-49; Solomon et al. 2007, pp. 21-35). Further confirmation of the role of GHGs comes from analyses by Huber and Knutti (2011, p. 4), who concluded it is extremely likely that approximately 75 percent of global warming since 1950 is caused by human activities.

Scientists use a variety of climate models, which include consideration of natural processes and variability, as well as various scenarios of potential levels and timing of GHG emissions, to evaluate the causes of changes already observed and to project future changes in temperature and other climate conditions (e.g., Meehl et al. 2007, entire; Ganguly et al. 2009, pp. 11555, 15558; Prinn et al. 2011, pp. 527, 529; van Vuuren et al. 2001, entire). All combinations of models and emissions scenarios yield very similar projections of increases in the most common measure of climate change, average global surface temperature (commonly known as global warming), until approximately 2035. After 2035, model projections diverge depending on initial assumptions about GHG emissions (Kirtman et al. 2013, pp. 978-980, 1004-1012; Collins et al. 2013, p. 1093). Although projections of the magnitude and rate of warming differ after 2035, the overall trajectory of all projections is one of increased global warming through the end of the century, even for the projections based on scenarios that assume that GHG emissions will stabilize or decline. Thus, there is strong scientific support for projections that warming will continue through the 21st century, and that the magnitude and rate of change will be influenced substantially by the amount of GHG emissions (IPCC 2014a, pp. 56-63; Meehl et al. 2007, pp. 760-764 and 797-811; Ganguly et al. 2009, pp. 15555-15558; Prinn et al. 2011, pp. 527, 529). Other changes in the global climate are likely to include longer and more frequent heat waves, extreme precipitation events over mid-latitude land masses, intensified precipitation variability related to El Niño-Southern Oscillation (ENSO), reductions in spring snow cover and summer sea ice, sea level rise, ocean acidification, and decreases in the dissolved oxygen content of the ocean (IPCC 2014a, pp. 60-62).

Various changes in climate may have direct or indirect effects on listed species. These effects may be positive, neutral, or negative, and they may change over time. Identifying likely effects involves aspects of climate change vulnerability analysis. Vulnerability refers to the degree to which a species (or system) is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the type, magnitude, and rate of climate change and variation to which a species is exposed, its sensitivity, and its adaptive capacity (IPCC 2007, p. 89; see also Glick et al. 2011, pp. 19-22). There is no single method for conducting such analyses that applies to all situations (Glick et al. 2011, p. 3). We use our expert judgment and appropriate analytical approaches to weigh relevant information, including uncertainty, in our consideration of various aspects of climate change. In general, many species will face increased extinction risk as the future climate changes, especially when climate changes are combined with other factors including habitat loss, modification, or degradation; but this risk can be reduced through management actions, including those that reduce the impacts of non-climate change stressors (IPCC 2014b, pp. 14-15).

7.2.2 Regional and Local Climate Projections

Global climate projections are informative, and in some cases, the only or the best scientific information available. However, projected changes in climate and related impacts can vary substantially across and within different regions (e.g., IPCC 2007, pp. 8-12). We, therefore, use "downscaled" projections, when they are available and have been developed through appropriate scientific procedures, because such projections provide better resolution and information that is more relevant to spatial scales used when conducting analyses (see Glick *et al.* 2011, pp. 58–61, for a discussion of downscaling). The spatial scales addressed by the climate studies reviewed here range from the entire Northeast Pacific to specific areas of Puget Sound.

Many reports discussing downscaled or regional projections of climate change use a suite of climate models and one or more scenarios for anthropogenic carbon emissions over time. The exact suite of models and scenarios varies among reports, but the climate models generally encompass a range of sensitivities to climate scenarios, and the emissions scenarios typically include a lower-emissions scenario and a higher-emissions scenario. Some studies report projections for the 2030s, within the timeframe of the proposed action. However, most report outcomes for the mid- or late 21st century, beyond the timeframe of the proposed action. These projections indicate the direction of various environmental changes (i.e., increases vs. decreases), but are not informative about the magnitude of the expected change within the timeframe of the proposed action, because some changes may accelerate over time, while others may approach a new equilibrium during the timeframe of the projections.

7.2.2.1 Projected Changes in the Physical Environment

Projected changes to climate include air and sea surface temperature increases, changes in precipitation patterns and seasonality, and increases in the frequency and intensity of extreme rainfall events (Mauger et al. 2015, pp. 2-1 thru 2-18). Air temperature warming is already underway, and is expected to continue, with mid-21st century projections approximately 4 to 6 degrees Fahrenheit (F) (2.2 to 3.3 degrees Celsius [C]) warmer than the late 20th century (Mauger et al. 2015, p. 2-5). Similarly, sea surface temperatures are already rising, and the warming is expected to continue, with an increase of 2.2 degrees F (1.2 degrees C) projected for Puget Sound between the late 20th century and mid-21st century (Mote and Salathe 2010, p. 16). For the Strait of Georgia, projections suggest an increase from 2.7 to 5.4 degrees F (1.5-3 degrees C) by the end of the 21st century (Riche et al. 2014, p. 41). Summer precipitation is expected to decrease by 22 percent (averaged across models, relative to the late 20th century) by the mid-21st century, while winter precipitation is expected to increase (Mauger et al. 2015, p. 2-7). In particular, heavy rainfall events are projected to occur approximately three times more frequently (and to be more intense, on average), in the late 21st century (Warner et al. 2015, pp. 123-124).

The warming and precipitation trends may be masked by naturally-occurring climate cycles, such as the ENSO and the Pacific Decadal Oscillation (PDO) (Reeder et al. 2013, p. 76). These oscillations or patterns have similar effects in the Pacific Northwest, with relatively warm coastal water and warm, dry winter conditions prevailing during a “positive” warm phase, followed by cooler coastal water and cooler, wetter winter conditions during the cool “negative” phase (Moore et al. 2008, p. 1747). They differ in that one phase of the ENSO cycle typically lasts between 6 and 18 months (one to three years for a full cycle), whereas, during the 20th century, each phase of the PDO cycle lasted approximately 20 to 30 years (approximately 40 to 60 years for a full cycle) (Mantua and Hare 2002, p. 36). Some studies break the PDO into two components, one with a full cycle length between 16 and 20 years and the other with a 50- to 70-year period, with the longer component referred to as the Pacific Multidecadal Oscillation (PMO) (Steinman et al. 2015, p. 988). Another recent study has identified a 60-year cycle separate from the longer component of the PDO, also referring to this as the PMO (Chen et al. 2016, p. 319). An additional pattern, the North Pacific Gyre Oscillation, is associated with changes in the longshore winds that drive upwelling and appears to complete approximately one cycle per decade (Di Lorenzo et al. 2008, pp. 2-3).

The warming projections described above will be superimposed over the natural climate oscillations. The climate models used to project future trends account for naturally occurring cycles (IPCC 2014a, p. 56). Therefore, the projected trend combined with the existing cycles mean that temperatures during a cool phase will be less cool than they would be without climate change, and warm phases will be warmer. During the winter of 2014-2015, the climate shifted from a negative cool phase of the PDO to a positive warm phase (Peterson et al. 2016, p. 46). Additionally, one study predicts that the PMO will enter a positive warm phase around the year 2025 (Chen et al. 2016, p. 322). The phases of these long-term climate cycles in addition to the projected warming trend imply that we should expect sea surface temperatures during the period from 2017 through 2036 to be especially warm. However, climate change may also alter the patterns of these oscillations, for example, by shortening the cycle length of the PDO (Zhang and Delworth 2016, pp. 6007-6008). Many studies of climate effects to marine species and ecosystems use indices of these climate oscillations, rather than individual climate variables such as sea surface temperature, as their measures of the climatic state (e.g., Becker and Beissenger 2006, p. 473). Therefore, if climate factors that covary with a given oscillation become decoupled, the relationships inferred from these studies may no longer be valid in the future.

These changes in temperature and the seasonality of precipitation affect the freshwater inflows to Puget Sound. Spring and summer freshwater inflows are expected to be warmer and reduced in volume, whereas winter freshwater inflows are expected to increase (Lee and Hamlet 2011, p. 110; Mauger et al. 2015, p. 3-8; Moore et al. 2015, p. 6; Mote et al. 2003, p. 56). Many watersheds draining to Puget Sound have historically been fed by a mix of rain and snowmelt, but are expected to be increasingly dominated by rainfall, which will cause the timing of peak flows to shift from spring to winter (Elsner et al. 2010, pp. 248-249; Hamlet et al. 2001, pp. 9-11; Hamlet et al. 2013, pp. 401-404; Mauger et al. 2015, pp. 3-4 – 3-5). With winter warming and increases in heavy rainfall events, flooding has increased, and this increase is expected to continue (Hamlet and Lettenmaier 2007, pp. 25-16; Lee and Hamlet 2011, p. 113; Mauger et al. 2015, pp. 3-6 thru 3-7). Increased winter freshwater inflows, in combination with melting glaciers, are expected to bring increased sediments to Puget Sound; however, it is uncertain whether these sediments are more likely to enter the Puget Sound or to be deposited in estuaries (Czuba et al. 2011, p. 2; Lee and Hamlet 2011, pp. 129-134; Mauger et al. 2015, pp. 5-7 thru 5-10).

These changes in seasonal freshwater inflows are expected to alter water circulation and stratification, and to affect the rate and timing of exchange of waters through the SJF (Babson et al. 2006, pp. 29-30; MacReady and Banas 2016, p. 13; Mauger et al. 2015, p. 6-2, Riche et al. 2014, pp. 37-39, 44-45, 49-50). This exchange occurs in two layers, with fresh water at the surface flowing toward the ocean, and denser, more saline ocean waters flowing from the ocean at greater depths (Babson et al. 2006, p. 30). With the projected changes in timing of freshwater inflows, the rate of exchange is expected to increase during winter and decrease during summer (Mauger et al. 2015, pp. 6-2 thru 6-3). The effect of changes in freshwater inflow on stratification is likely to vary by location, with greater potential for effect in, for example, Budd

Inlet and Commencement Bay than in well-mixed channels like Admiralty Inlet and Dana Passage (Newton et al. 2003, p. 721).

If changes in upwelling occur along the outer coast of Washington, these changes will also affect the interchange of waters through the SJF (Babson et al. 2006, p. 30; Newton et al. 2003, p. 718). It has been hypothesized, that as climate change accentuates greater warming of air over land than over the ocean, longshore winds will intensify, which will lead to an increase in upwelling (Bakun 1990, entire). Historical records show that these winds have intensified over the past several decades (Bylhower et al. 2013, p. 2572; Sydeman et al. 2014, p. 78-79). Projections for future changes in upwelling offer some support for this hypothesis, but are more equivocal (Foreman et al. 2011, p. 10; Moore et al. 2015, p. 5; Mote and Mantua 2002, p. 53-3; Rykaczewski et al. 2015, p. 6426; Wang et al. 2010, pp. 263, 265). Some studies indicate a trend toward a later, shorter (but in some cases, more intense) upwelling season (Bograd et al. 2009, p. 2; Bylhower et al. 2013, p. 2572; Foreman et al. 2011, p. 8). Upwelling provides waters rich in nutrients such as nitrates, phosphates, and silicates, but these waters are also acidic (due to high dissolved carbon dioxide content) and low in dissolved oxygen (Johannessen et al. 2014, p. 220; Krembs 2012, p. 109; Riche et al. 2014, pp. 45-46, 48; Sutton et al. 2013, p. 7191).

Regardless of potential changes in the timing or intensity of upwelling, the dissolved oxygen content of marine waters is expected to decrease. The solubility of oxygen in water decreases with increasing temperature, so as the climate becomes warmer, the dissolved oxygen content of the marine environment is expected to decrease (IPCC 2014a, p. 62; Mauger et al. 2015, pp. 7-3, 7-8). The oxygen content in the North Pacific Ocean has declined significantly since measurements began in 1987 (Whitney et al. 2007, p. 184), and this decline is projected to continue (Whitney et al. 2013, p. 2204). As these waters flow into the action area, they drive down the oxygen content, although there is considerable variation over time, space, and depth, due to patterns of circulation and mixing within the action area (Bassin et al. 2011; Johannessen et al. 2014, pp. 214-220). For example, Hood Canal is particularly susceptible to hypoxic conditions, partly because circulation of water through Hood Canal is slow (Babson et al. 2006, p. 30), whereas the vigorous tidal currents in Haro Strait allow for the mixing of oxygen-rich surface water throughout the water column (Johannessen et al. 2014, p. 216). Increased stratification, as is expected during winter with the larger freshwater inflows, can lead to hypoxic conditions in deeper waters (Mauger et al. 2015, p. 6-3; Whitney et al. 2007, p. 189). On the other hand, weaker stratification, as expected in the summer, may decrease the probability of low oxygen due to greater mixing, or increase the probability of low oxygen due to slower circulation (Newton et al. 2003, p. 725). If upwelling does increase in intensity, the effect would likely be to further reduce the oxygen content of marine waters, but these changes are not likely to be consistent throughout the action area or throughout the year. Changes in oxygen content, or in the timing of low-oxygen periods, may have important biological consequences (see below). Oxygen content also responds to biological activity. In addition to climate change-induced effects, some locations will likely experience reductions in oxygen content stemming from biological responses to eutrophication in areas that receive (and do not quickly flush) nutrient inputs from human activities (Cope and Roberts 2013, pp. 20-23; Mackas and Harrison 1997, p. 14; Roberts et al. 2014, pp. 103-104, 108; Sutton et al. 2013, p. 7191).

Similarly, acidification of marine waters is expected to increase, regardless of any changes in upwelling. Acidification results when carbon dioxide in the air dissolves in surface water and is the direct consequence of increasing carbon dioxide emissions (IPCC 2014a, pp. 41, 49). Marine waters are projected to continue becoming more acidic (IPCC 2014a, pp. 8-9, 49). Both the surface and upwelled waters of the North Pacific Ocean have become more acidic due to carbon dioxide emissions (Feely et al. 2008, pp. 1491-1492, Murray et al. 2015, pp. 962-963), and this trend is expected to continue (Byrne et al. 2010, p. L02601; Feely et al. 2009, pp. 40-46). These waters contribute to acidification in the action area as they flow in through the SJF (Feely et al. 2010, p. 446, Murray et al. 2015, p. 961), and any changes in upwelling intensity or seasonality would respectively increase acidification or change the timing of pH changes in the action area. It is unknown whether regional carbon dioxide emissions cause additional localized acidification (Newton et al. 2012, p. 36), but it is likely that other products of fossil fuel combustion, such as sulfuric acid, do contribute (Doney et al. 2007, pp. 14582-14583). Linked to reductions in dissolved oxygen (Riche et al. 2014, p. 49), acidification has important biological consequences (see below) and responds to biological activity. For example, local areas of eutrophication are likely to experience additional acidification beyond that caused directly or indirectly by carbon dioxide emissions (Newton et al. 2012, pp. 32-33).

Sea level rise is also expected. Sea level rise is a consequence of the melting of glaciers and ice sheets combined with the expansion of water as it warms (IPCC 2014a, p. 42). At regional and local scales, numerous factors affect sea level rise, including ocean currents, wind patterns, and plate tectonics (Mauger et al. 2015, p. 4-1; Dalrymple 2012, p. 81; Petersen et al. 2015a, p. 21). Sea levels are rising at many locations (Mauger et al. 2015, p. 4-2; Dalrymple 2012, pp. 79-81; Shaw et al. 1998, p. 37). These increases in sea level are likely to continue and may accelerate in the near future (Bromirski et al. 2011, pp. 9-10; Mauger et al. 2015, pp. 4-3 thru 4-5; Mote et al. 2008, p. 10; Dalrymple 2012, p. 71; Petersen et al. 2015a, pp. 21 and 29, and Petersen et al. 2015b). However, in some places, such as Neah Bay, plate tectonics are causing upward land movement that are currently outpacing sea level rise (Mote et al. 2008, pp. 7-8; Dalrymple 2012, p. 80; Petersen et al. 2015a, pp 24-26). In other places, sea-level rise is expected to have consequences for near-shore ecosystems (see below).

7.2.2.2 Projected Biological Consequences of Climate Change

7.2.2.2.1 Primary Productivity

Changes in temperature, carbon dioxide, and nutrient levels are likely to affect primary productivity by phytoplankton, macroalgae, kelp, eelgrass, and other marine photosynthesizers (Mauger et al. 2015, p. 11-5). In general, warmer temperatures, higher carbon dioxide concentrations, and higher nutrient levels lead to greater productivity (Gao and Campbell 2014, pp. 451, 454; Newton and Van Voorhis 2002, p. 10; Roberts et al. 2014, pp. 11, 22, 108; Thom 1996, pp. 386-387), but these effects vary by species and other environmental conditions, such as sunlight levels or the ratios of available nutrients (Gao and Campbell 2014, pp. 451, 454; Krembs 2012, p. 109, Low-Decarie et al. 2011, p. 2530). In particular, phytoplankton species that form calcium carbonate shells, such as coccolithophores, show weaker shell formation and alter their physiology in response to acidification (Feely et al. 2004, pp. 365-366; Kendall 2015, pp. 26-46). Due to changes in the seasonality of nutrient flows associated with upwelling and freshwater inputs, there may also be alterations in the timing, location, and species composition of bursts of primary productivity, for example, earlier phytoplankton blooms (Allen and Wolfe 2013, pp. 6, 8-9; MacCready and Banas 2016, p. 17; Mauger et al. 2015, p. 6-3). Changes in primary productivity are not expected to occur in every season: during winter, sunlight is the major limiting factor through most marine waters (Newton and Van Voorhis 2002, pp. 9, 12), and climate change is not expected to alter winter sunlight. Changes in primary productivity are also likely to vary; for example, primary productivity in Possession Sound is more sensitive to nutrient inputs than other areas within Puget Sound (Newton and Van Voorhis 2002, pp. 10-11). In sum, we expect an overall increase in primary productivity, but there are likely to be changes in the timing, location, and species dominance of primary producers.

Eelgrass (*Zostera marina*) is a particularly important primary producer. In some areas, such as Padilla Bay, sea level rise is expected to lead to larger areas of suitable depth for eelgrass meadows. In such areas, eelgrass cover, biomass, and net primary production are projected to increase during the next 20 years (Kairis 2008, pp. 92-102), but these effects will depend on the current and future topography of the tidal flats in a given area. In addition, eelgrass photosynthetic rates increase with increasing dissolved carbon dioxide concentrations (Short and Neckles 1999, pp. 184-186; Thom 1996, pp. 385-386). However, increasing temperatures are not likely to be beneficial for eelgrass, and in combination with increased nutrients, could favor algal competitors (Short and Neckles 1999, pp. 172, 174; Thom et al. 2014, p. 4). Between 1999 and 2013, eelgrass growth rates in Sequim Bay have increased, but at a site in central Puget Sound, shoot density over a similar time period was too variable to detect trends (Thom et al. 2014, pp. 5-6). Taken together, these studies indicate that climate change may benefit eelgrass over the next 20 years, particularly at some sites, but there is the potential for negative effects to dominate at other sites (Thom et al. 2014, pp. 7-9).

Kelp forests also make important contributions to primary productivity but are less well studied than eelgrass. Like eelgrass, bull kelp (*Nereocystis luetkeana*) responds to higher carbon dioxide concentrations with greater productivity (Thom 1996, pp. 385-386). Warming waters (among other factors) have reduced the range of giant kelp (*Macrocystis pyrifera* [Agardh]) (Edwards and Estes 2006, pp. 79, 85; Ling 2008, p. 892), but it is not clear that giant kelp populations will be negatively affected by the projected additional increases in temperature. Along the western portion of the SJF, bull kelp and giant kelp canopy area increased between 1989 and 2004, but this increase is likely due to factors unrelated to climate change, such as harvesting of sea urchins, which graze on kelp (Berry et al. 2005, p. 4). It is unclear what the future effects of climate change may be for kelp.

In contrast, increases in toxic algae (also known as red tides or harmful algal blooms) have been documented over the past several decades, and these changes may be due to climate change (Trainer et al. 2003, pp. 216, 222). Future conditions are projected to favor higher growth rates and longer bloom seasons for these species. In the case of one species, *Alexandrium catanella,* increases in the length of bloom season are projected primarily due to increases in sea surface temperature (Moore et al. 2015, pp. 7-9). As with other climate change effects discussed above, increases in the length of the toxic algae bloom season is likely to vary. In the eastern end of the SJF and the inlets of southern Puget Sound, the *A. catanella* bloom season is projected to increase by 30 days per year by 2069, in contrast with Whidbey basin, where little or no change in season length is projected (Moore et al. 2015, p. 8). For another species of toxic algae, *Pseudo-nitzschia fraudulenta*, toxin concentrations increase with increasing acidification of the water, especially under conditions in which silicic acid (used to construct the algal cell walls) is limiting (Tatters et al. 2012, pp. 2-3). This species also exhibits higher growth rates with higher carbon dioxide concentrations (Tatters et al. 2012, pp. 3-4). These results indicate that with future climate change, toxic algae blooms are likely to be more frequent, larger, and more toxic.

7.2.2.2.2 Higher Trophic Levels

There are several pathways by which climate change may affect species at higher trophic levels (i.e., consumers). Changing physical conditions, such as increasing temperatures, hypoxia, and acidification will have direct effects on some species. Other consumers will be affected via changes in the abundance, distribution, and/or other characteristics of their competitors or prey species. Changes in the timing of seasonal events may lead to mismatches in the timing of life history requirements and habitat conditions (including prey availability) (Mackas et al. 2007, p. 249). The combination of these effects is likely to cause changes in community dynamics (e.g., competitive interactions, predator-prey relationships, etc.), but the magnitude of these effects cannot be predicted with confidence (Busch et al. 2013, pp. 827- 831).

A wide variety of marine species are directly affected by ocean acidification. Like their phytoplankton counterparts, *foraminiferans* and other planktonic consumers that form calcium carbonate shells are less able to form and maintain their shells in acidic waters (Feely et al. 2004, pp. 356-366). Similarly, chemical changes associated with acidification interfere with shell development and maintenance in pteropods (sea snails) and marine bivalves (Busch et al. 2014, pp. 5, 8; Waldbusser et al. 2015, pp. 273-278). These effects on bivalves can be exacerbated by hypoxic conditions (Gobler et al. 2014, p. 5), or ameliorated by very high or low temperatures (Kroeker et al. 2014, pp. 4-5), so it is not clear what the effect is likely to be in a future that includes acidification, hypoxia, and elevated temperatures. Acidification affects crustaceans, for example, slowing growth and development in Pacific krill (*Euphausia pacifica*) and Dungeness crabs (*Cancer magister*) (Cooper et al. 2017, p. 4; Miller et al. 2016, pp. 118-119). Salmon are also negatively affected by acidification, including negative growth rates, and reduced metabolic rates in juvenile pink salmon (*Oncorhynchus gorbuscha*) at carbon dioxide concentrations comparable to those recently observed in the Strait of Georgia (Ou et al. 2015, pp. 951, 954).

Climate effects are expected to alter interactions within the marine food web. When prey items decrease in abundance, their consumers are also expected to decrease; this can also create opportunities for other species to increase. In California's Farallon Islands, the recently increasing variance of climate drivers is leading to increased variability in abundance of prey species such as euphausiids and juvenile rockfish (*Sebastes* spp.), associated with corresponding variability in the demography of predators such as seabirds and salmon (Sydeman et al. 2013, pp. 1662, 1667-1672). In future scenarios with strong acidification effects to benthic prey from the California Current, euphausiids and several fish species are expected to decline, while other species are expected to increase (Kaplan et al. 2010, pp. 1973-1976). An investigation of the planktonic food web off of Oregon shows that sea surface temperature has contrasting effects on different types of zooplankton, and competitive interactions are much more prevalent during warm phases of ENSO or PDO than during cool phases (Francis et al. 2012, pp. 2502, 2505-2506).

A food web model of Puget Sound shows that moderate or strong acidification effects to calcifying species are expected to result in reductions in fisheries yield for several species, including salmon and Pacific herring, and increased yield for others (Busch et al. 2013, pp. 827-829). Additionally, the same model shows that these ocean acidification effects are expected to cause reductions in forage fish biomass, which are in turn expected to lead to reductions in diving bird biomass (Busch et al. 2013, p. 829). While Busch and coauthors (2013, p. 831) express confidence that this model is accurate in terms of the nature of ocean acidification effects on the future Puget Sound food web, they are careful to note that there is a great deal of uncertainty when it comes to the magnitude of the changes. The model also illustrates that some of the effects to the food web will dampen or make up for other effects to the food web, so that changes in abundance of a given prey species will not always correspond directly to changes in the abundance of their consumers (Busch et al. 2013, pp. 827, 830).

Changes in seasonality at lower trophic levels may lead to changes in population dynamics or to interactions between species at higher trophic levels. For example, for a study area in British Columbia, earlier spring phytoplankton blooms are associated with lower pink salmon productivity, likely mediated by zooplankton grazers (Malick et al. 2015, pp. 703-706). Similarly, if salmon hatchery release dates are not adjusted to account for changes in peak timing of phytoplankton blooms, this can lead to a mismatch between release dates and marine productivity peaks, which has been shown to reduce smolt-to-adult survival in the Strait of Georgia (Chittenden et al. 2010, pp. 8-9). At Triangle Island in British Columbia, Cassin's auklet (*Ptychoramphus aleuticus*) breeding success is reduced during years when the peak in copepod prey availability comes earlier than the birds' hatch date, and this mismatch is associated with warm sea surface temperatures (Hipfner 2008, pp. 298-302). However, piscivorous seabirds (i.e., tufted puffins [*Fratercula cirrhata*], rhinoceros auklets [*Cerorhinca monocerata*], and common murres [*Uria aalge*]) breeding at the same Triangle Island site may be able to adjust their breeding dates to ocean conditions (Bertram et al. 2001, pp. 292-293; Gjerdrum et al. 2003, p. 9379), as have Cassin's auklets breeding in the Farallon Islands of California (Abraham and Sydeman 2004, p. 240). Because of the changes in tufted puffin, rhinoceros auklet, and common murre hatch dates at Triangle Island, the breeding periods of these species have converged to substantially overlap with one another and with that of Cassin's auklet (Bertram et al. 2001, pp. 293-294), but studies have not addressed whether this overlap has consequences for competitive interactions among the four species. [Note: all four of these bird species are in the family Alcidae, which also contains marbled murrelets. These species also breed in, or just outside, the action area and forage within the action area. However, we did not locate any studies addressing these types of effects within the action area.]

Studies have suggested that climate change is one of several factors allowing jellyfish to increase their ecological dominance, at the expense of forage fish (Parsons and Lalli 2002, pp. 117-118; Purcell et al. 2007, pp. 154, 163, 167-168; Richardson et al. 2009, pp. 314-216). Many (though not all) species of jellyfish increase in abundance and reproductive rate in response to ocean warming, and jellyfish are also more tolerant of hypoxic conditions than fish (Purcell 2005, p.

472; Purcell et al. 2007, pp. 160, 163; see Suchman et al. 2012, pp. 119-120 for a Northeastern Pacific counterexample). Jellyfish may also be more tolerant of acidification than fish (Atrill et al. 2007, p. 483; Lesniowski et al. 2015, p. 1380). Jellyfish abundance in southern and central Puget Sound has increased since the 1970s (Greene et al. 2015, p. 164). Over the same time period, herring abundance has decreased in south and central Puget Sound, and surf smelt (abundance has decreased in south Puget Sound, although other Puget Sound forage fish populations may be stable or increasing (Greene et al. 2015, pp. 160-162). Forage fish abundance and jellyfish abundance were negatively correlated within Puget Sound and Rosario Strait (Greene et al. 2015, p. 164). It is not clear whether there is a causal relationship between forage fish and jellyfish abundance, or whether the two groups are simply responding in opposite ways to climate and other anthropogenic factors.

Many species of forage fish will be disadvantaged in the changing climate, regardless of any competitive interactions with jellyfish. In the Gulf of Alaska, Anderson, and Piatt (1999, pp. 119-120) documented the crash of capelin (*Mallotus villosus*), Pacific herring, species of Irish lord (*Hemilepidotus* spp.), prickleback (Stichaeidae family), greenlings and mackerel (*Hexagrammos* and *Pleurogrammus* spp.), as well as several shrimp species, as part of a major community reorganization following a climate regime shift from a cool phase to a warm phase in the 1970s. In the northeastern Pacific Ocean, capelin, sand lance, and rockfish abundance are all negatively correlated with seasonal sea surface temperatures (Thayer et al. 2008, p. 1616). A model of multiple climate change effects (e.g., acidification and deoxygenation) to marine food webs in the northeast Pacific consistently projects future declines in small pelagic fish abundance (Ainsworth et al. 2011, pp. 1219, 1224). As an example in Puget Sound, abundance of surf smelt and Pacific herring in the Skagit River estuary are positively associated with coastal upwelling during the spring and early summer, likely because nutrient-rich upwelled water increases food availability (Reum et al. 2011, pp. 210-212). If projections of later, shorter upwelling seasons are correct (see above), the delays may lead to declines in these stocks of herring and surf smelt, as documented in 2005 (Reum et al. 2011, p. 212). Similarly, delayed upwelling in 2005 led to reduced growth rates, increased mortality, and recruitment failure for juvenile northern anchovies (*Engraulis mordax*) off the Oregon and Washington coasts (Takahashi et al. 2012, pp. 397-403). In the northeastern Pacific, Chavez, and coauthors (2003, pp. 217-220) have described a shift between an “anchovy regime” during the cool negative phase of the PDO, and a “sardine regime” during the warm positive phase, where the two regimes are associated with contrasting physical and biological states. However, global warming may disrupt ecological responses to the naturally occurring oscillation or alter the pattern of the oscillation itself (Chavez et al. 2003, p. 221; Zhang and Delworth 2016, entire).

7.2.2.2.3 Marbled Murrelets

Marbled murrelets will experience changes in foraging and breeding ecology as the climate continues to change. Within the action area, there is no research attempting to measure or project the effects of climate change on marbled murrelets. However, several related studies have been conducted outside of the action area, and the results are likely to be applicable to marbled murrelets within the action area. Additionally, numerous studies of other alcids (from Mexico to British Columbia) indicate that alcids as a group are vulnerable to climate change in the northeastern Pacific.

Studies suggest that the effects of climate change may reduce marbled murrelet reproductive success, likely mediated through climate change effects to prey. In British Columbia, there is a strong negative correlation between sea surface temperature and the number of marbled murrelets observed at inland sites displaying behaviors associated with nesting (Burger 1999, p. 728). In central California, marbled murrelet diets vary depending on ocean conditions, and there is a trend toward greater reproductive success during cool water years, likely due to the abundant availability of prey items such as euphausiids and juvenile rockfish (Becker et al. 2007, pp. 273-274). In the Georgia Basin, much of the yearly variation in marbled murrelet abundance from 1958 through 2000 can be explained by the proportion of fish (as opposed to euphausiids or amphipods) in the birds' diet (Norris et al. 2007, p. 879). If climate change leads to further declines in forage fish populations (see above), those declines are likely to influence marbled murrelet population numbers and abundance.

The conclusion that climate change is likely to reduce marbled murrelet breeding success via changes in prey availability is further supported by several studies of other alcid species in British Columbia and California. Common murres, Cassin's auklets, rhinoceros auklets, and tufted puffins in British Columbia; pigeon guillemots (*Cepphus columba*), common murres, and Cassin's auklets in California; and even Cassin's auklets in Mexico all show altered reproductive rates, altered chick growth rates, or changes in the timing of the breeding season, depending on sea surface temperature or other climatic variables, prey abundance, prey type, or the timing of peaks in prey availability (Abraham and Sydeman 2004, pp. 239-243; Ainley et al. 1995, pp. 73-77; Albores-Barajas 2007, pp. 85-96; Bertram et al. 2001, pp. 292-301; Borstad et al. 2011, pp. 291-299; Gjerdrum et al. 2003, pp. 9378-9380; Hedd et al. 2006, pp. 266-275). The abundance of Cassin's auklets and rhinoceros auklets off southern California declined by 75 and 94 percent, respectively, over a period of ocean warming between 1987 and 1998 (Hyrenbach and Veit 2003, pp. 2546, 2551). Although the details of the relationships between climate variables, prey, and demography vary between bird species and locations, the consistent demonstration of such relationships indicates that alcids as a group are sensitive to climate-related changes in prey availability, prompting some researchers to consider them indicator species for climate change (Hedd et al. 2006, p. 275; Hyrenbach and Veit 2003, p. 2551).

In addition to effects on foraging ecology and breeding success, climate change may expose adult marbled murrelets to additional risks. For example, it is likely that marbled murrelets will experience more frequent domoic acid poisoning, as this toxin originates from the harmful algae blooms that are expected to become more prevalent (see above). In central California, domoic acid poisoning was determined to be the cause of death for at least two marbled murrelets recovered during a harmful algae bloom in 1998 (Peery et al. 2006, p. 84). During this study, which took place between 1997 and 2003, the mortality rate of radio-tagged marbled murrelets was highest during the algae bloom (Peery et al. 2006, p. 83). Domoic acid poisoning has previously been shown to travel through the food chain to seabirds, via forage fish that feed on the toxic algae (Work et al. 1993, p. 59). Another species of harmful algae was found to produce a foam that can contribute to plumage fouling and subsequent mortality of common murres and other seabird species (Oregon and Washington, October 2009); similar events may become more frequent with climate change (Phillips et al. 2011, pp. 120, 122-124). Climate change may also promote conditions in which alcids become exposed to novel pathogens, as occurred in Alaska during 2013, when crested auklets (*Aethia cristatella*) and thick-billed murres (*Uria lomvia*) washed ashore after dying of avian cholera (Bodenstein et al. 2015, p. 935). Counterintuitively, in a 1997-2003 study of radio tagged marbled murrelets in California, marbled murrelet adult survival was higher during warm-water years and lower during cold-water years, likely because they did not breed and therefore avoided the associated physiological stresses and additional predator risk (Peery et al. 2006, pp. 83-85).

8 CURRENT CONDITION OF THE SPECIES IN THE ACTION AREA

8.1 Factors Responsible for the Condition of the Species

Marbled murrelets were listed as threatened in 1992, due in large part to habitat loss and predation in the terrestrial environment, and oil spills and net fisheries entanglement in the marine environment (57 FR 45333-45336; October 1, 1992). In 2012, the Service convened the marbled murrelet Recovery Implementation Team which concluded that the primary cause of continued population declines is low recruitment (USFWS 2012a). Sustained low recruitment may be caused by nest failures, low numbers of nesting attempts, and/or low juvenile survival rates due to 1) terrestrial habitat loss, 2) nest predation, 3) changes in marine forage base and prey resource availability and/or quality, and 4) the cumulative effects of multiple impacts. The Service's most recent 5-year review (USFWS 2009, pp. 27-67) identified the following additional threats in marine waters:

- Exposure to marine polychlorinated biphenyls in prey;
- Changes in prey abundance, availability, and quality;
- Harmful algal blooms, biotoxins, and 'dead zones;'
- Derelict fishing gear and sources of entanglement;
- Energy development projects (wave, tidal, and onshore wind energy projects);
- Disturbance, injury, and mortality in the marine environment from exposures to elevated sound levels (caused by pile driving, underwater detonations, vessel traffic); and
- Climate change in the Pacific Northwest, which may exacerbate many threats in the marine environment, as described above.

Recent evidence affirms the importance of terrestrial nesting habitat, marine foraging habitat, as well as the spatial juxtaposition and proximity of the two essential habitat types. For example, in Conservation Zone 1 (which includes the action area), the marine human footprint is a primary determinant (i.e., second only to the quantity and quality of nearby nesting habitat) for the abundance of marbled murrelets in a given marine location (Falxa and Raphael 2016, pp. 106-110). Since 1993, Washington has lost more nesting habitat than have Oregon or California, but a smaller proportion of the remaining habitat is used in Washington than in other portions of the range; this suggests that other factors are limiting the marbled murrelet population in Washington (Falxa and Raphael 2016, p. 71; Lorenz et al. 2016a, p. 13). Throughout the listed range of the marbled murrelet, sustained low recruitment appears to be the primary cause of continuing population declines (UWFWS 2012, p. 3).

In Washington state, the proportion of adult marbled murrelets attempting to breed is lower than in any other area of the species' range where breeding propensity has been measured (Lorenz et al. 2016a, p. 11). The low breeding propensity of marbled murrelets in Washington is likely due in part to high energetic costs associated with breeding. Nesting adult marbled murrelets have the longest commuting distances between nest and sea, compared with marbled murrelets that have been studied elsewhere in the species range (Lorenz et al. 2016a, p. 12). Elsewhere in the range, breeding marbled murrelets forage in marine areas close to their nesting habitat, which minimizes energetic costs associated with inland flights between nest and sea (Peery et al. 2009, pp. 127, 130). Long flight paths or commuting distances are associated both with the distance of nesting habitat from the coast, and the distance of foraging habitat from the shore (Lorenz et al. 2016a, pp. 9, 12-13). This pattern suggests that marbled murrelet breeding attempts experience low success not only because of a lack of high-quality coastal nesting habitat, but also because of poor or poorly distributed foraging habitat. Marbled murrelet diet quality has decreased over the last 150 years, with concomitant declines in marbled murrelet productivity, suggesting that diet quality may now be a limiting factor for marbled murrelet populations (Gutowsky et al. 2009, pp. 249-250; Norris et al. 2007, pp. 878-880).

Post-fledging mortality also contributes to sustained low recruitment, but less information is available about these causes of mortality. Sources of post-fledging mortality in the marine environment include entanglement in gillnets, purse seines, and derelict gear; oil spills; and impulsive underwater sound from impact pile driving and underwater detonations (USFWS 2012a, p. 13).

Some efforts are being made to control, remove, and ameliorate threats. Numerous state, Tribal, and federal agencies participate in nearshore restoration efforts, which are intended in part to improve and protect habitat for forage fish (WDFW 2015). Between 2002 and 2016, the Northwest Straits Initiative's Derelict Fishing Gear Program removed 5,667 derelict fishing nets from Puget Sound (NWSF 2016b; Wilson, A. in litt. 2016b). However, it is unknown whether these efforts will be effective in restoring high-quality marine habitat, much less slow or reverse the decline of the marbled murrelet population. For example, the prevalence of unpermitted shoreline armoring calls into question reported progress on shoreline restoration (Dunagan 2016; Kinney et al. 2015, pp. 8-13). Other trends may magnify these threats. For example, we expect climate change may further exacerbate the decline in foraging habitat quality.

8.2 Conservation Role of the Action Area

The final Recovery Plan for the Marbled Murrelet (USFWS 1997, entire) outlines the conservation strategy for the species. Of the primary recovery plan recommendations, the most pertinent to the needs of marbled murrelets within the action area are 1) protect the quality of the marine environment essential for marbled murrelet recovery, and 2) reduce adult and juvenile mortality in the marine environment. Marbled murrelets appear to be declining due to habitat loss and degraded marine conditions, which lead to low reproductive success. The loss of individuals through death or injury in the marine environment is also a major threat. Conservation Zone 1 is identified as the portion of the three-state listed range where net fisheries may result in considerable mortality for marbled murrelets (USFWS 1997, pp. 125, 140).

The action area provides foraging habitat that is essential to marbled murrelet survival and recovery. All waters of Puget Sound and SJF are considered to be concentration areas for breeding marbled murrelets and are essential for foraging and loafing (USFWS 1997, p. 135). During the nesting season adult marbled murrelets depend on the action area as foraging habitat for themselves and their nestlings. Outside of the nesting season, the action area provides foraging habitat for a mixed population of marbled murrelets that originate from both British Columbia and Conservation Zones 1 and 2 in Washington.

As outlined by the final Recovery Plan (USFWS 1997, pp. 112), increasing habitat quantity and quality in the marine environment is essential to the conservation and recovery of the marbled murrelet. Marbled murrelet presence in marine waters is linked with tidal activity (Speich and Wahl 1995, p. 323) and prey availability, which can vary depending on upwelling conditions and seafloor topography (Becker and Beissinger 2003, pp. 251-252). Marbled murrelet foraging habits change (including seasonally) depending on whether or not they are nesting and provisioning young. When nesting, marbled murrelets tend to forage closer to shore, primarily on small pelagic fish. During non-breeding seasons, marbled murrelets may disperse and can be found much farther offshore foraging on both small fish and crustaceans. The final Recovery Plan recommends protection of nearshore waters extending two kilometers (1.2 miles) from shore, to include estuaries, river mouths, and the ocean floor (USFWS 1997, p. 136).

Reducing adult mortality in the marine environment is a key element of the strategy to conserve and recover the marbled murrelet (USFWS 1997, pp. 112, 122, 125, 140-141, 154). Historically, net fisheries and oil spills are primary threats causing marbled murrelet mortality in the marine environment, especially in Conservation Zone 1 (USFWS 1997, pp. 125, 140-141, 154). Impulsive underwater sound and harmful algal blooms are additional sources of mortality (USFWS 2012a, pp. 13-14). Other factors, such as marine pollution, low food availability, and boat traffic, may lead to lower survivorship, injury, or increased energy expenditure by marbled murrelets, but these effects are less clear (USFWS 1997, pp. 155-156; USFWS 2012a, p. 13).

A well-distributed, viable marbled murrelet population must be maintained in Conservation Zone 1 to allow for the long-term survival and recovery of the species throughout the listed range (USFWS 1997, pp. 115-122). Marbled murrelets spend the majority of their time in the marine environment, so most feeding and mortality events also happen in the marine environment (USFWS 1997, p. 120). Because the conservation of marbled murrelets in Zone 1 is essential to marbled murrelet conservation across the listed range.

8.3 Climate Change

Consistent with Service policy, our analyses under the ESA include consideration of ongoing and projected changes in climate. The term “climate” refers to the mean and variability of weather conditions over time, with 30 years being a typical period for such measurements, although shorter or longer periods also may be used (IPCC 2014a, pp. 119-120). The term “climate change” thus refers to a change in the mean or variability of one or more measures of climate (e.g., temperature or precipitation) that persists for an extended period, typically decades or longer, whether the change is due to natural variability, human activity, or both (IPCC 2014a, p.

119). Various types of changes in climate can have direct or indirect effects on species and critical habitats. These effects may be positive, neutral, or negative, and they may change over time. The nature of the effect depends on the species' life history, the magnitude and speed of climate change, and other relevant considerations, such as the effects of interactions of climate with other variables (e.g., habitat fragmentation) (IPCC 2014b, pp. 64, 67-69, 94, 299). In our analyses, we use our expert judgment to weigh relevant information, including uncertainty, in our consideration of various aspects of climate change and its effects on species and their critical habitats. We focus in particular on how climate change affects the capability of species to successfully complete their life cycles, and the capability of critical habitats to support that outcome.

9 EFFECTS OF THE ACTION: Marbled Murrelet

The 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 but that are not part of the 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 (50 CFR 402.02).

Adverse exposures and effects to marbled murrelets are expected to result from the DOE's program of marine research, equipment testing, and associated activities. However, because there are or have been few previous examples, for actions of this nature, scope, and scale, the Service' assessment and description of potential exposures, effects, and outcomes, necessarily draw upon surrogate settings and previous findings for surrogate species (e.g., north Atlantic Ocean settings, Atlantic Ocean alcid species).

9.1 Overview

The Service expects that the proposed action will directly expose and affect marbled murrelets; a variety of stressors, potential exposures, effects, and outcomes are described below (i.e., in the subsections that follow). For the proposed activities that may result in adverse exposures and effects, including possible incidental take (Sections 9.1.10, 9.1.13, and 9.1.14), impacts and totals are determined and reported for an expected five-year term of operations.

9.1.1 Surface Platforms and Buoys

Deployments of structures to float on surface waters in the action area have the potential to affect marbled murrelets through possible entanglement in mooring lines or shading of benthic substrate and the water column. However, the proposed activities include and will implement PDCs to avoid and minimize the potential for adverse exposures or effects (e.g., platforms will be grated or otherwise constructed to allow ample light penetration to the water column; platforms will be constructed of corrosion resistant, non-toxic materials; and, anchors and midlines will be selected to minimize bed scour, and to minimize line slack and/or entanglement).

According to the DOE's PBA (p. 4-1), mooring line slack will be avoided through use of tensile materials that do not produce looping during slack tidal conditions, and/or use of midline floats that help keep vertical mooring lines taut. When a platform is deployed, marker buoys will accompany the deployment, and a buoy will "weathervane" around the surface platform, continually keeping any horizontal and vertical mooring lines semi-taut. Also, prevailing environmental conditions will typically track around the compass, and rarely switch directions (e.g., 180 degrees) suddenly, such that the buoy would be pushed into a platform or otherwise cause enough slack in the horizontal mooring line to potentially form a loop. Even in the unlikely event that winds were directly opposite the current, the drag area of submerged platform hulls is likely to be greater that the above-water portion of the marker buoys exposed to the wind, making it unlikely that buoys would be pushed into a surface platform (and thereby cause enough slack to potentially form a loop) (PBA, p. 4-1).

Marbled murrelets will likely be exposed to deployed platforms and buoys, but with successful implementation of the proposed PDCs, we expect that any effects will be insignificant and/or discountable. Shading of benthic substrate and the water column will be minimized, and we expect that any measurable impacts to physical habitat (e.g., impacts to SAV) will be limited in duration (i.e., temporary), limited in physical extent, and will not appreciably reduce habitat function at the scale of the action area or in Sequim Bay.

Various deployments and activities (including surface platforms and buoys) may present or result in mild forms of temporary, behavioral disruption. Marbled murrelets may pause foraging, and may temporarily avoid some deployment areas, but we do not expect that surface platforms or buoys will displace marbled murrelets, or prevent them from successfully feeding, moving, and sheltering in the action area. We expect that marbled murrelets will continue to forage and loaf in the vicinity of deployments, including in nearby unaffected habitats. And finally, based on available information, we conclude it is extremely unlikely that surface platforms and buoys, or their anchors, hardware, and mooring lines, will cause or contribute to instances of marbled murrelet entrainment, entanglement, physical injury, or mortality; these outcomes are considered discountable. With successful implementation of the proposed PDCs, surface platforms and buoys are not likely to adversely affect the species.

9.1.2 Dock Installations

Installation of equipment or instruments on the PNNL-Sequim floating dock, pier, and pilings will be limited to those locations, will be completed by hand, and will not disturb the benthos. Therefore, it is unlikely that any measurable or significant exposures or effects to marbled murrelets will result. With successful implementation of the proposed PDCs, dock installations are not likely to adversely affect the species.

9.1.3 Seabed Installations

Installations on the seabed will include a variety of structures, from inert targets for detection (e.g., scuba tanks) to larger benthic landers housing multiple instruments. These proposed activities include and will implement PDCs to avoid and minimize the potential for adverse exposures or effects (e.g., deployments will be temporary; installations will not exceed 50 sq ft, excluding cable(s); and equipment and instruments are anchored to the seabed with screw or helical anchors, or tethered to concrete or corrosion resistant metal moorings).

All projects and activities are subject to and will include implementation of the following overarching (program level) PDC: No deployments will occur in SAV. [Note: Exceptions are given for Seagrass Macroalgae and Intertidal Research, Seabed Installations, and Benthic Characterization Surveys, since the explicit purpose for these activities is to investigate SAV (PBA, p. 2-1).] Methods for anchoring will minimize sedimentation and avoids areas with macroalgae or other SAV, unless these physical habitat features are the specific focus of the research.

Various deployments and activities (including seabed installations) may present or result in mild forms of temporary, behavioral disruption. Marbled murrelets may pause foraging, and may temporarily avoid some deployment areas, but we do not expect that seabed installations will displace marbled murrelets, or prevent them from successfully feeding, moving, and sheltering in the action area. We expect that marbled murrelets will continue to forage and loaf in the vicinity of deployments, including in nearby unaffected habitats. With successful implementation of the proposed PDCs, seabed installations are not likely to adversely affect the species.

9.1.4 Vessel Use and Operations

Vessel operations in Sequim Bay and the SJF can include vessel-based surveys, vessel towed sensors/instruments, and other vessels used in support of research and deployments.

The Service has previously assessed and evaluated potential temporary exposures and effects attributable to typical operations of small- and medium-sized vessels, work vessels, and skiffs (USFWS 2016, pp. 113-116; *Biological Opinion – Programmatic Consultation for Shellfish Activities in Washington State Inland Marine Waters*, Ref. No. 01EWFW00-2016-F-0121, August 26, 2016). The Service found and concluded that temporary impacts to the sound and visual environment are low intensity and limited in both physical extent and duration, exposures are often transient and passing, and are unlikely to significantly interfere with conspecific vocalizations among marbled murrelets, social foraging, or predator detection and avoidance. "Marbled murrelets exposed to elevated underwater and in-air sound levels resulting from the operation of vessels, motors, and other … equipment (e.g., gas-powered air compressors, hydraulically powered onboard equipment) will not experience [temporary hearing] threshold shift … and non-injurious [exposures] occurring in the marine environment [are] unlikely to significantly disrupt normal marbled murrelet behaviors (i.e., the ability to successfully feed, move, and/or shelter)" (USFWS 2016, p. 115). The Service found previously, when considering the transient and low intensity nature of sound and visual disturbances resulting from these activities, most foraging marbled murrelets are likely to resume their activity with nothing more than a short delay (USFWS 2016, pp. 113-116).

The activity (i.e., vessel use and operations) will have minor and temporary effects on marbled murrelets and will not significantly disrupt their foraging or loafing behaviors. With successful implementation of the proposed PDCs, vessel use, and operations are not likely to adversely affect the species.

9.1.5 Autonomous Vehicle Surveys and Operations

Operations of remote or autonomous AUVs and ASVs present a low risk of exposure or effects to marbled murrelets. However, as part of some research activities, the AUVs/ASVs will carry and deploy instruments, including instruments which may present significant sources of sound or visual disturbance (e.g., acoustics or LiDAR). Instruments that present significant sources of sound or visual disturbance are discussed in subsections that follow.

The activity (i.e., AUV operations, ASV operations) will have minor and temporary effects on marbled murrelets and will not significantly disrupt their foraging or loafing behaviors. With successful implementation of the proposed PDCs, AUV/ASV operations are not likely to adversely affect the species.

9.1.6 Benthic Surveys

Benthic surveys will disturb the benthos and bottom habitat near sampling locations. Benthic surveys may also cause temporary, minor increases in turbidity. However, these temporary impacts will not displace marbled murrelets, or prevent marbled murrelets from successfully foraging and loafing in the action area.

Benthic surveys, including those conducted with autonomous crawlers, will avoid known marine forage fish spawning areas during spawning periods (i.e., unless a forage fish survey precedes the work). Benthic habitat sampling, characterization, and sediment collection are of short duration, with temporary impacts. These activities would affect a very small portion of the action area.

The activity (i.e., benthic surveys) will have minor and temporary effects on marbled murrelets and will not significantly disrupt their foraging or loafing behaviors. With successful implementation of the proposed PDCs, benthic surveys are not likely to adversely affect the species.

9.1.7 Water Column Sampling

Water column sampling will not displace marbled murrelets or prevent marbled murrelets from successfully foraging and loafing in the action area. These activities are of short duration, with temporary impacts. These activities would affect a very small portion of the action area.

The activity (i.e., water column sampling) will have minor and temporary effects on marbled murrelets and will not significantly disrupt their foraging or loafing behaviors. With successful implementation of the proposed PDCs, water column sampling is not likely to adversely affect the species.

9.1.8 Dye and Particulate Releases

Dye and particulate releases will not displace marbled murrelets or prevent marbled murrelets from successfully foraging and loafing in the action area. These activities are of short duration, with temporary impacts. These activities would affect a very small portion of the action area.

The activity (i.e., dye and particulate releases) will have minor and temporary effects on marbled murrelets and will not significantly disrupt their foraging or loafing behaviors. With successful implementation of the proposed PDCs, dye and particulate releases are not likely to adversely affect the species.

9.1.9 Seagrass, Macroalgae, and Intertidal Research

Most research activities will avoid sensitive habitats, such as eelgrass beds, SAV, and intertidal areas. However, some research is focused specifically on these habitats. The PDCs place strict limits on allowable impacts to SAV, and impacts will occur only at scales that do not diminish or degrade functions at the scale of the action area (including prey production). Furthermore, natural recovery is expected, and impacts will therefore be temporary.

The activity (i.e., seagrass, macroalgae, and intertidal research) will have minor and temporary effects on marbled murrelets and will not significantly disrupt their foraging or loafing behaviors. With successful implementation of the proposed PDCs, these research activities are not likely to adversely affect the species.

9.1.10 Light Emitting Devices and Operations

Operation of lasers for LiDAR and other applications has the potential to cause ocular injury. There is very little research available with empirical data to describe or assess ocular laser injury for marine birds. There is, however, an extensive background on laser safety as it pertains to ocular injury in humans. By combining knowledge of human and other eye anatomies, an extension of known human eye safety standards can be applied (Zorn et al. 2000).

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

Because of the relatively high attenuation coefficient in marine waters typical of Sequim Bay and the SJF (0.4 to 0.7 m^{-1} for green light) even relatively strong laser sources are not visible to marine life except within relatively short distances. Figure 15 shows the estimated irradiance by distance from the source (for attenuation coefficients of 0.4 and 0.7) for the green laser described in Table 12. In general, light is scattered such that after approximately 11 attenuation lengths (inverse of attenuation coefficient) light will appear diffuse rather than focused, 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 16 and 28 m, at which point the irradiance would be approximately 10^{-8} W/cm^2.

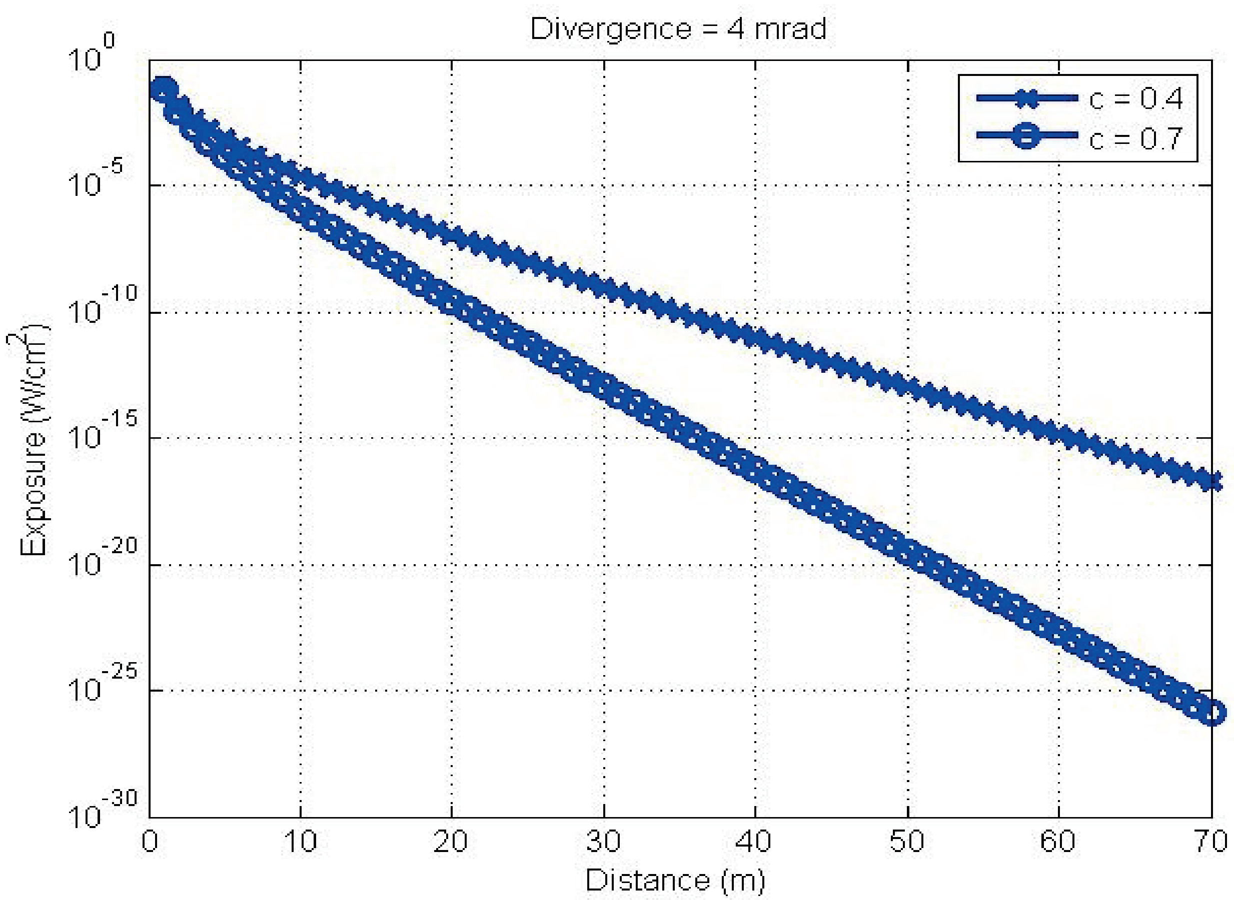

Figure 15. Green laser visibility at zero scattering angle (PBA, p. 4-14).

Effects of laser light sources and exposures for marbled murrelets will be partially mitigated with PSOs during non-eye-safe laser / LiDAR operations (PDC Section 0). All non-eye-safe laser/LiDAR operations will be paused or discontinued if any marbled murrelets are observed within 50 m, or if observed within the area prior to or during aerially scanning (PDC Section 0). Additionally, engineering controls will be implemented when possible. For example, the UMSLI system uses an automatic shut-off control, so if an organism is detected within 10 m of the light source, the green laser is shut off.

Other artificial light sources (specifically those not known to be potentially harmful) may attract forage fish, but previously we found these sources are not harmful and will not significantly disrupt foraging marbled murrelets (USFWS 2018; Letter of Concurrence – Five-Year Plan for Habitat Mapping and Monitoring Tools for Marine Hydrokinetics; FWS Ref. No. 01EFW00-2018-I-1605, October 29, 2018).

Green laser light sources are known to be harmful to some organisms' eyes and may be harmful to others (e.g., birds [Harris 2021]). Research activities and deployments that may use or include green laser light sources are described in Section 0; such as the UMSLI LiDAR imager for tracking objects and animals near the hydrokinetic devices. 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 (PBA, p. 4-15). Marbled murrelets are generally 25 cm or shorter in length and may be too small to be detected at 10 m. For this reason, the area within 50 m of all underwater activities employing green lasers will be monitored by a PSO for the purpose of shutting down laser operations if a marbled murrelet is observed (Section 0). Devices with an automated shutdown capability will have that capability enabled during deployment. The DOE will implement PSOs and automated shutdown capabilities for any configuration of one or more green laser light-emitting instruments, including any associated with marine renewable energy research deployments (e.g., tidal turbines).

As indicated in this section, aerial bathymetric LiDAR applications using a green laser have the potential to expose and adversely affect marbled murrelets at the water surface. Attenuation is much less in air than in water, and the green laser light source may extend hundreds of meters. The areal extent of the laser footprint on surface water (produced by a single emission), and the extent of surface water habitat that could be exposed to laser emissions (and where marbled murrelets may be affected), will depend on a variety of case-specific factors.

The DOE will request verification(s) for aerial bathymetric LiDAR applications using green laser light sources, to determine the likely case-specific effects, and will collaborate with the Service for case-specific best practices and minimization measures. Even with implementation of these measures, adverse marbled murrelet exposures and effects may result (including a likelihood of injury) from research activities and deployments that use or include green laser light sources.

Even with implementation of all appropriate PDCs, limited adverse marbled murrelet exposures and effects are still likely to occur. Marbled murrelets are cryptic, PSOs may sometimes fail to detect or identify individuals, and marbled murrelet behavior around green laser light sources is an unknown. Nearfield detection and auto-shutdown features may fail to consistently detect marbled murrelets due to their small size. For these reasons, with consideration for the scope and scale of the operations, and the estimated marbled murrelet densities in the action area, the Service expects that up to two marbled murrelets may suffer forms of injury (i.e., eye injury or other) as a result of light emitting devices and operations; no lethal exposures or mortality are expected or foreseeable.

9.1.11 Acoustic Devices and Operations

Many of the proposed research activities and deployments include or produce sound emissions. Sound may be classified as either impulsive or non-impulsive. Impulsive sounds are typically transient, brief (less than one second), broadband, and consist of high peak sound pressure levels (SPLs) with rapid rise time and rapid decay; impulsive sounds include those produced by impact pile driving, explosives, and air guns. Non-impulsive sounds can be broadband, narrowband, or tonal; brief or prolonged; and continuous or intermittent; but typically, do not include high peak

SPLs with rapid rise/decay time. Non-impulsive sounds include those produced by vibratory pile drivers, sonar, communication modems, echosounders, and other sources. The DOE's proposed research activities and deployments in Sequim Bay and SJF do not include impulsive sound sources; all the equipment and instruments described below are considered non-impulsive.

Marbled murrelet vocalizations range from 480 Hz to 11 kHz (SAIC 2011) and, in general, the species is not sensitive to frequencies above 20 kHz (Beason 2004) with a peak at approximately 3 kHz (SAIC 2011). Teachout (2012) assumed a functional hearing range of approximately 500 Hz to 12.5 kHz. Thresholds for hearing injury and barotrauma were determined through consensus summarized in SAIC (2011) (Table 25). There is very little information about the effect of underwater sound on diving bird behavior; the Service uses 150 dB_{RMS} as the behavioral threshold (Teachout 2012).

Table 25. Functional hearing range and injury and behavioral thresholds.

Fish	Functional Hearing Range	Injury Threshold[(a)]		Behavioral Threshold
	10 Hz to 4 kHz	187(<2g)/183(>2g) dB SEL_{cum}		150 dB_{rms}
Marbled Murrelet	Functional Hearing Range[(b)]	Injury Threshold[(c)]	Barotrauma[(c)]	Behavioral Threshold[(b)]
	500 Hz to 12.5 kHz	202 dB SEL_{cum}	208 dB SEL_{cum}	150 dB_{rms}

(a) Caltrans 2015
(b) Teachout 2012
(c) SAIC 2011

The activity (i.e., acoustic devices and operations) will have minor and temporary effects on marbled murrelets and will not significantly disrupt their foraging or loafing behaviors. With successful implementation of the proposed PDCs, acoustic devices and operations are not likely to adversely affect the species.

9.1.12 Operations Producing Electromagnetic Fields

EMF are generated by devices and cables. Marbled murrelets may be exposed to EMF from research activities, installations, and deployments.

EMF are comprised of electric fields (E-fields) and magnetic fields (B-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 may occur intermittently or for a defined time period.

EMF emissions may also be generated from anthropogenic sources such as electric motors, telecommunications equipment, electronics, and tidal, wave, or offshore wind energy deployments. For example, electric motors and loudspeakers have built in 0.4^{-1} T magnets and produce magnetic fields of at least that magnitude. Magnetic field strength decreases rapidly with distance; for example, the field surrounding a 1.25 T Neodymium magnet decreases to nano-Tesla levels within 1 m. The area of potential effect (the upper limit) for a 1.25 T

Neodymium magnet would be very small (PBA, p. 4-21). Virtually all electric fields are constrained with wrapped insulation; however, magnetic fields are difficult to similarly constrain as they travel through insulation.

As reviewed in Gill and Desender (2020), most research has been limited to controlled laboratory simulations of B- or E-fields, or surveys of subsea cables using field measurements to study magnetoreception and electroreception in fish, responses of marine life to electric and magnetic emissions, and 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 phases, 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.

Species that are highly mobile (e.g., the marbled murrelet) are less likely to experience effects. Species that associate with the benthos as primary habitat, and that are located in or very near a benthic EMF field, may experience some measurable effect. EMF devices (point sources) operating with fields of 1.25 T or less from discrete locations will have minor impacts (PBA, p. 4-21). Benthic species may respond by moving short distances to nearby unaffected habitat.

EMF generated by cables will not produce or reach levels that are likely to cause adverse effects. Research activities and deployments that produce EMF fields will be restricted to a small portion of the action area, and mostly associated with benthic habitats. There are reports of sensitivity for some species, but at EMF levels well above those proposed here (see Gill and Desender 2020). The small relative area and temporary operations are expected to result in minor impacts (PBA, p. 4-21).

The activity (i.e., operations producing EMF) will have minor and temporary effects on marbled murrelets and will not significantly disrupt their foraging or loafing behaviors. With successful implementation of the proposed PDCs, operations producing EMF are not likely to adversely affect the species.

9.1.13 Community and Research Scale Marine Energy Devices

Marine energy devices, including WECs are described in Section 4.1.14. The *OES-Environmental 2020 State of the Science Report* comprehensively discusses the current knowledge of marine renewable energy and associated environmental effects (Copping and Hemery 2020). Installation and operation of these devices may affect protected species 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). However, as proposed by the DOE, Community and Research Scale Marine Energy Devices present fewer risks and reduced collision risk, because these devices include fewer submerged moving parts that have collision potential (Sparling et al. 2020). Furthermore, deployment locations for these devices are not limited to the inlet channel to Sequim Bay (i.e., devices will more likely be deployed in open, offshore waters), and devices are therefore likely to be placed further from marine forage fish spawning habitats.

Community and Research Scale Marine Energy Devices capture the marine environment's kinetic energy by harnessing the sea's movement from waves and swells using several experimental WEC device designs. Operations and rate of movement of moving parts are dependent on wind, wave, temperature, and/or tidal currents; therefore, these are expected to be intermittent and variable, respectively. These devices do not operate with turbine blades, and therefore entrainment risk and risk of 'strike' are considered much lower. These devices do present some hazards (i.e., pinch points, moving parts, unique movement).

Observers (PSOs) will make observations during deployments and devices/operations will be paused or discontinued if protected species are observed within 50 m. Screens will be installed (as necessary) to reduce the potential for impingement and entrapment. These devices and deployments will extend into the water column from the surface or seabed (Figure 5). Deployments may result in temporary displacement or disruption of foraging or other habitat use (Copping and Hemery 2020). Even with implementation of all appropriate PDCs, limited adverse marbled murrelet exposures and effects are still likely to occur.

The Service expects that the activity (i.e., Community and Research Scale Marine Energy Devices) will in some cases displace individual marbled murrelets and significantly disrupt their normal behaviors (i.e., the ability to successfully feed, move, and/or shelter). However, because the devices will more likely be deployed in open, offshore waters, and further from marine forage fish spawning habitats where marbled murrelets are likely to concentrate, we expect that relatively few individuals will be exposed and adversely affected.

For these reasons, with consideration for the scope and scale of the operations, and the estimated marbled murrelet densities in the action area, the Service expects that up to three marbled murrelets will be exposed to Community and Research Scale Marine Energy Devices in a manner that creates a likelihood of injury; we expect, lethal exposures or mortality will not exceed one individual marbled murrelet.

9.1.14 Tidal Turbine Research

Horizontal- and vertical-axis turbines (described in Section 4.1.15) extend into the water column from the seabed or surface. Use of floating platforms for tidal turbine installations is considered in Section 9.1.1. Sound and EMF generated from operations are considered in Sections 9.1.11 and 9.1.12, respectively. Underwater sound produced by tidal turbines is below levels typically emitted by fishing and recreational vessels (Sparling et al. 2020).

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 16. This can also be viewed as a cumulative distribution function (Figure 17), 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 rotating 42 percent of the time, decreasing the likelihood of collision, and rotation would be lower than 30 rpm for two-thirds of the deployment. Operations, turbine speed, and collision risk are influenced by intermittent and variable current speed.

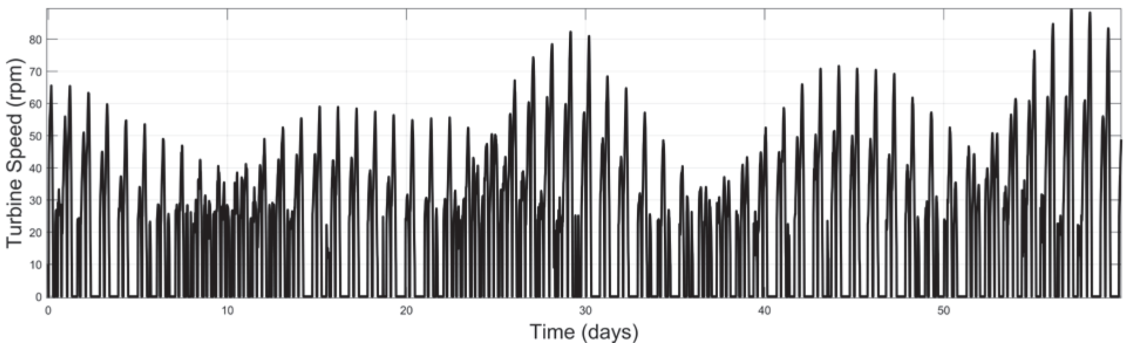

Figure 16. Two-month simulation of rotation rate; 86-cm diameter vertical-axis turbine.

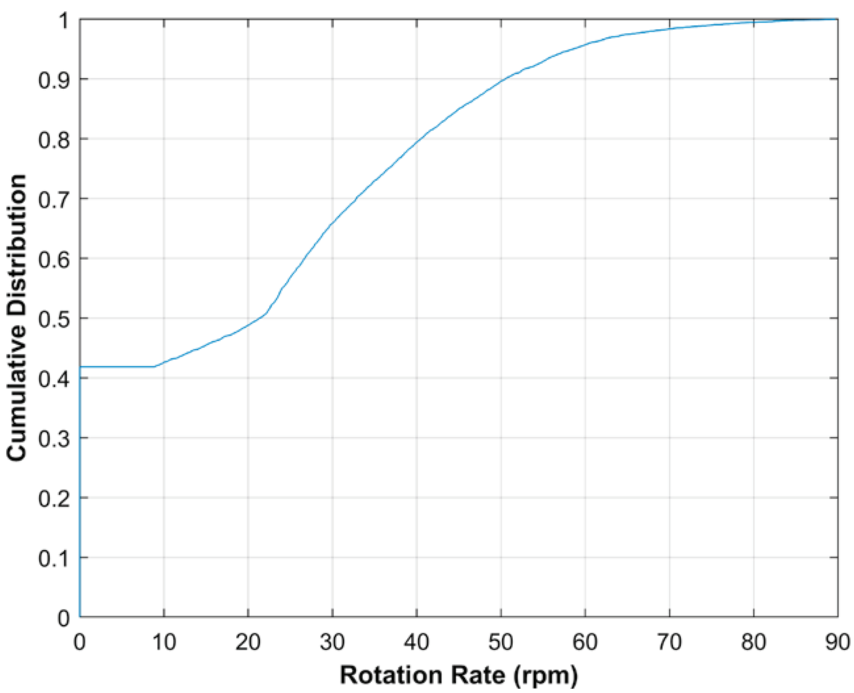

Figure 17. Turbine rotation rate; example cumulative distribution.

Despite the potential for encounters and collisions, knowledge of actual risk is limited because the frequency of these events and their consequences are generally unknown (Sparling et al. 2020). While there have been no studies evaluating marbled murrelet behavior near tidal turbines, Furness et al. (2012) assessed seabird sensitivity to tidal turbines, and described alcids (Family: Alcidae) as highly vulnerable to tidal turbine impacts due to diving behavior and depth, use of tidal races for foraging, feeding range, and habitat specialization.

Concerns have been raised that tidal turbines may have impacts to seabirds through collision, disturbance, habitat loss, and/or changes to food availability. However, few devices have been deployed to enable monitoring of impacts, and there have been few studies of the ecological implications and magnitude of any impacts to seabird populations (Robbins 2017). Vulnerability may differ among deployment locations, and assessments should quantify habitat-use using dedicated and site-specific surveys to reduce uncertainty (Waggitt et al. 2017).

Da Silva et al. (2022) reviewed and synthesized literature describing marine renewable energy (MRE) system interactions and collision risk for marine animals. There are no reports in the literature for collisions with marine mammals, diving seabirds, or other animals (da Silva et al. 2022). This does not mean that they do not occur; collisions may not be detected due to the limited number of projects, and the significant challenges associated with effective 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 and operating parameters 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 and at the relevant depths. 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) (such as described for murrelets in Sections 7.1.1.1 and 4.2.3.1 and 0), could also influence encounter rates and collision risk (Cox et al. 2013, Sparling et al. 2020) and is largely unknown for the action area.

Furthermore, collision risk estimated on the basis of wide-scale information may not reflect actual risk at any specific site (Sparling et al. 2020). Estimating collision risk for the action area is inherently difficult, and specifically for the currently proposed tidal turbine deployment areas (Figure 8); site-specific information is lacking, and estimates would be highly uncertain.

Given the substantial sources of uncertainty about possible effects, the DOE choose to take a conservative approach. In addition to inherent intermittent operation and variable tip-speed, the DOE will minimize risk of collision by adaptively managing tidal turbine deployments (PDC in Section 4.1.15), and by incorporating information obtained from monitoring (Section 4.2). The DOE will deploy up to one additional tidal turbine at a time, which over time may include up to five turbines deployed concurrently, with a maximum of 10 turbines deployed in any given year. Any subsequent larger deployments will rely on future adaptive management between DOE and the Services. The current proposed action includes deployment of one tidal turbine at a time, an adaptive approach to subsequent tidal turbine deployments, and exchanges of information with the Services (including monitoring results) during and prior to subsequent turbine deployments.

The monitoring protocols in Sections 4.2.3 and 4.2.4 were developed to address perceived collision risk for marbled murrelets, marine mammals, and fish. PSOs will monitor, gather, and report information to describe the spatiotemporal distribution of marbled murrelets during tidal turbine deployment(s) and decommissioning (Section 4.2.3), and nearfield underwater surveillance and detection technologies/devices will monitor for potential collisions and interactions (Section 4.2.4).

Lastly, as mentioned in Section 7.1.1.1, marbled murrelets are expected to congregate within the inlet channel to Sequim Bay. First, the inlet channel is the only way that outmigrating salmonids (which are prey for marbled murrelets [Burkett 1995]) can enter the marine environment from Sequim Bay tributaries. Second, forage fish (also prey of marbled murrelets) spawn within or adjacent to the inlet channel. Third, marbled murrelet occurrence in areas of tidal mixing is expected (Speich and Wahl 1995). Therefore, we expect marbled murrelets will be attracted to the inlet channel where the tidal turbines are deployed.

Even with implementation of all appropriate PDCs, limited adverse marbled murrelet exposures and effects are still likely to occur. Marbled murrelets are cryptic, PSOs may sometimes fail to detect or identify individuals, and marbled murrelet behavior around tidal turbines is an unknown. Nearfield detection and auto-shutdown features may fail to consistently detect marbled murrelets due to their small size. For these reasons, with consideration for the scope and scale of the operations, and the estimated marbled murrelet densities in the action area, the Service expects that up to 10 marbled murrelets may suffer forms of injury as a result of tidal turbine devices and operations; we expect, lethal exposures or mortality will not exceed three individual marbled murrelets.

10 CUMULATIVE EFFECTS: Marbled Murrelet

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

Within the action area, all State, Tribal, local, and private actions that place fill or discharge to navigable waters are required to obtain a U.S. Army Corps of Engineers permit(s) under the authority of Section 10 of the Rivers and Harbors Act and/or Section 404 of the Clean Water Act. Therefore, future actions that place fill or discharge to navigable waters will require section 7 consultation with the Service.

Similarly, fisheries within the action area are managed under the authority of the Pacific Fishery Management Council, as specified by the Magnuson-Stevens Fishery Conservation Management Act, or other authorities with a federal nexus (e.g., BIA funding for Treaty Tribal fisheries). Therefore, fisheries and associated activities, including those that may affect marbled murrelets, will require section 7 consultation with the Service.

However, marbled murrelets will continue to be affected by other ongoing non-federal activities within the action area, and along rivers and watercourses draining to the action area. Threats to marine habitat quality that do not involve a federal nexus include shoreline development and armoring above MHHW (Carman et al. 2010, p. 49), human population growth and associated development, urbanization, and an increase to the amount of impervious surfaces and associated discharges, pressures on water supplies, and water and air pollution. The population of the Puget Sound region is growing quickly, with an estimated increase of 700,000 people between 2008 and 2020 (Washington Department of Ecology 2016).

Human population increases result in higher levels of toxic chemicals entering Puget Sound from surface runoff, groundwater discharges, and municipal and wastewater outfall discharges. These discharges contain oil, grease, possible polychlorinated biphenyls (PCBs) and/or polycyclic aromatic hydrocarbons (PAHs), heavy metals, and other contaminants. Many areas surrounding Puget Sound are urbanized or urbanizing, and development is spreading to surrounding areas; increasingly, agriculture and forested lands are being converted to impervious surfaces. The increase in impervious surfaces leads to additional storm water runoff, which carries contaminants into the action area (Washington Department of Ecology 2006; Washington Department of Ecology and King County 2011, p. 30). Air pollution increases due to development and urbanization also lead to the deposition of contaminants such as polybrominated diphenyl ethers (PBDEs, used as flame retardants) into the marine environment (Washington Department of Ecology and King County 2011, p. 32).

Contaminants have been found in marbled murrelet prey species at levels that may impair prey health and reproductive success (Liedtke et al. 2013, p. 5; USFWS 2009, p. 39-40). Some or many of these contaminants increase in concentration as they move up the food chain (Borga et al. 2001, pp. 191-196), which means that piscivorous birds like the marbled murrelet are exposed to higher doses of contaminants than are the fish they prey upon. Contaminants have been shown to cause developmental abnormalities, wasting, disruption of thyroid function, immunosuppression, and decreased reproductive success in fish-eating birds (reviewed in Luebke et al. 1997, pp. 7-10; Rolland 2000, pp. 615, 620-626).

Oil tanker and barge traffic in and near the action area is increasing (Felleman 2016, p. 27; Etkin et al. 2015, p. 271). In particular, the Kinder Morgan Trans Mountain pipeline expansion was approved in 2019 and, when soon completed, will nearly triple the amount of oil transported through the SJF (https://www.transmountain.com/project-overview). Increases in oil transportation raise the likelihood of an oil spill affecting the action area. A major oil spill into the action area could potentially kill significant numbers of marbled murrelets, as has been documented for other previous oil spills (Carter and Kuletz 1995, entire). Oil spills may also cause sublethal injury and may affect forage fish populations (Carter and Kuletz 1995, p. 264). Oil spill remediation can result in additional damage, including to forage fish populations (Pentilla 2007, p. 19).

These cumulative effects, acting in concert with other stressors on marbled murrelets, are likely to increase marbled murrelet mortality rates and depress reproductive rates over time.

11 INTEGRATION AND SYNTHESIS OF EFFECTS: Marbled Murrelet

The Integration and Synthesis section is the final step in assessing 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 and the cumulative effects to the status of the species and critical habitat, and the environmental baseline, to formulate our Opinion as to whether the proposed action is likely to: (1) appreciably reduce the likelihood of both survival and recovery of the species in the wild by reducing its numbers, reproduction, or distribution; or (2) result in the destruction or adverse modification of designated critical habitat.

11.1 Summary of Proposed Action

The DOE proposes to conduct a broad program of research activities at PNNL (Sequim, Sequim Bay, and the SJF). Specific fields of research focus include development and testing of technologies and systems to monitor changes in the marine environment, marine and coastal resources, environmental chemistry, water resources and modeling, ecotoxicology, biotechnology, materials science, renewable energy development, overwater and underwater surveillance and detection technologies, and national security. Research activities are located at the PNNL campus in Sequim, in Sequim Bay, and the adjacent portions of the SJF (i.e., between Dungeness Spit and Protection Island) (Figure 1). Research activities are described in 14 categories (Sections 4.1.1 through 4.1.14); of those 14 categories, three are expected to result in measurably adverse marbled murrelet exposures and effects causing a likelihood of injury (i.e., Light Emitting Devices and Operations, Community and Research Scale Marine Energy Devices, and Tidal Turbine Research).

11.2 Summary of Marbled Murrelets within the Action Area

The action area includes Sequim Bay and the adjacent portion of the SJF between Dungeness Spit and Protection Island (Figure 1). The action area lies within Conservation Zone 1 which includes the U.S. portions of the Puget Sound, the SJF, and the Strait of Georgia. Surveys for marbled murrelets conducted as part of the NWFPEM resulted in a population estimate of 3,797 marbled murrelets (95 percent confidence interval [CI] of 2,781 - 4,829) in Conservation Zone 1 in 2022, the last year for which an estimate is available (Table 24, McIver et al. 2023, p. 17). However, the action area makes up only a very small portion of Conservation Zone 1. As part of the biennial at-sea NWFPEM surveys, surveys are conducted in the SJF outside of Sequim Bay (Zone 1, Strata 1, PSU 8); however, those surveys are statistically insufficient for providing marbled murrelet numbers and densities for the action area (S. Pearson, pers. comm., Dec. 13, 2021).

During the 1978 and 1979 National Oceanic and Atmospheric Administration (NOAA) Marine Ecosystem Analysis Program (MESA), marine bird surveys of northern Puget Sound censuses were established and conducted (Speich and Wahl 1995, p. 313). During the MESA program, northern Puget Sound was divided into 11 major regions and 72 subregions, largely based upon marine and terrestrial geography and water depth. For Sequim Bay, seasonal densities for marbled murrelet were observed with the highest densities being in the fall (2.54 birds/km^2) followed by winter (0.92 birds/km^2), summer (0.33 birds/km^2), and spring (0.00 birds/km^2) (Speich and Wahl 1995, p. 315). Since those surveys have not been repeated in the following 45 years, it is difficult to be certain if those results were either completely unique to that year or if there have been any trends since then. However, WDFW has been conducting mid-winter aerial surveys (December through February) since 1996 (Figure 14) with densities ranging from 0.32 birds/km^2 (2003) to 3.41 birds/km^2 (2010), which is similar to the fall and winter numbers observed for the MESA program surveys.

11.3 Marbled Murrelet Conservation Needs

Reestablishing an abundant supply of high-quality marbled murrelet nesting habitat is a vital conservation need given the extensive removal of that habitat during the 20th century. Much of the federal land managed under the Northwest Forest Plan that currently does not provide marbled murrelet nesting habitat is expected to transition into mature and older-forest habitat over the next few decades (Raphael et al. 2011, p. 44).

In addition to increasing nesting habitat, there are other conservation imperatives. Foremost among those is increasing marbled murrelet reproductive success and productivity (i.e., fecundity) by increasing the number of breeding adults, improving marbled murrelet nest success (due to low nestling survival and low fledging rates), and reducing anthropogenic stressors in marine and terrestrial habitat that reduce individual marbled murrelet fitness or lead to mortality. Marbled murrelets would also likely benefit from improvements in the health of the marine food web in the Salish Sea and along the Pacific Coast in Washington (Lorenz et al. 2016a, p. 14).

General criteria for marbled murrelet recovery and delisting are established under the *Marbled Murrelet Recovery Plan* (USFWS 1997, p. 114-115). These general criteria include:

- Documenting stable or increasing trends in population size, density, and productivity in four of the six Conservation Zones for a 10-year period; and
- Implementing management and monitoring strategies in the marine and terrestrial environments to ensure protection of marbled murrelets for at least 50 years.

Thus, increasing marbled murrelet reproductive success and reducing the frequency, magnitude, or duration of any anthropogenic stressor that directly or indirectly affects marbled murrelet fitness or survival in the marine and terrestrial environments are the priority conservation needs of the species. The Service estimates recovery of the marbled murrelet will require at least 50 years (USFWS 1997).

11.4 The Effects of the Proposed Action, Effects to Marbled Murrelet Numbers, Productivity, and Distribution

This Opinion does not establish an expiration date. The foreseeable adverse exposures and effects described and quantified herein, are based upon an annual rate for five years. This Opinion and programmatic ESA coverage can and will remain effective and valid, unless and until additional adverse exposures and effects (i.e., effects not described herein) are anticipated, or until the amount(s) or type(s) of issued incidental take are approached or exceeded. The ESA establishes standard provisions and ‘triggers’ for reinitiation of consultation (e.g., ‘new information reveals the effects of an action;’ ‘an action is modified in a manner that causes an effect not considered;’ ‘a new species is listed, or critical habitat is designated that may be affected’); nothing stated here, alters, or changes the standard provisions and ‘triggers’ for reinitiation of consultation. The DOE is responsible for all monitoring, tracking, and reporting, that is required as part of implementing the programmatic ESA coverage.

This Opinion describes and quantifies measurably adverse marbled murrelet exposures and effects causing a likelihood of injury, and attributes those to three research activity categories (i.e., Light Emitting Devices and Operations, Community and Research Scale Marine Energy Devices, and Tidal Turbine Research). In summary, with consideration for the scope and scale of the operations, and the estimated marbled murrelet densities in the action area, the Service has described and expects the following:

- Up to two (2) marbled murrelets may suffer forms of injury (i.e., eye injury or other) as a result of Light Emitting Devices and Operations; no lethal exposures or mortality are expected or foreseeable.
- Up to three (3) marbled murrelets will be exposed to Community and Research Scale Marine Energy Devices, in a manner that creates a likelihood of injury; we expect, lethal exposures or mortality will not exceed one (1) individual marbled murrelet.
- Up to ten (10) marbled murrelets may suffer forms of injury as a result of Tidal Turbine Research (Devices and Operations); we expect, lethal exposures or mortality will not exceed three (3) individual marbled murrelets.
- The Service expects, in total, the DOE's program of research activities will create a likelihood of injury for a maximum of fifteen (15) marbled murrelets; and will kill, cause, or contribute to the mortality of a maximum of four (4) marbled murrelets.

The DOE, PNNL, their research partners, and contractors, will implement all relevant and applicable overarching (program level) and activity-specific PDCs; including, PDCs specific to Protected Species Observers/PSOs; above water marbled murrelet monitoring; underwater (and near-field) tidal turbine monitoring; adaptive management of tidal turbine deployments; reporting requirements for tidal turbine research and deployment timeframes; reporting requirements for community and research scale marine energy devices and deployment timeframes; and, reporting requirements for light emitting devices and deployment timeframes. If/when the DOE cannot or will not implement specific PDCs, the DOE must identify these as minor deviations or minor modifications (i.e., when making notifications and/or requesting verifications).

For or at the scale of Conservation Zone 1, the current marbled murrelet population estimate is 3,797 individuals (95% confidence interval; 2,781 to 4,829 individuals), with a density of approximately 1.09 birds per km^2 (Table 24). Based on available information, the action area may support above average winter season densities (i.e., as indicated by recent WDFW aerial surveys) (Figure 14). Available spring and summer season marbled murrelet density estimates are old and very incomplete; the reported MESA surveys for Sequim Bay (1978-1979), characterized densities as 'low' (summer) or 'absent' (spring).

Based on previous surveys and all available and reliable information, the Service believes that non-breeding seasonal patterns of marbled murrelet presence in the action area, may be more prevalent and significant than breeding seasonal patterns of presence and use of the action area. Furthermore, the Service expects that many or most of the exposed and adversely affected marbled murrelets (i.e., individuals), will be non-breeding adults, and/or non-breeding post-fledge individuals (or subadults). A maximum of four mortalities will or would represent approximately 0.14 percent of the current marbled murrelet population in Conservation Zone 1 (conservatively estimated). A likelihood of injury for fifteen marbled murrelets, will or would represent approximately 0.54 percent of the current marbled murrelet population in Conservation Zone 1 (conservatively estimated).

The Service finds and concludes, that the marbled murrelet injury and mortality that is likely and foreseeable as a consequence of the proposed action (i.e., a likelihood of injury for fifteen marbled murrelets; a maximum of four mortalities), will modestly reduce the number of individuals at the scale of the action area. However, we also find and conclude, that the proposed action is unlikely to cause or contribute to a measurable or discernible long-term decline in marbled murrelet numbers (abundance) or reproduction (productivity) at the scale of the action area. With implementation of the PNNL program of research activities, we expect that long term marbled murrelet numbers (abundance), reproduction (productivity), and distribution will be maintained and not reduced at the scale of the action area.

The anticipated direct and indirect effects of the action, combined with the effects of interrelated and interdependent actions, and the cumulative effects associated with future state, tribal, local, and private actions, will not appreciably reduce the likelihood of survival and recovery of the species. The effects of the action (permanent and temporary) will not measurably reduce marbled murrelet numbers, reproduction, or distribution, at the scale of Conservation Zone 1, or at the scale of the species' range. The foreseeable effects of the action will not alter the status of the marbled murrelet at the scale of Conservation Zone 1 or the species' range.

12 CONCLUSION: Marbled Murrelet

After reviewing the current status of the marbled murrelet, the environmental baseline for the action area, the effects of the proposed action, and the cumulative effects, it is the Service's Biological Opinion that the action, as proposed, is not likely to jeopardize the continued existence of the marbled murrelet. No critical habitat has been designated in the action area for the marbled murrelet; therefore, none will be affected by the proposed action.

13 INCIDENTAL TAKE STATEMENT

Section 9 of the ESA and federal regulation pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct. *Harm* is defined by the Service as an act which actually kills or injures wildlife. Such an act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavior patterns, including breeding, feeding, or sheltering (50 CFR 17.3). *Harass* is defined by the Service as an intentional or negligent act or omission which creates 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 (50 CFR 17.3). Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the ESA provided that such taking is in compliance with the terms and conditions of this Incidental Take Statement.

The measures described below are non-discretionary and must be undertaken by the Department of Energy so that they become binding conditions of any grant or permit issued to the Pacific Northwest National Laboratory, as appropriate, for the exemption in section 7(o)(2) to apply. The Department of Energy has a continuing duty to regulate the activity covered by this Incidental Take Statement. If the Department of Energy 1) fails to assume and implement the terms and conditions or 2) fails to require the Pacific Northwest National Laboratory to adhere to the terms and conditions of the Incidental Take Statement through enforceable terms that are added to the permit or grant document, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impact of incidental take, the Pacific Northwest National Laboratory must report the progress of the action and its impact on the species, as specified in this Incidental Take Statement [50 CFR 402.14(i)(4)].

14 AMOUNT OR EXTENT OF TAKE

As described in the Opinion, the Service expects limited but unavoidable incidental take of marbled murrelets to result from implementation of the proposed PNNL program of Marine Research and Equipment Testing. Specifically, we find that three of the 14 proposed activities present a reasonable potential to result in incidental take of marbled murrelets: Light Emitting Devices and Operations; Community and Research Scale Marine Energy Devices; and Tidal Turbine Research (Devices and Operations).

14.1 Light Emitting Devices and Operations

Light Emitting Devices and Operations, specifically operations including non-eye-safe green light lasers, present a reasonable potential to injure and result in incidental take of marbled murrelets:

- Harass – Two (2) marbled murrelets; likelihood of injury (i.e., eye injury or other).
- Harm – No lethal exposures or mortality are expected or foreseeable.

14.2 Community and Research Scale Marine Energy Devices

Community and Research Scale Marine Energy Devices present a reasonable potential to injure and result in incidental take of marbled murrelets:

- Harass – Three (3) marbled murrelets; likelihood of physical injury.
- Harm – One lethal exposure or mortality (one marbled murrelet/individual). Community and Research Scale Marine Energy Devices will kill, cause, or contribute to the mortality of one (1) marbled murrelet.

14.3 Tidal Turbine Research, Devices, and Operations

Tidal Turbine Research, Devices, Operations, and deployments present a reasonable potential to injure, kill, and result in incidental take of marbled murrelets:

- Harass – Ten (10) marbled murrelets; likelihood of physical injury.
- Harm – Three (3) lethal exposures or mortalities (three marbled murrelets/individuals). Tidal Turbine Research, Devices, and Operations will kill, cause, or contribute to the mortality of three (3) marbled murrelets.

14.4 Program Totals

The Service expects, in total, the DOE's program of research activities will create a likelihood of injury for a maximum of fifteen (15) marbled murrelets; and will kill, cause, or contribute to the mortality of a maximum of four (4) marbled murrelets.

Table 26. Incidental marbled murrelet take over the duration of the Opinion.

Research Activities Category	Lethal Take	Total Take
Light Emitting Devices and Operations	0	2
Community and Research Scale Marine Energy Devices	1	3
Tidal Turbine Research, Devices, and Operations	3	10
Total	**4**	**15**

15 EFFECT OF THE TAKE

In the accompanying Opinion, the Service determined that this level of anticipated take is not likely to result in jeopardy to the species. No critical habitat has been designated in the action area for the marbled murrelet; therefore, none will be affected by the proposed action.

16 REASONABLE AND PRUDENT MEASURES

The Service finds that the following Reasonable and Prudent Measures (RPMs) are necessary and appropriate to minimize the impacts of incidental take of marbled murrelet:

1. Provide the Service with 30-day (all activities, excluding Tidal Turbine Research) and 90-day (Tidal Turbine Research) minimum notification 'windows' (as outlined in Sections 4.1.2 through 4.1.15); plan and allow for a robust verification process.

2. All projects and activities are subject to and will include implementation of the overarching (program level) and activity-/category-specific Project Design Criteria (PDCs). DOE and PNNL shall review projects and activities, in the proposal and funded stages, to determine the scope and life cycle of the work; shall evaluate projects and activities for incorporation of all relevant PDCs. If/when the DOE cannot or will not implement specific PDCs, the DOE shall identify these as minor deviations or minor

modifications (i.e., when making notifications and/or requesting verifications). The DOE shall track, monitor, and report outcomes for all projects and activities. The DOE will provide annual project summaries to the Service; these will document yearly deployments, projects/activities, impacts, and effects.

3. Implement Protected Species Observers (PSOs), above water marbled murrelet monitoring, underwater (and near-field) tidal turbine monitoring, and adaptive management of tidal turbine deployments, as described in the project description and Opinion.

4. Notify the Service within 48 hours if monitoring detects or determines possible incidental take of a marbled murrelet(s).

17 TERMS AND CONDITIONS

In order to be exempt from the prohibitions of section 9 of the ESA, the Department of Energy and PNNL must comply with the following Terms and Conditions, which implement the RPMs described above and outline monitoring and reporting requirements. These Terms and Conditions are non-discretionary.

1. To implement RPMs 1 and 2:

    a. For projects and activities that require notification only, the DOE shall provide an email to the Service a minimum of 30 days before the project or activity begins. Email correspondence and attachments will describe the project or activity to be undertaken, the schedule (approximate), and identify/specify implementation of the relevant Project Design Criteria (PDCs).

    b. For projects and activities that require verification (excluding Tidal Turbine Research, Devices, and Operations), the DOE shall submit an email to the Service a minimum of 30 days before the project or activity begins. Email correspondence and attachments shall include:

        i. A description of the proposed project or activity.
        ii. A description of the relevant Project Design Criteria (PDCs). The DOE shall clearly identify all PDCs proposed for full implementation. The DOE shall clearly identify any minor deviations or minor modifications.
        iii. An approximate schedule for implementation of the project or activity (including monitoring and reporting); i.e., when, for how long, will the project or activity occur.
        iv. A description of approximate location(s) (e.g., Sequim Bay, ½ mile south of Travis Spit).
        v. A description of any additional conservation measure(s) and/or compensatory mitigation that will be implemented. [Note: Specific activities requiring verification may also be subject to compensatory

mitigation (i.e., those activities described in Sections 4.1.2, 4.1.4.1, 4.1.14, and 4.1.15).]

vi. Plan sheets, figures, and/or specifications for marine energy devices (Community and Research Scale Marine Energy Devices).

c. For projects and activities that require verification (for Tidal Turbine Research, Devices, and Operations, specifically), the DOE shall submit an email to the Service a minimum of 90 days before the project or activity begins. Email correspondence and attachments shall include:

i. A description of the proposed project or activity.

ii. A description of the relevant Project Design Criteria (PDCs). The DOE shall clearly identify all PDCs proposed for full implementation. The DOE shall clearly identify any minor deviations or minor modifications.

iii. An approximate schedule for implementation of the project or activity (including monitoring and reporting); i.e., when, for how long, will the project or activity occur.

iv. A description of approximate location(s) (e.g., Sequim Bay, ½ mile south of Travis Spit).

v. A description of any additional conservation measure(s) and/or compensatory mitigation that will be implemented. [Note: Specific activities requiring verification may also be subject to compensatory mitigation (i.e., those activities described in Sections 4.1.2, 4.1.4.1, 4.1.14, and 4.1.15).]

vi. Plan sheets, figures, and/or specifications for tidal turbine deployments (Tidal Turbine Research, Devices, and Operations).

d. All DOE notifications, requested verifications, email correspondence, and attachments shall be submitted to the Washington Fish and Wildlife Office (Email: <<WashingtonFWO@fws.gov>>), Attn: *CLAM Assistant Field Supervisor and Staff*, Subject Line: *DOE / PNNL / Sequim Programmatic, Notice or Requested Verification (FWS XRef. No. 2024-0008431)*.

e. Activities that do not include all relevant PDCs, and that would result in additional adverse effects and/or incidental take (i.e., activities that are not consistent with and covered by the completed formal consultation and Opinion), will require individual consultation. For projects (activities or parts thereof) that will or may result in measurable adverse exposures or effects, verification(s) may (only as necessary) include identification of additional PDCs and/or conservation measures that must be implemented by the DOE and PNNL.

2. To implement RPM 3:

a. The DOE and PNNL shall implement Protected Species Observers (PSOs) as described in the project description and Opinion.

b. The DOE and PNNL shall implement above water marbled murrelet monitoring as described in the project description and Opinion.

c. The DOE and PNNL shall implement underwater (and near-field) tidal turbine monitoring as described in the project description and Opinion.

d. The DOE and PNNL shall implement adaptive management for tidal turbine deployments as described in the project description and Opinion.

e. The DOE and PNNL shall monitor and report all relevant and observable outcomes; shall monitor and report all outcomes for Light Emitting Devices and Operations, Community and Research Scale Marine Energy Devices, and Tidal Turbine Research (Devices and Operations), specifically.

f. The DOE and PNNL shall implement underwater equipment systems that allow for near-field monitoring (i.e., AMP, AMP-equivalent, or similar equipment), and shall adaptively manage marine energy device and tidal turbine deployments, to obtain relevant biological information and address specific needs:

   i. The AMP (AMP-equivalent, or similar equipment) will be required by default. If/when the DOE cannot or will not implement the AMP (AMP-equivalent, or similar equipment), the DOE shall identify such proposals as a deviation(s) or modification(s).
   ii. The DOE and PNNL shall collect, process, compile, and report near-field monitoring data in a timely manner; in the event of a blade strike or other physical contact with a marine energy device or tidal turbine, post-processing shall determine if the target was debris, if the target was an organism, and (if an organism) the species and disposition or condition of the target.

g. The DOE shall compile and provide annual project summaries and reports to the Service; these will document yearly deployments, projects/activities, impacts, and effects. Each annual report shall be provided to the Service by the anniversary date of the issuance of the Opinion (Email: <<WashingtonFWO@fws.gov>>, Attn: *CLAM Assistant Field Supervisor and Staff*, Subject Line: *DOE / PNNL / Sequim Programmatic, FWS XRef. No. 2024-0008431*).

3. To implement RPM 4:

   a. The DOE shall contact the Washington Fish and Wildlife Office (Email: <<WashingtonFWO@fws.gov>>, Attn: *CLAM Assistant Field Supervisor and Staff*, Subject Line: *DOE / PNNL / Sequim Programmatic, FWS XRef. No. 2024-0008431*) within 48 hours of any observed or documented incidental take of marbled murrelet (lethal or non-lethal). Activities causing or contributing to the incidental take should be ceased until further notice and issue resolution.

b. Projects and activities that are not consistent with and covered by the completed formal consultation and Opinion will require individual consultation.

The Service has determined that fewer than twenty (20) marbled murrelets will be incidentally taken as a result of the proposed action. The DOE's program of research activities will create a likelihood of injury for a maximum of fifteen (15) marbled murrelets; and will kill, cause, or contribute to the mortality of a maximum of four (4) marbled murrelets. The RPMs, with their implementing Terms and Conditions, are designed to minimize the impact of incidental take that might otherwise result from the proposed action. If, during the course of the action, this level of incidental take is exceeded, such incidental take requires reinitiation of consultation and review of the RPMs. The federal action agency (Department of Energy) must immediately provide an explanation of the causes of the taking, and review with the Service the need for possible modification of the RPMs.

The Service is to be notified within three working days upon locating a dead, injured or sick endangered or threatened species specimen. Initial notification must be made to the nearest U.S. Fish and Wildlife Service Law Enforcement Office. Notification must include the date, time, precise location of the injured animal or carcass, and any other pertinent information. Care should be taken in handling sick or injured specimens to preserve biological materials in the best possible state for later analysis of cause of death, if that occurs. In conjunction with the care of sick or injured endangered or threatened species or preservation of biological materials from a dead animal, the finder has the responsibility to ensure that evidence associated with the specimen is not unnecessarily disturbed. Contact the U.S. Fish and Wildlife Service Law Enforcement Office at (425) 883-8122, or the Service's Washington Fish and Wildlife Office at (360) 753-9440.

18 CONSERVATION RECOMMENDATIONS

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

The Service recommends that the DOE and PNNL implement additional measures to avoid and minimize the incidental take of marbled murrelets. Effective additional measures may include:

1. Above Water Marbled Murrelet Monitoring during tidal turbine deployments (PBA, 0).

In order for the Service to be kept informed, of actions minimizing or avoiding adverse effects (or benefitting listed species or their habitats), we request notification of the implementation of any conservation recommendations.

19 REINITIATION NOTICE

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

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APPENDIX A - STATUS OF THE SPECIES: MARBLED MURRELET

Appendix A
Status of the Species: Marbled Murrelet

The marbled murrelet (*Brachyramphus marmoratus*) (murrelet) was listed by the U.S. Fish and Wildlife Service (Service) as a threatened species in Washington, Oregon, and California in 1992. The primary reasons for listing included extensive loss and fragmentation of the older-age forests that serve as nesting habitat for murrelets, and human-induced mortality in the marine environment from gillnets and oil spills (57 FR 45328 [Oct. 1, 1992]). Although some threats such as gillnet mortality and loss of nesting habitat on Federal lands have been reduced since the 1992 listing, several threats persist, such as climate change, timber harvest, fire, predation, and coastal and nearshore development (75 FR 3424 [Jan. 21, 2010]; Service 2024, p. 15). This document will briefly discuss the life history and terrestrial distribution of the murrelet before examining population status and threats to survival and recovery, followed by an overview of the conservation needs of the species and its recovery.

1. **Life History**

The murrelet is a small, fast-flying seabird in the Alcidae family that occurs along the Pacific coast of North America. Murrelets forage for small schooling fish or invertebrates in shallow, nearshore, marine waters and primarily nest in coastal older-aged coniferous forests. The murrelet lifespan is unknown, but is expected to be in the range of 10 to 20 years based on information from similar alcid species (De Santo and Nelson 1995, pp. 36-37). Murrelet nesting is asynchronous and spread over a prolonged season. In Washington, the murrelet breeding season extends from April 1 to September 23. Egg laying and incubation occur from April to early August and chick rearing occurs between late May and September, with all chicks fledging by late September (Hamer et al. 2003; Service 2012a).

Murrelets lay a single-egg which may be replaced if egg failure occurs early in the nesting cycle, but this is rare (Nelson 1997, p. 17). During incubation, one adult sits on the nest while the other forages at sea. Adults typically incubate for a 24-hour period, then exchange duties with their mate at dawn. Chicks hatch between May and August after 30 days of incubation. Hatchlings appear to be brooded by an adult for several days (Nelson 1997, p. 18). Once the chick attains thermoregulatory independence, both adults leave the chick alone at the nest for the remainder of the rearing period, except during feedings. Both parents feed the chick, which receives one to eight meals per day (Nelson 1997, p. 18). Most meals are delivered early in the morning while about a third of the food deliveries occur at dusk and intermittently throughout the day (Nelson and Hamer 1995, p. 62).

Murrelets and other fish-eating alcids exhibit wide variations in nestling growth rates. The nestling stage of murrelet development can vary from 27 to 40 days before fledging (De Santo and Nelson 1995, p. 45). The variations in alcid chick development are attributed to constraints on feeding ecology, such as unpredictable and patchy food distributions, and great distances between feeding and nesting sites (Øyan and Anker-Nilssen 1996, p. 830). Food limitation during nesting often results in poor growth, delayed fledging, increased mortality of chicks, and nest abandonment by adults (Øyan and Anker-Nilssen 1996, p. 836).

Murrelets are believed to be sexually mature at two to four years of age (Nelson 1997, p. 19). Adult birds may not nest every year, especially when food resources are limited. For example, in central California, the proportion of murrelets attempting to breed was more than four times higher (50 percent versus 11 percent) in a year when prey availability was apparently good than in a year when more foraging effort was required (Peery et al. 2004, p. 1095). In Oregon, there was similarly a four-fold increase in vacancy rates of previously-occupied nesting habitat following the poorest ocean conditions, as compared with the years following the best ocean conditions (Betts et al. 2020, p. 6). In 2017, none of the 61 murrelets radio-tagged in Oregon attempted nesting, likely because anomalous ocean conditions reduced prey availability (Horton et al. 2018, p. 77). At other times and places, radio-telemetry and demographic modeling indicate that the proportion of adults breeding in a given year may vary from 5 to 95 percent (Lorenz et al. 2017, p. 312; McShane et al. 2004, p. 3-5). In other words, in some years, very few murrelets attempt nesting, but in other years, almost all breeding-age adults may initiate nesting.

Murrelets in the Marine Environment

Murrelets spend most (>90 percent) of their time at sea. They generally forage in pairs on the water, but they also forage solitarily or in small groups. In addition to foraging, their activities in the marine environment include preening, social behaviors, and loafing. Following the breeding season, murrelets undergo the pre-basic molt, in which they exchange their breeding plumage for their winter plumage. They replace their flight feathers during this molt, and for a few weeks they are flightless. Therefore, they spend this entire period at sea. Their preferred marine habitat includes sheltered, nearshore waters, although they occur farther offshore in some locations and during the nonbreeding season (Huff et al. 2006, p. 19).

Breeding Season Distribution

The murrelet is widely distributed in nearshore waters along the west coast of North America. It occurs primarily within five km of shore (in Alaska, within 50 km), and primarily in protected waters, although its distribution varies with coastline topography, river plumes, riptides, and other physical features (Nelson 1997, p. 3). For example, along the Pacific coast of Washington, the most heavily-used area during the breeding season extends to at least eight km from the coast, with use in some years concentrated in the outer portions of this area (Bentivoglio et al. 2002, p. 29; McIver et al. 2021, pp. 22, 24; Menza et al. 2015, pp. 16, 20-21). The distribution of murrelets in marine waters during the summer breeding season is highly variable along the Pacific coast, with areas of high density occurring along the Strait of Juan de Fuca in Washington, the central Oregon coast, and northern California (Raphael et al. 2015, p. 20). Low-density areas or gaps in murrelet distribution occur in central California, and along the southern Washington coast (Raphael et al. 2015, p. 21). Murrelet marine habitat use is strongly associated with the amount and configuration of nearby terrestrial nesting habitat (Raphael et al. 2015, p. 17). In other words, they tend to be present in marine waters adjacent to areas of suitable breeding habitat. Local aggregations or "hot spots" of murrelets in nearshore marine waters are strongly associated with landscapes that support large, contiguous areas of mature and old-growth forest. In Puget Sound and along the Strait of Juan de Fuca, these "hot spots" are also strongly associated with a low human footprint in the marine environment, for example, areas natural shorelines and relatively little vessel traffic (Raphael et al. 2016a, p. 106).

Non-breeding adults and subadults are thought to occur in similar areas as breeding adults. This species does occur farther offshore during the breeding season, but in much reduced numbers (Drew and Piatt 2020; Strachan et al. 1995, p. 247). Their offshore occurrence is probably related to current upwelling and plumes during certain times of the year that tend to concentrate their prey species. Even within the breeding season, individual murrelets may make large movements, and large average marine home ranges (505 km^2 and 708 km^2, respectively) have been reported for northern California and Washington (Hébert and Golightly 2008, p. 99; Lorenz et al. 2017, p. 318).

Non-breeding Season Distribution

Marbled murrelet marine habitat use during the non-breeding season is poorly documented, but they are present near breeding sites year-round in most areas (Nelson 1997, p. 3). Murrelets exhibit seasonal redistributions following the pre-basic molt (Peery et al. 2008a, p. 119), and can move up to 750 km from their breeding season locations (Hébert and Golightly 2008, p. 101; Adrean et al. 2018). The southern end of the range extends as far south as the Southern California Bight; but some individuals also move northward at the end of the breeding season (Hall et al. 2009, p. 5081; Peery et al. 2008a, p. 121). Generally, they are more dispersed and may be found farther offshore than during the breeding season, up to approximately 50 miles from shore (Adams et al. 2014; Ballance 2015, in litt.; Drew and Piatt 2020; Pearson 2019, p. 5; Speich and Wahl 1995, p. 322).

The highest concentrations likely still occur close to shore and in protected waters, but given the limited data available regarding non-breeding season murrelet distribution or densities, a great deal of uncertainty remains (Nelson 1997, p. 3; Pearson 2019, p. 5). More information is available regarding non-breeding season murrelet density and distribution in some areas of Washington. Murrelets move from the outer exposed coasts of Vancouver Island and the Straits of Juan de Fuca into the sheltered and productive waters of northern and eastern Puget Sound (Beauchamp et al. 1999, entire; Burger 1995, p. 297; Speich and Wahl 1995, p. 325). However, in central and southern Puget Sound, murrelet densities are often lower during the non-breeding season than they are during the breeding season (Pearson et al. 2022, pp. 7-9). Known areas of winter concentration include and southern and eastern end of Strait of Juan de Fuca (primarily Sequim, Discovery, and Chuckanut Bays) and the San Juan Islands, Washington (Speich and Wahl 1995, p. 314).

Foraging and Diet

Murrelets dive and swim through the water by using their wings in pursuit of their prey; their foraging and diving behavior is restricted by physiology. They usually feed in shallow, nearshore water less than 30 m (98 ft) deep, which seems to provide them with optimal foraging conditions for their generalized diet of small schooling fish and large, pelagic invertebrates: Pacific sand lance (*Ammodytes personatus*), northern anchovy (*Engraulis mordax*), Pacific herring (*Clupea harengus*), surf smelt (*Hypomesus* sp.), euphausiids, mysids, amphipods, and other species (Nelson 1997, p. 7). However, they are assumed to be capable of diving to a depth of 47 m (157 ft) based on their body size and diving depths observed for other Alcid species (Mathews and Burger 1998, p. 71). Murrelets forage in deeper waters when upwelling, tidal rips, and daily activity of prey concentrate prey near the surface (Strachan et al. 1995).

Murrelets are highly mobile, and some make substantial changes in their foraging sites within the breeding season. For example, Becker and Beissinger (2003, p. 243) found that murrelets in California responded rapidly (within days or weeks) to small-scale variability in upwelling intensity and prey availability by shifting their foraging behavior and habitat selection within a 100-km (62-mile) area. In Washington, changes in water temperature, likely also related to prey availability, influence foraging habitat use, but the influence of upwelling is less clear (Lorenz et al. 2017, pp. 315, 318).

The duration of dives appears to depend upon age (adults vs. juveniles), water depth, visibility, and depth and availability of prey. Dive duration has been observed ranging from eight seconds to 115 seconds, although most dives are between 25 to 45 seconds (Day and Nigro 2000; Jodice and Collopy 1999; Thoresen 1989; Watanuki and Burger 1999). Diving bouts last over a period of 27 to 33 minutes (Nelson 1997, p. 9).

Historically, energy-rich fishes such as herring and northern anchovy comprised the majority of the murrelet diet (Becker and Beissinger 2006, p. 470; Gutowsky et al. 2009, p. 247). In the Puget Sound–Georgia Basin region, the diet of murrelet nestlings has shifted to include a larger proportion of Pacific sand lance than it did previously (Gutowsky et al. 2009, p. 251). This is significant because sand lance have the lowest energetic value of the fishes that murrelets commonly consume. For example, a single northern anchovy has nearly six times the energetic value of a sand lance of the same size (Gutowsky et al. 2009, p. 251), so a murrelet would have to eat six sand lance to get the equivalent energy of a single anchovy. Reductions in the abundance of energy-rich forage fish species is likely a contributing factor in the poor reproduction in murrelets (Becker and Beissinger 2006, p. 470).

For more information on murrelet use of marine habitats, see literature reviews in McShane et al. 2004, Service 2009, and Service 2019.

Murrelets in the Terrestrial Environment

Murrelets are dependent upon older-age forests, or forests with an older tree component, for nesting habitat (Hamer and Nelson 1995, p. 69). Specifically, murrelets prefer high and broad platforms for landing and take-off, and surfaces which will support a nest cup (Hamer and Nelson 1995, pp. 78-79). Within the listed range, murrelet nests have been found in live conifers, specifically, western hemlock (*Tsuga heterophylla*), Sitka spruce (*Picea sitchensis*), Douglas-fir (*Pseudotsuga menziesii*), western red cedar (*Thuja plicata*), and in California, coast redwood (*Sequoia sempervirens*) (Hamer and Nelson 1995, p. 74; Hamer and Meekins 1999). Most murrelets appear to nest within 37 miles of the coast, although occupied behaviors have been recorded up to 52 miles inland, and murrelet presence has been detected up to 70 miles inland in Washington (Huff et al. 2006, p. 10). At the southern end of the range, nesting occurs in a narrower band within around 15 miles of the coast (Halbert and Singer 2017, pp. 5-6). Nests occur primarily in large, older-aged trees. Overall, nests have been found in trees greater than 19 inches in diameter-at-breast and greater than 98 ft tall. Nesting platforms include limbs or other branch deformities that are greater than four inches in diameter, and are at greater than 33 ft above the ground. Substrates such as moss or needles on the nest platform are important for protecting the egg and preventing it from falling off (Huff et al. 2006, p. 13).

Murrelets do not form the dense colonies that are typical of most other seabird species. Limited evidence suggests they may form loose colonies in some cases (Ralph et al. 1995). The reliance of murrelets on cryptic coloration to avoid detection suggests they utilize a wide spacing of nests in order to prevent predators from forming a search image (Ralph et al. 1995). Individual murrelets are suspected to have fidelity to nest sites or nesting areas, although this has only been confirmed with marked birds in a few cases (Huff et al. 2006, p. 11). There are at least 15 records of murrelets using nest sites in the same or adjacent trees in successive years, but it is not clear if they were used by the same birds (McShane et al. 2004, p. 2-14). At the landscape scale, murrelets are probably faithful to specific watersheds for nesting (McShane et al. 2004, pp. 2-14). Murrelets have been observed visiting nesting habitat during non-breeding periods in Washington, Oregon, and California, which may indicate adults are maintaining fidelity and familiarity with nesting sites and/or stands (Naslund 1993; O'Donnell et al. 1995, p. 125).

Loss of nesting habitat reduces nest site availability and displaces any murrelets that may have had nesting fidelity to the logged area (Raphael et al. 2002, p. 232). Murrelets have demonstrated fidelity to nesting stands and, in some areas, fidelity to individual nest trees (Burger et al. 2009, p. 217). Murrelets returning to recently logged areas may not breed for several years or until they have found suitable nesting habitat elsewhere (Raphael et al. 2002, p. 232). The potential effects of displacement due to habitat loss include nest site abandonment, delayed breeding, failure to initiate breeding in subsequent years, and failed breeding due to increased predation risk at a marginal nesting location (Divoky and Horton 1995, p. 83; Raphael et al. 2002, p. 232). Each of these outcomes has the potential to reduce the nesting success for individual breeding pairs, and could ultimately result in the reduced recruitment of juvenile birds into the local population (Raphael et al. 2002, pp. 231-233).

Detailed information regarding the life history and conservation needs of the murrelet are presented in the *Ecology and Conservation of the Marbled Murrelet* (Ralph et al. 1995), the Service's 1997 *Recovery Plan for the Marbled Murrelet* (Service 1997), and in subsequent 5-year status reviews (McShane et al. 2004; Service 2009; Service 2019).

2. **Terrestrial Distribution**

Murrelets are distributed along the Pacific coast of North America, with birds breeding from central California through Oregon, Washington, British Columbia, southern Alaska, westward through the Aleutian Island chain, with presumed breeding as far north as Bristol Bay (Nelson 1997, p. 2), and non-breeding distribution extending as far south as the Southern California Bight (Hall et al. 2009, p. 5081). The federally-listed murrelet population in Washington, Oregon, and California is classified by the Service as a distinct population segment (75 FR 3424). The coterminous United States population of murrelets is considered significant as the loss of this distinct population segment would result in a significant gap in the range of the taxon and the loss of unique genetic characteristics that are significant to the taxon (75 FR 3430).

The inland nesting distribution of murrelets is strongly associated with the presence of mature and old-growth conifer forests. Murrelets have been detected farther than 100 km inland in Washington (70 miles). The inland distribution in the Siskiyou Mountains portion of the species range (southern Oregon and northern California) is associated with the extent of the hemlock/tanoak vegetation zone, which occurs up to 16-51 km inland (10-32 miles) (Evans Mack et al. 2003, pp. 3-4). At the southernmost extent of the range, murrelets are restricted to the western slopes of the Santa Cruz Mountains (Halbert and Singer 2017, pp. 5-6). Although murrelets are distributed throughout their historical range, the area of occupancy within their historic range appears to be reduced from historic levels. The distribution of the species also exhibits five areas of discontinuity: a segment of the border region between British Columbia, Canada and Washington; southern Puget Sound, WA; Destruction Island, WA to Tillamook Head, OR; Humboldt County, CA to Half Moon Bay, CA; and the entire southern end of the breeding range in the vicinity of Santa Cruz and Monterey Counties, CA (McShane et al. 2004, pp. 3-70).

Murrelets use inland habitats primarily for nesting, including egg laying, incubation, and feeding of nestlings. In addition, murrelets have been observed in nesting habitat demonstrating social behaviors, such as circling and vocalizing, in groups of up to ten birds (Nelson and Peck 1995, p. 51). Nest sites tend to be clustered spatially, indicating that although murrelets are not colonial seabirds, they also are not strictly solitary in their nesting behavior; in other words, at least in some circumstances, they nest semi-colonially (Conroy et al. 2002, p. 131; Naslund et al. 1995, p. 12). In California and southern Oregon, murrelets occupy habitat more frequently when there is another occupied habitat within five km (Meyer et al. 2002, p. 103), and we assume that the same is true in Washington. Usually, multiple nests can be found in a contiguous forested area, even in places where they are not strongly clustered (Evans Mack et al. 2003, p. 6). In previously unoccupied nesting habitat in Oregon, murrelets were much more likely to display behaviors associated with occupancy in places where recordings of murrelet calls had been broadcast the previous year, compared with control sites where no recordings were played (Valente et al. 2021, p. 7). This indicates that murrelets select nesting habitat in part based on the apparent presence of conspecifics.

Distribution of Nesting Habitat

The loss of nesting habitat was a major cause of the murrelet's decline over the past century and may still be contributing as nesting habitat continues to be lost to fires, logging, insects, tree diseases, and wind storms (Miller et al. 2012, p. 778; Raphael et al. 2016b, pp. 80-81). Among 21 million habitat capable lands in Washington, Oregon, and California, 1.49 million acres (~7 percent) were higher probability nesting habitat for the murrelet in 2017 (Lorenz et al. 2021, p. 48).

Monitoring of murrelet nesting habitat within the Northwest Forest Plan (NWFP) area indicates higher probability nesting habitat has decreased from an estimated 1.51 million acres in 1993 to an estimated 1.49 million acres in 2017, a total decrease of about 1.4 percent (Lorenz et al. 2021, p. 28). Timber harvest is the primary cause of nesting habitat loss on both Federal and non-Federal lands (Lorenz et al. 2021, p. 33). While most (71 percent) of the potential habitat is located on federal lands, a substantial amount of nesting habitat occurs on nonfederal (29 percent) (Table 1).

In Zone 6, monitoring of nesting habitat has not been carried out in the same way as within the NWFP area. Most of the existing nesting habitat within Zone 6 is located on state and local public lands, where logging has not occurred (Halbert and Singer 2017, p. 1). During August of 2020, over 60 percent of the nesting habitat in Zone 6 burned in a large wildfire (Singer 2021, in litt.). Preliminary data indicate that this fire has resulted in substantial habitat loss, though some lost habitat features may recover over the next several years. Many trees within the burned areas survived the fire, including the "Father of the Forest" redwood where murrelet nesting has been documented repeatedly (California Department of Parks and Recreation 2020, p. 2; Halbert and Singer 2017, p. 35); however, suitable platforms likely burned even in trees that survived the fire, leading to a loss of suitability for many years as branches regrow (Singer 2020, in litt.). In a sample of 40 previously-identified potential nest trees within Big Basin State Park, 22 trees (55 percent) appeared to have survived the fire (Singer 2021, in litt.). If this sample is representative, more than one quarter (i.e. 45 percent x 60 percent) of potential murrelet nest trees in Zone 6 may have been killed by the fire, with platform structures lost from a substantial percentage of the remaining trees. Future monitoring will be necessary to refine these estimates of habitat loss.

Table 1. Estimates of higher probability murrelet nesting habitat by State and major land ownership within the area of the NWFP – derived from 2017 data.

State	**Habitat capable lands** (1,000s of acres)	**Habitat on Federal reserved lands** (1,000s of acres)	**Habitat on Federal non-reserved lands** (1,000s of acres)	**Habitat on non-federal lands** (1,000s of acres)	**Total higher probability nesting habitat (all lands)** (1,000s of acres)	**Percent of habitat capable land that is currently in habitat**
WA	10,849.3	702.4	39.6	194.0	936.0	9 %
OR	6,609.5	273.8	38.3	205.7	517.8	8 %
CA	3,250.1	11.2	0.5	26.9	38.6	1 %
Totals	20,708.9	987.4	78.4	426.5	1,492.2	7 %
Percent		66 %	5 %	29 %	100 %	-

Source: (Lorenz et al. 2021, pp. 3, 28).

3. **Population Status**

<u>Conservation Zones</u>

The 1997 *Recovery Plan for the Marbled Murrelet* (Service 1997) identified six Conservation Zones throughout the listed range of the species: Puget Sound (Conservation Zone 1), Western Washington Coast Range (Conservation Zone 2), Oregon Coast Range (Conservation Zone 3), Siskiyou Coast Range (Conservation Zone 4), Mendocino (Conservation Zone 5), and Santa Cruz Mountains (Conservation Zone 6) (Figure 1). Conservation Zones are the functional equivalent of recovery units as defined by Service policy (Service 1997, p. 115).

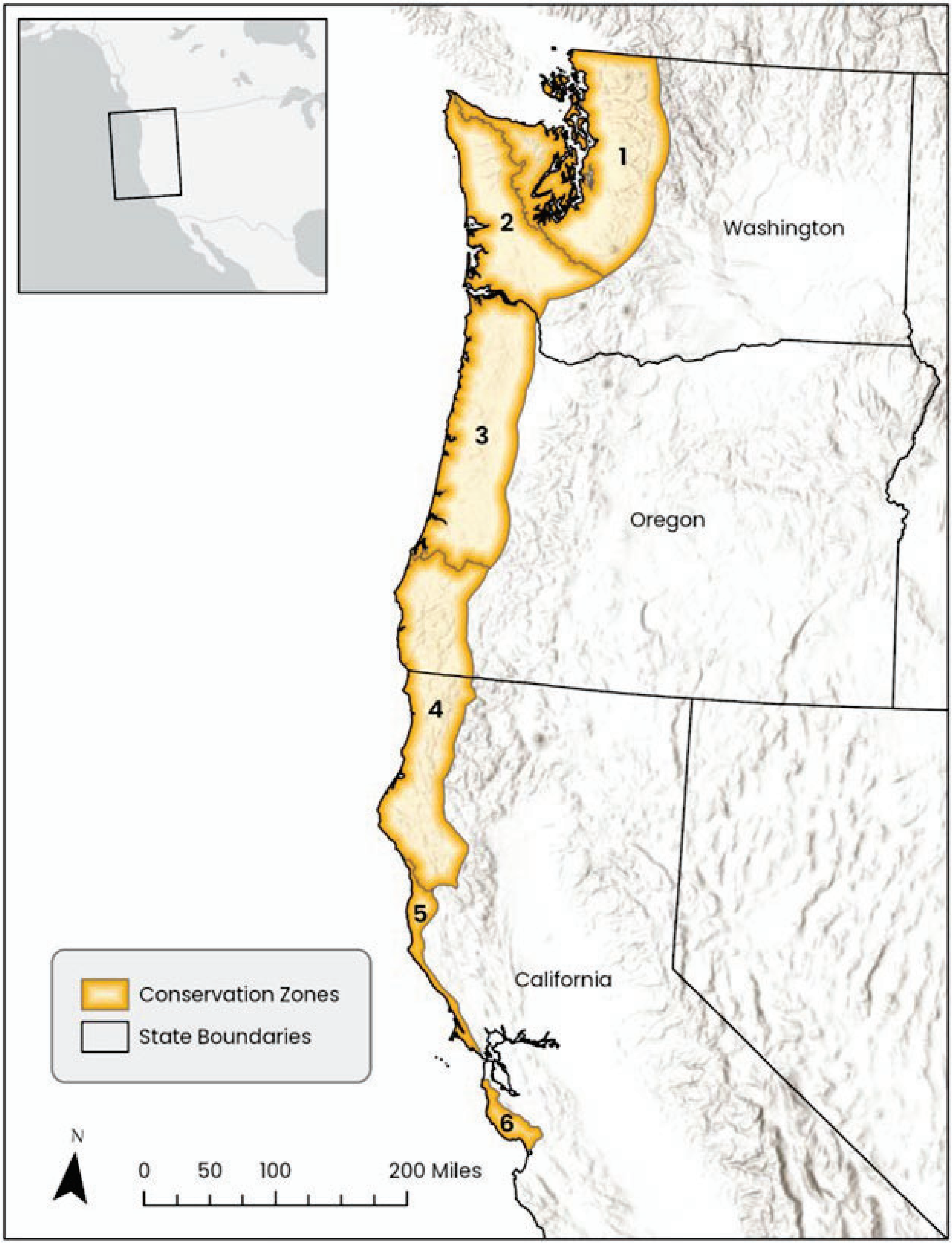

Figure 1. The six geographic areas identified as Conservation Zones in the recovery plan for the marbled murrelet (Service 1997).

The subpopulations within each Zone are not discrete. There is some movement of murrelets between Zones, as indicated by radio-telemetry studies (e.g., Bloxton and Raphael 2006, p. 162), but the degree to which murrelets migrate between Zones is unknown. Genetic studies also indicate that there is movement of murrelets between Zones, although Zone 6 is more isolated genetically than the other Zones (Friesen et al. 2005, pp. 611-612; Hall et al. 2009, p. 5080; Peery et al. 2008b, pp. 2757-2758; Peery et al. 2010, p. 703; Vásquez-Carrillo et al. 2014, pp. 251-252). For the purposes of consultation, the Service treats each of the Conservation Zones as separate sub-populations of the listed murrelet population.

Population Status and Trends

Population estimates for the murrelet are derived from marine surveys conducted during the nesting season as part of the NWFP effectiveness monitoring program. Surveys from 2001 to 2022 indicated that the murrelet population growth rate in Conservation Zones 1 through 5 (NWFP area) was 0% per year (McIver et al. 2024, p. 4) (Table 2), indicating that at the scale of the NWFP area, population size is not changing. At the state scale, Washington exhibited a significant declining trend between 2001 and 2022 (4.1 percent decrease per year, while Oregon and California showed significant positive trends (OR = 1.7 percent increase per year; CA = 3.6 percent increase per year) (McIver et al. 2024, p. 4) (Table 2). Zone 1 shows the greatest decline of 4.6 percent per year, while the decline in Zone 2 is smaller, 3.5 percent per year (Table 2). Zone 4 shows the greatest increase of 2.8 percent per year, while Zone 3 shows a smaller increase of 1.6 percent per year (McIver et al. 2024, p. 20) (Table 2). Although Zone 5 showed a positive trend of 1.5 percent per year, the evidence for a non-zero trend is inconclusive, given the wide confidence intervals that include zero (McIver et al. 2024, p. 20).

While the direct causes for population declines in Washington are unknown, potential factors include the loss of nesting habitat, including cumulative and time-lag effects of habitat losses over the past 20 years (an individual murrelets potential lifespan), changes in the marine environment reducing the availability or quality of prey, increased densities of nest predators, and emigration (Miller et al. 2012, p. 778). As with nesting habitat loss, marine habitat degradation is most prevalent in the Puget Sound area, where anthropogenic activities (e.g., shipping lanes, boat traffic, shoreline development) are an important factor influencing the marine distribution and abundance of murrelets in Conservation Zone 1 (Falxa and Raphael 2016, p. 110).

The most recent population estimate for the entire NWFP area in 2023 was 19,000 murrelets (95 percent confidence interval [CI]: 15,000 to 23,200 birds) (McIver et. al 2024, p. 4). The largest murrelet subpopulations now occur off the Oregon and northern California coasts, while subpopulations in Washington have experienced the greatest rates of decline.

The murrelet subpopulation in Conservation Zone 6 (central California- Santa Cruz Mountains) is outside of the NWFP area and is monitored separately by California State Parks and the U.S. Geological Survey using slightly different at-sea survey methods (Felis et al. 2022a, pp. 2-3). Surveys in Zone 6 indicate a small population of murrelets with no clear trends. Population estimates from 2001 to 2021 have fluctuated from a high of 585 murrelets in 2003, to a low of 163 murrelets in 2008 (Felis et al. 2022a p. 5). In 2022, surveys indicated an estimated population of 397 murrelets in Zone 6 (95 percent CI: 277-568), with no trends in abundance detected (Felis et al. 2022a, p. 3-4) (Table 2). Any effect of the major loss of nesting habitat in Zone 6 is not yet evident in the population estimate, although 2021 survey results were more variable than usual from one survey to the next (Felis et al. 2022b, p. 10).

Table 2. Summary of murrelet population estimates and trends (2001-2021/2022) at the scale of Conservation Zones and states. Asterisk (*) indicates statistically significant annual rate of change (P-value ≤ 0.05).

Zone	Year	Estimated number of murrelets	95% CI Lower	95% CI Upper	Average density (at sea) (murrelets /km^2)	Average annual rate of population change (%)	95% CI Lower	95% CI Upper
1	2022	3,797	2,781	4,829	1.086	-4.6*	-6.4	-2.7
2	2023	1,088	651	1,401	0.659	-3.5*	-5.8	+1.0
3	2022	8,249	5,405	11,901	5.170	+1.6*	+0.3	+2.9
4	2023	6,411	4,472	9,367	6,752	+2.8*	+1.3	+4.4
5	2021	42	0	79	0.473	+1.5	-7.7	+11.7
Zones 1-5	2022	19,033	14,877	23,190	2.193	-0.8	-0.8	0.8
Zone 6	2022	397	277	568	na	na	na	na
WA	2022	4,850	3,732	5,968	0.94	-4.1*	-5.2	-3.0
OR	2022	9,603	6,339	12,868	4.64	+1.7*	+0.8	+2.7
CA Zones 4 & 5	2023	5,047	3,492	6,602	3.72	+3.6*	+2.2	+5.1

Sources: (McIver et al. 2024, pp. 17-20, Felis et al. 2022a, p. 5).

Factors Influencing Population Trends

Population monitoring data show murrelet populations declining in Washington, but increasing in Oregon and northern California (McIver et al. 2024, p. 4). Murrelet population size and distribution is strongly and positively correlated with the amount and pattern (large contiguous patches) of suitable nesting habitat, and population trend is most strongly correlated with trend in nesting habitat, although marine factors also contribute to this trend (Raphael et al. 2016a, p. 115). From 1993 to 2017, there was a net gain of about 2.9 percent of higher probability potential nesting habitat on federal lands, compared to a net loss of about 10.7 percent on nonfederal lands, for a total cumulative loss of about 7.8 percent of higher probability habitat across the NWFP area (Lorenz et al. 2021, p. 28). Cumulative habitat losses since 1993 have been greatest in Washington, with most habitat loss in Washington occurring on non-Federal lands due to timber harvest (Lorenz et al. 2021, p. 31) (Table 3).

Table 3. Distribution of higher probability murrelet nesting habitat by Conservation Zone, and summary of net habitat changes from 1993 to 2017 within the NWFP area.

Conservation Zone	**1993**	**2017**	**Change (acres)**	**Change (percent)**
Zone 1 - Puget Sound/Strait of Juan de Fuca	512,645	476,793	-35,852	-7.0 %
Zone 2 - Washington Coast	487,372	459,186	-28,186	-5.8 %
Zone 3 - Northern to central Oregon	439,852	474,561	+34,709	+7.9 %
Zone 4 - Southern Oregon - northern California	71,100	79,611	+8,511	+12.0 %
Zone 5 - North-central California	2,107	2,077	-30	-1.5 %

Source: (Lorenz et al. 2021, pp. 39, 41).

The decline in murrelet populations from 2001 to 2013 is weakly correlated with the decline in nesting habitat, with the greatest declines in Washington, and the smallest declines in California, indicating that when nesting habitat decreases, murrelet abundance in adjacent marine waters may also decrease. At the scale of Conservation Zones, the strongest correlation between habitat loss and murrelet decline is in Zone 2, where murrelet habitat has declined most steeply, and murrelet populations have also continued to decline. However, these relationships are not linear, and there is much unexplained variation (Raphael et al. 2016a, p. 110). While terrestrial habitat amount and configuration (i.e., fragmentation) and the terrestrial human footprint (i.e., cities, roads, development) appear to be strong factors influencing murrelet distribution in Zones 2-5; terrestrial habitat and the marine human footprint (i.e., shipping lanes, boat traffic, shoreline development) appear to be the most important factors that influence the marine distribution and abundance of murrelets in Zone 1 (Raphael et al. 2016a, p. 106).

Like other marine birds, murrelets depend for their survival on their ability to successfully forage in the marine environment. Despite this, it is apparent that the location, amount, and landscape pattern of terrestrial nesting habitat are strongest predictors of the spatial and temporal distributions of murrelets at sea during the nesting season (Raphael et al. 2015, p. 20). Outside of Zone 1, various marine habitat features (e.g., shoreline type, depth, temperature, human footprint, etc.) apparently have only a minor influence on murrelet distribution at sea. Despite this relatively weak spatial relationship, marine factors, and especially any decrease in forage species, likely play an important role in explaining the apparent population declines, but the ability to detect or model these relationships is currently limited (Raphael et al. 2015, p. 20). Over both the long and short term, there is evidence that diet quality is related to marbled murrelet abundance, the likelihood of nesting attempts, and reproductive success (Becker et al. 2007, p. 276; Betts et al. 2020, pp. 6-7; Norris et al. 2007, p. 881).

The interplay between marine and terrestrial habitat conditions also influences murrelet population dynamics. A recent analysis indicates that in Oregon, over a 20-year period, nesting activity was most likely to occur following years with cool ocean temperatures (indicating good forage availability), and at sites where large blocks of mature forest were close to the coast (Betts et al. 2020, pp. 5-9). Even when ocean conditions were poor, nesting murrelets colonized new sites that were surrounded by abundant old forest, but during good ocean conditions, even sites with less old forest could be colonized (Betts et al. 2020, p. 6). This relationship has not been investigated in other parts of the range, but is consistent with observations in Washington, where murrelets occupy nesting habitat at lower rates, often fly long distances to reach foraging areas, breed at very low observed rates, and the population continues to decline (Lorenz et al. 2017, pp. 312-313, 318; McIver et al. 2022, p. 20).

<u>Reproduction</u>

Overall fecundity is a product of the proportion of murrelets that attempt nesting and the proportion of nest attempts that succeed. Telemetry studies can be used to estimate both the proportion of murrelets attempting nesting, and the proportion of nest attempts that succeed. When telemetry estimates are not available, at-sea surveys that separately count the number of hatch-year and after-hatch-year birds can be used to estimate productivity. Telemetry estimates are typically preferred over marine counts for estimating breeding success due to fewer biases (McShane et al. 2004, p. 3-2). However, because of the challenges of conducting telemetry studies, estimating murrelet reproductive rates with an index of reproduction, referred to as the juvenile ratio (**Ŕ**),1 continues to be important, despite some debate over use of this index (see discussion in Beissinger and Peery 2007, p. 296).

Although current estimates of productivity are not available at a range-wide scale, various studies of limited geographic scope have been undertaken over the past two decades. Without exception, these studies indicate low reproductive capacity within the listed range.

Murrelet fecundity is likely limited in part by low rates of nesting attempts in some parts of the range. Radio-telemetry monitoring Washington between 2004 and 2008 indicated only a small proportion of 158 tagged adult birds actually attempted to nest (13 to 20 percent) (Lorenz et al. 2017, p. 316). A recent study in Oregon reported a similar result: 33 of 239 tagged birds (13.8 percent) attempted nesting (Woodis et al. 2022, p. 121). Studies from California also report low rates, though higher than those reported in Washington and Oregon. Two studies from central and northern California reported that an average of around 30 percent of radio-tagged murrelets attempted to nest (Hébert and Golightly 2006, p. 130; Peery et al. 2004, p. 1093). These low rates of nesting are not intrinsic to the species; other studies outside of the listed range reported that between 46 and 80 percent of murrelets attempted to breed each year (Barbaree et al. 2014, p. 177; Bradley et al. 2004, p. 323), and most population modeling studies suggest a range of 80 to 95 percent of adults breed each year (McShane et al. 2004, p. 3-5). The process of radio-tagging or the additional weight and drag of the radio tag itself may reduce the probability that a

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1 The juvenile ratio (**Ŕ**) for murrelets is derived from the relative abundance of hatch-year (HY; 0-1 yrs.-old) to after-hatch-year (AHY; 1+ yrs.-old) birds (Beissinger and Peery 2007, p. 297) and is calculated from marine survey data. All ratios presented here are date-corrected using the methods of Peery et al. (2007, p. 234) to account adults incubating and chicks not yet fledged at the time of the survey.

tagged individual will attempt to breed, but studies reporting higher rates of attempted nesting used similar radio tags, so radio-telemetry methods do not fully account for differences between the studies conducted in the listed range and those conducted elsewhere (Peery et al. 2004, p. 1094).

Although difficult to obtain, nest success rates[2] are available from telemetry studies conducted in California (Hébert and Golightly 2006; Peery et al. 2004, p. 1094), Washington (Lorenz et al. 2017, p. 312; Lorenz et al. 2019, p. 160), and Oregon (Woodis et al. 2022, p. 121). In northwestern Washington, Lorenz, and others (2017, p. 312; 2019, pp. 159-160) documented a nest success rate of 0.20 (3 chicks fledging from 15 nest starts). In central California, murrelet nest success is 0.16 (Peery et al. 2004, p. 1098) and in northern California it ranges from 0.069 to 0.243 (Hébert and Golightly 2006, p. 129). In Oregon, out of 33 nesting attempts, chicks successfully fledged from 10 nests, a rate of 0.33 (Woodis et al. 2022, p. 121).

At least one telemetry study reported overall fecundity rates, combining both the rates of nesting attempts with the rates of fledging success. In central California, the fecundity rate was estimated to be 0.027, or 2.7 female chicks produced per year for every 100 females of breeding age (Peery et al. 2004, p. 1094). In other studies, the overall fecundity rate is not known, because it is not clear how many of the radio-tagged birds were of breeding age. However, in northern California, of 102 radio-tagged birds, at least two and at most six successfully produced fledglings (Hébert and Golightly 2006, pp. 130-131); in Oregon, of 239 tagged birds, ten produced fledglings; and in Washington and southern Vancouver Island, of 157 radio-tagged birds, four produced fledglings (Lorenz et al. 2017, p. 312). If we assume (as in Peery et al. 2004, p. 1094) that 93 percent of captured birds in each sample were of breeding age, and that half of all captured birds and half of all fledged chicks were female, fecundity rates from these samples would be 0.027 in Washington, 0.045 in Oregon, and between 0.021 and 0.063 in northern California.

Unadjusted and adjusted values for estimates of murrelet juvenile ratios also suggest low reproductive rates. In northern California and Oregon, annual estimates for **Ŕ** range from 0 to 0.179, depending on the year and area surveyed (Strong 2018, p. 7; Strong 2020, p. 21; Strong 2021, p. 17). In Conservation Zone 4, the annual average between 2000 and 2011 was 0.046 (Strong and Falxa 2012, p. 11). In central California, estimates of **Ŕ** range from 0 to 0.12, with an annual average of 0.052, over 20 years of survey between 1996 and 2021 (Felis et al. 2022b, p. 9). An independent calculation of **Ŕ** among murrelets captured in central California between 1999 and 2003 resulted in estimates ranging from 0 to 0.111, with an average of 0.037 (Peery et al. 2007, p. 235). Estimates of **Ŕ** for Oregon and California may be unreliable, because at-sea observations are not made in the optimal time period for observing recently-hatched juveniles. Estimates for **Ŕ** in the San Juan Islands in Washington, which include observations better timed to observe juveniles, tend to be higher, ranging from 0.02 to 0.12, with an average of 0.067, over 18 years of survey between 1995 and 2012 (Lorenz and Raphael 2018, pp. 206, 211). Notably, **Ŕ** in the San Juan Islands did not show any temporal trend over the 18-year period, even while the abundance of adult and subadult murrelets declined (Lorenz and Raphael 2018, pp. 210-211).

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2 Nest success here is defined by the annual number of known hatchlings departing from the nest (fledging) divided by the number of nest starts.

Although these estimates of **Ŕ** are higher than one would expect based on fecundity rates derived from radio-telemetry studies, they are below the level thought to be necessary to maintain or increase the murrelet population. Demographic modeling, historical records, and comparisons with similar species all suggest that murrelet population stability requires juvenile ratios between 0.176 and 0.3 (Beissinger and Peery 2007, p. 302; Service 1997, p. B-13). Even the lower end of this range is higher than any current estimate for **Ŕ** for any of the Conservation Zones. This indicates that the murrelet reproductive rate is likely insufficient to maintain stable population numbers throughout all or portions of the species' listed range. These sustained low reproductive rates appear to be at odds with the potentially stable population size measured for Zones 1 through 5, and are especially confusing in light of apparent population increases in Oregon and California.

Integration and Summary: Murrelet Abundance, Distribution, Trend, and Reproduction

At the scale of the NWFP area, murrelet population size is not changing in a detectable way (McIver et al. 2024, pp. 4, 20). However, at the state and conservation zone scales, trends in abundance are variable, with a statistically significant decline detected in Washington for the 2001-2022 period (Table 2) while Oregon and California show a statistically meaningful increase (McIver et al. 2024, p. 4). At the conservation zone scale, the murrelet population declined in Conservation Zones 1 and 2, increased in Zones 3 and 4, and showed no significant trend in Conservation Zone 5 (Table 2). Outside of the NWFP area, in Conservation Zone 6, no trends in abundance were detected for the 1999–2022-time frame (Felis et al. 2022a, p. 3-4)

Regardless of the methodology used to obtain estimates of productivity, all estimates are well below the level thought to be necessary to maintain population size. Demographic modeling, historical records, and comparisons with similar species all suggest that murrelet population stability requires fecundity to be between 0.20 and 0.46 or juvenile ratios to between 0.15 and 0.3 at the end of the breeding season (Beissinger 1995, p. 390; Beissinger and Peery 2007, p. 302; Service 1997, p. B-13). Even the lower end of these ranges is higher than any current estimate of productivity for any of the conservation zones. This indicates that the murrelet reproductive rate is likely insufficient to maintain stable population numbers throughout all the species' listed range. These sustained low reproductive rates are at odds with the apparently stable population size measured for Conservation Zones 1 through 5.

A number of factors could contribute to the discrepancy between low reproductive rates and population increases in some parts of the range. For example, population increases could be caused by an influx of murrelets moving from the Canadian population into Oregon and California, or into Washington and displacing Washington birds to Oregon and California. The possibility of a population shift from Washington to Canada has previously been dismissed, based on nest-site fidelity and the fact that both Washington and British Columbia populations are declining simultaneously (Falxa et al. 2016, p. 30), but these arguments do not rule out the possibility that non-breeding murrelets originating in Canada may be spending time foraging in Oregon or California waters.

Another possibility is the proportion of birds present on the water during surveys, rather than inland at nest sites, may be increasing. If so, this would artificially inflate population estimates.

Such a shift could be driven by low nesting rates, as were observed in Oregon in 2017 (Adrean et al. 2018, p. 2; Horton et al. 2017, p. 77), by shifts toward earlier breeding, for which there is anecdotal evidence (for example, Havron 2012, p. 4; Pearson 2018, in litt.; Strong 2019, p. 6; Strong 2022, p. 2), or a combination of both factors. In either case, individuals that would in earlier years have been incubating an egg or flying inland to feed young, and therefore unavailable to be counted, would now be present at sea and would be observed during surveys. For the same number of birds in the population, the population estimate would increase as adults spend more of the survey period at sea.

Finally, the shift that occurred in 2015 to sampling only half of the Conservation Zones in each survey year (McIver et al. 2022, p. 6) resulted in increased uncertainty associated with interpretation of survey results, especially in light of large-scale movements that can occur during the breeding season, sometimes involving numerous individuals (Horton et al. 2018, p. 77; Peery et al. 2008a, p. 116). Murrelets that move into or out of the zone being sampled during the breeding season could artificially inflate or deflate the population estimates. Even interannual movements among the Zones could temporarily resemble population growth, without an actual increase in the number of birds in the population (McIver et al. 2021 pp. 28, 30).

Some of these factors would also affect measures of fecundity and juvenile ratios. For example, if murrelets are breeding earlier on average, then the date adjustments applied to juvenile ratios may be incorrect, possibly resulting in inflated estimates of **Ŕ**. If current estimates of **Ŕ** are biased high, this would mean that the true estimates of **Ŕ** are even lower, exacerbating, rather than explaining, the discrepancy between the apparently sustained low reproductive rates and the apparently stable or increasing subpopulations south of Washington. A shift toward later breeding could result in more adults being present at sea during surveys, and would also result in artificially low estimates of **Ŕ**. We are not aware of evidence for a widespread shift toward later breeding, but this kind of alteration in seasonal behavior may be more difficult to detect than a shift to earlier breeding. Early-fledging juveniles are conspicuous when observed at sea, whereas late-fledging juveniles are not.

Considering the best available data on abundance, distribution, population trend, and the low reproductive success of the species, the Service concludes the murrelet population within the Washington portion of its listed range currently has little or no capability to self-regulate, as indicated by the significant, annual decline in abundance the species is currently undergoing in Conservation Zones 1 and 2. Populations in Oregon and California are apparently more stable, but reproductive rates remain low in those areas, and threats associated with habitat loss and fragmentation continue to occur. The Service expects the species to continue to exhibit further reductions in distribution and abundance, due largely to the expectation that the variety of environmental stressors present in the marine and terrestrial environments (discussed in the *Threats to Murrelet Survival and Recovery* section) will continue into the foreseeable future.

4. **Threats to Murrelet Survival and Recovery**

When the murrelet was listed under the Endangered Species Act in 1992, several anthropogenic threats were identified as having caused the dramatic decline in the species:

- habitat destruction and modification in the terrestrial environment from timber harvest and human development caused a severe reduction in the amount of nesting habitat
- unnaturally high levels of predation resulting from forest "edge effects;"
- the existing regulatory mechanisms, such as land management plans (in 1992), were considered inadequate to ensure protection of the remaining nesting habitat and reestablishment of future nesting habitat; and
- manmade factors such as mortality from oil spills and entanglement in fishing nets used in gill-net fisheries.

The regulatory mechanisms implemented since 1992 that affect land management in Washington, Oregon, and California (for example, the NWFP) and new gill-netting regulations in northern California and Washington have reduced the threats to murrelets (Service 2004, pp. 11-12). However, additional threats were identified, and more information was compiled regarding existing threats, in the Service's 5-year reviews (Service 2009, pp. 27-67; Service 2019, pp. 19-65) and Species Biological Report for Marbled Murrelet (Service 2024, pp. 15-46). These stressors include:

- Habitat destruction and modification in the terrestrial environment from natural and human-caused wildfire
- Habitat destruction, modification, or curtailment of the marine environmental conditions necessary to support murrelets due to:
  - climate change in the Pacific Northwest.
  - elevated levels of toxic contaminants, including polychlorinated biphenyls, polybrominated diphenyl ether, polycyclic aromatic hydrocarbons, and organochlorine pesticides, in murrelet prey species;
  - the presence of microplastics in murrelet prey species;
  - changes in prey abundance and availability;
  - changes in prey quality;
  - harmful algal blooms that produce biotoxins leading to domoic acid and paralytic shellfish poisoning that have caused murrelet mortality;
  - harmful algal blooms that produce a proteinaceous foam that has fouled the feathers of other alcid species, and affected areas of murrelet marine habitat; and
  - hypoxic or anoxic events in murrelet marine habitat;

- Manmade factors that affect the continued existence of the species include:
  - disturbance in the marine environment (from exposures to lethal and sub-lethal levels of high underwater sound pressures caused by pile-driving, underwater detonations, and potential disturbance from high vessel traffic);
  - derelict fishing gear leading to mortality from entanglement; and
  - wind energy generation, currently limited to onshore projects, leading to mortality from collisions.

Since the time of listing, some murrelet subpopulations have continued to decline due to lack of successful reproduction and recruitment, and while other subpopulations appear to be stable or increasing, productivity in these populations remains lower than the levels likely to support sustained population stability. The murrelet Recovery Implementation Team identified five major mechanisms that appear to be contributing to poor demographic performance (Service 2012b, pp. 10-11):

- Ongoing and historic loss of nesting habitat.
- Predation on murrelet eggs and chicks in their nests.
- Changes in marine conditions, affecting the abundance, distribution, and quality of murrelet prey species.
- Post-fledging mortality (predation, gill-nets, oil spills).
- Cumulative and interactive effects of factors on individuals and populations.

Climate Change

Climate change is a multi-dimensional threat that impacts both the terrestrial and marine environments occupied by murrelets. Within the listed range of the murrelet, observed and projected changes in climate include increases in air and sea surface temperature, precipitation seasonality changes, increases in frequency and intensity of extreme rainfall events, and increasing amounts of carbon dioxide released into the atmosphere (Mote and Salathé 2010, p. 29; Salathé et al. 2010, pp. 72-73; Mauger et al. 2015, pp. 2:1-18). These stressors changes the structure and availability of nesting habitat; alter prey availability, abundance, and quality; and potentially increase exposure to disease agents. Terrestrial habitats are affected by climate change mainly via changes in forest disturbances such as drought mortality, wildfire, insects, and tree diseases. Marine habitats are affected by climate change primarily via changes in temperature, precipitation, water circulation, oxygen content, acidity, and nutrient availability, all of which directly or indirectly impact the quantity and quality of prey species for the murrelet.

Climate change in the terrestrial environment

In the terrestrial habitat, atmospheric changes associated with climate change impact the frequency and intensity of forest disturbances like drought, fires, and insects. These disturbances can result in elevated levels of habitat loss and modification that ultimately affect murrelet nesting success.

Atmospheric changes in temperature and precipitation. Temperature and precipitation constitute the primary atmospheric variables affected by climate change. The Pacific Northwest has already experienced widespread trends in seasonal warming between 1920 and 2012 (Abatzoglou et al. 2014, pp. 2128-2133) as well as increasing trends in extreme heat events in June and July (Oswald and Rood 2014, pp. 572-575, 577). Warming air temperatures are expected to continue, with the mid-21st century projected to be approximately 2.2 to 3.3 degrees Celsius (°C) (4 to 6 degrees Fahrenheit (°F)) warmer than the late 20th century (Mauger et al. 2015, p. 2-5; USGCRP 2017, pp. 196-197). Between 1920 and 2012, winter precipitation appears to have increased (Abatzoglou et al. 2014, p. 2,132), but increases in winter temperatures have resulted in substantial losses of snowpack (Salathé et al. 2010, p. 16) and subsequent water deficits in the summer (Abatzoglou et al. 2014, p. 2,134). Winter precipitation is expected to continue to increase while summer precipitation decreases (Mote and Salathé 2010, pp. 42-44; Mauger et al. 2015, p. 2-7; USGCRP 2017, p. 217), and heavy rainfall events are projected to occur more frequently and intensely in the late 21st century (Warner et al. 2015, pp. 123-124).

Forest disturbances. Forested habitats in the Pacific Northwest are affected by climate change mainly via changes in disturbances, including drought mortality, wildfire, insects, and tree diseases. Nesting habitat for murrelets is impacted not only by habitat loss from these disturbances, but also modification of habitat features and ecotype change.

Historically, forests in the listed range of the murrelet have not typically been water limited, especially in Washington and northern Oregon (McKenzie et al. 2001, p. 531; Nemani et al. 2003, p. 1560; Littell et al. 2010, p. 139). However, in recent decades the number of wet summer days has decreased, the rain-free period has become longer in much of the murrelet's listed range (Holden et al. 2018, p. 4), and every part of the listed range has been affected by multi-year drought at some point from 1918 to 2014 (Crockett and Westerling 2018, p. 345). In western Washington, Oregon, and southwestern British Columbia, tree mortality more than doubled from 1975 to 2005, likely due to increasing water stress (van Mantgem et al. 2009, pp. 522-523), which may be caused by warm dry conditions in and of themselves, or when dry conditions compound the effects of insects, tree disease, and fire. Increased summer warming, decreased spring snowpack, and decreased summer precipitation are projected to result in water deficits that will increase demand on smaller amounts of soil water in the forest during the growing season (McKenzie and Littell 2017, pp. 33-34).

Additionally, extreme climate conditions are likely to further increase drought stress and tree mortality, especially since trees in the moist forests of Washington and northern Oregon are unlikely to be well-adapted to drought stress (Allen et al. 2010, p. 669; Anderegg et al. 2013, p. 705; Allen et al. 2015, pp. 19-21; Prestemon and Kruger 2016, p. 262; Vose et al. 2016, p. 10; Crockett and Westerling 2018, p. 342). Coastal redwood forests in northwestern and central California, on the other hand, are more resistant to drought effects (Brodrick et al. 2019, pp. 2757-2758). Water deficits in 21st century forests will not be uniform, with the California and southern Oregon Coast Ranges, Klamath region, eastern Olympic Peninsula, and parts of the Cascades and northern Oregon Coast Range projected to experience greater hydrological drought, while some portions of the Washington Cascades and Olympic Mountains projected to experience reductions in water deficit (McKenzie and Littell 2017, p. 31). In Washington and most of Oregon, spring droughts are projected to decrease in frequency, while spring droughts in most of California are projected to increase in frequency (Martinuzzi et al. 2019, p. 6).

Increased drought conditions are associated with increased annual fire extent, and changes in the intensity and frequency of wildfire are in no small part related to climatic changes (Reilly et al. 2017, pp. 9-10). Historical fire regimes have varied throughout the range of the murrelet. In many of the moist forests of western Washington and Oregon, the fire regime has historically been typified by large, stand-replacing fires occurring at intervals of 200 years or more (Halofsky et al. 2018a, pp. 3-4; Haugo et al. 2019, pp. 2-3; Long et al. 1998, p. 784). Parts of the murrelet range in southern Oregon and California have historically had low- and mixed-severity fires occurring every 35 years or less (Haugo et al. 2019, pp. 2-3; Perry et al. 2011, p. 707). Still other areas throughout the range historically had mixed severity fires occurring between 35 and 200 years apart (Haugo et al. 2019, pp. 2-3; Perry et al. 2011, p. 707). Within each type of historical fire regime, fire has occurred less frequently during the recent decades usually used for statistical analyses of fire behavior or projections of future fire than it did historically (Huago et al. 2019, pp. 8-9; Littell et al. 2010, p. 150).

Between 1993 and 2012, monitoring based on a database of large (1,000 acres or greater) fire perimeters detected losses associated with wildfires of 22,063 acres of Maxent-modeled high-quality murrelet nesting habitat on federal and non-federal lands in the NWFP area (Raphael et al. 2016b, pp. 80-81). Fire was the leading natural cause of habitat loss within the NWFP area, but this ranking was driven by the 20,235-acre loss to fire on federal lands in the Klamath Mountains, and fire was far less important elsewhere in the range. South of the NWFP area, extreme heat and unusual lightning activity contributed to the 2020 fires that burned through much of the remaining murrelet habitat in central California, and these conditions were likely exacerbated by climate change (Goss et al. 2020, p. 11; Higuera and Abatzoglou 2021, entire; Romps et al. 2014, p. 853).

Under all climate change scenarios, wildfires in the listed range of the murrelet are projected to increase in size, frequency, and severity in the future, reducing the extent and connectivity of late-seral and old growth forests (McKenzie et al. 2004, pp. 897-898; Rogers et al. 2011, pp. 6, 9; Littell et al. 2013, p. 132; Sheehan et al. 2015, p. 20). However, there is great uncertainty about the magnitude of these changes, which are likely to affect some areas more than others (Rogers et al. 2011, p. 6; Sheehan et al. 2015, p. 25; Davis et al. 2017, pp. 179-182). On forested lands in the Cascades, Coast Ranges, and Klamath Mountains ecoregions of Washington and Oregon, the percentage of forested area highly suitable for large fires is projected to increase, and the percentage of forested lands with low suitability for large fires is expected to decrease, with the greatest change in the Klamath Mountains ecoregion (Davis et al. 2017, pp. 179-181). By mid-century, the annual number of days with high wildfire potential is expected to nearly double throughout the listed range (Martinuzzi et al. 2019, pp. 3, 6). Two recent studies, modeling future fires based on projected climate and vegetation characteristics, projected a 1.5- to five-fold increase in forest fires in western Washington between the historical period and the 21st century (Halofsky et al. 2018b, p. 10), and a two- to four-fold increase in western Washington and Oregon between the late 20th century and mid-21st century (Sheehan et al. 2019, p. 14).
There is also an interactive effect between climate change and the prevalence of insects and diseases. Higher average temperatures and warmer winters likely increase the severity and

distribution of insects and diseases like bark beetles and Swiss needle cast, which can result in tree mortality and changes in canopy cover (Littell et al. 2010, p. 146; Shaw et al. 2021, p. 417).

The effect of climate change on blowdown frequency, extent, and severity is unknown, and there are reasons to believe that blowdowns may become either more or less frequent or extensive. However, the projected increase in the intensity and frequency of heavy rainfall events may foretell an increase in the intensity and frequency of blowdown events, which are often associated with atmospheric rivers.

The magnitude of future increases in forest disturbances such as drought, wildfire, insect damage, and disease is uncertain, but synergistic effects between these disturbances are likely to occur to some extent. While marked effects of climate-related forest disturbances are already occurring in drier forests, the moist forests within the range of murrelets are now experiencing mainly smaller-scale effects and are likely to experience habitat loss as a result of these forest disturbances later in time (Buotte et al. 2018, p. 8).

Climate change may also alter habitat features such as canopy closure or epiphyte cover on tree branches (Aubrey et al. 2013, p. 743). Forest edge environments can experience higher temperatures and solar radiation, lower humidity, stronger winds, and a more variable microclimate compared to interior forest (van Rooyen et al. 2011, p. 549). Epiphytes such as mosses, whose presence on tree platforms is crucial to murrelet nesting in the northern portions of the range, demonstrate reduced growth rates in edge habitat due to microclimate edge effects (van Rooyen et al. 2011, p. 549). As edge habitat has increased throughout the range of the murrelet, epiphyte cover is assumed to have decreased, and future changes in epiphyte cover from climate change will be additive or synergistic to changes resulting from the creation of forest edges through timber harvest (van Rooyen et al. 2011, pp. 555-556).

Following stand-replacing disturbances, climate conditions may not allow recruitment of the tree species that are currently present, leading to ecotype change; however, the effect of this kind of ecotype change may not directly affect murrelet habitat availability until many decades in the future. In western Washington and Oregon, vegetation is predicted to change from predominantly maritime to temperate conifer forests (Rogers et al. 2011, p. 7), then to cooler and then warmer subtropical mixed forests during the 21st century (Halofsky et al. 2011, p. 73; Rogers et al. 2011, p. 7; Sheehan et al. 2015, p. 22), beginning in the south and expanding northwards along the coast (Sheehan et al. 2015, p. 22). Higher elevation species, such as mountain hemlock (*Tsuga mertensiana*) and firs, are likely to experience a much greater reduction in distribution than lower elevation species like Sitka spruce, western red cedar, and western hemlock (Albright and Peterson 2013, p. 2129; DellaSala et al. 2018, p. 237) with significant losses of subalpine forests (Rogers et al. 2011, p. 6). By 2060, climate is projected to become unfavorable for Douglas fir in over 32 percent of its current range in Washington, focused mostly at lower elevations like south Puget Sound and the southern Olympic Mountains (Littell et al. 2010, p. 139). The California coast redwood ecotype is expected to see a three percent growth in distribution by 2050 but is expected to lose this growth by 2080 when coast redwood forests are expected to experience reduction of nearly one-fourth of their modeled climate envelope (DellaSala et al. 2018, p. 237). In the Santa Cruz Mountains of Conservation Zone 6, coast redwoods are modeled to potentially persist only on north-and northeast-facing slopes, leaving less than 10 percent of the coast redwoods within the middle 80 percent of the modeled suitable habitat (Flint and Flint 2012, pp. 37, 41-42).

Impact of forest disturbances on individuals and populations. The loss and modification of nesting habitat from climate-related forest disturbances reduces site availability and displaces murrelets with site fidelity, and can have several impacts on murrelets, including nest site abandonment, delayed breeding, failure to initiate breeding in subsequent years, and failed breeding due to increased predation risk at a marginal nesting location (Divoky and Horton 1995, p. 83; Raphael et al. 2002, p. 232). Each of these outcomes has the potential to reduce the nesting success for individual breeding pairs, which could ultimately result in the reduced recruitment of juvenile birds into the local population (Raphael et al. 2002, pp. 231-233).

Climate change in the marine environment

Physical changes in ocean condition resulting from climate change ultimately lead to altered forage conditions (i.e., prey availability, abundance, and quality) for murrelets, which can negatively impact reproductive success, fitness, and survival. These demographic indicators are further impacted by the increased exposure and vulnerability of murrelets to harmful algal blooms (HABs) and other diseases.

Physical changes in ocean condition. The primary changes to ocean conditions resulting from climate change include increasing sea surface temperatures; increasing frequency, severity, and duration of marine heatwaves; increasing ocean acidification; rising sea levels; and changes in primary productivity.

Along with air temperatures, sea surface temperatures are also expected to continue increasing, with projections between 1.2 °C (2.2 °F) and 3 °C (5.4 °F) for Puget Sound, the Strait of Georgia, and the Pacific Coast between the late 20th century and mid- or late-21st century (Mote and Salathé 2010, p. 16; Riche et al. 2014, p. 41; USGCRP 2017, p. 368). Temperature changes, precipitation changes, and the release of carbon dioxide into the atmosphere affect water circulation, oxygen content, acidity, and nutrient availability. These changes, in turn, affect organisms throughout the marine food web. For top predators like the murrelet, prey abundance, quality, and availability are all likely to be affected by climate change. Climate change is also likely to increase the murrelet’s level of exposure to toxic chemicals and potentially to disease agents.

Marine warming involves not only a gradual increase in average temperatures, but also extreme marine heatwaves, which have dramatic effects on marine ecosystems. Currently, a marine heatwave that formed in mid-May 2023 off the Canadian and U.S. west coasts, in which temperatures reach 5 °C above normal in some places, continues to increase in size (Leising et al. 2023, unpaginated). Warm water anomalies from the Gulf of Alaska to Baja California from 2013 to 2015 (Bond et al. 2015, p. 3414; Leising et al. 2015, pp. 36, 38, 61; NMFS 2016, p. 5) compressed the zone of cold upwelled waters to the nearshore (NMFS 2016, p. 7). The Pacific marine heatwave of 2014 to 2016 was one of the most extreme and persistent marine heatwaves recorded to date (Hobday et al. 2018, p. 168), with peak temperature anomalies exceeding 3 °C (5.4 °F) across much of the Gulf of Alaska, and anomalies greater than 2 °C (3.6 °F) persisted through two winters (Di Lorenzo and Mantua 2016, p. 1042). The longest Northeastern Pacific heatwave on record occurred in 2019 to 2021 (Barkhordarian et al. 2022, pp. 2-4). Anthropogenic climate change contributed to the development of these extreme heatwaves, and even more extreme heatwaves are likely to occur as climate change continues (Barkhordarian et al. 2022, p. 9). The National Oceanic and Atmospheric Administration (NOAA) forecasts an elevated risk (40 to 70 percent chance) of marine heatwaves in the western coast of the U.S. in spring 2024 (NOAA 2023, unpaginated). Mass marine bird mortality events, with significant increases in carcass encounter rates spanning multiple months and regions, are more likely to occur following marine heatwaves (Jones et al. 2023, p. 15).

The climate models used to project future trends in temperature and precipitation also account for naturally occurring climate cycles, such as the El Niño Southern Oscillation and the Pacific Decadal Oscillation (IPCC 2014, p. 56). These oscillations have relatively warm coastal water and warm, dry winter conditions during a "positive" warm phase, followed by cooler coastal water and cooler, wetter winter conditions during the cool "negative" phase (Moore et al. 2008, p. 1747). The projected overall warming trend combined with these existing cycles means that temperatures during a cool phase will be less cool than they would be without climate change, and warm phases will be warmer. Climate change may also alter the patterns of these oscillations, for example, by shortening the cycle length of the Pacific Decadal Oscillation (Zhang and Delworth 2016, pp. 6007-6008).

The California Current, where most of the marine portion of the listed range of the murrelet is located, is strongly influenced by upwelling. Upwelling along the West Coast leads to an influx of cold waters rich in nutrients such as nitrates, phosphates, and silicates, but that are also acidic and low in dissolved oxygen (Krembs 2013, p. 109; Sutton et al. 2013, p. 7191; Johannessen et al. 2014, p. 220; Riche et al. 2014, pp. 45-46, 48). Trends and projections for the future of upwelling in the California Current are variable (Macias et al. 2012, pp. 4-5; Wang et al. 2015, p. 391; Taboada et al. 2019, p. 95). Upwelling is also a fundamental nutrient delivery mechanism in the Salish Sea (Moore-Maley and Allen 2022, p. 144), but strong vertical circulation and mixing serves as a physical buffer to keep waters cooler relative to the continental shelf during marine heatwaves (Khangaonkar et al. 2021, p. 18).

In Conservation Zone 1, spring and summer freshwater inflows are expected to be warmer and reduced in volume, whereas winter freshwater inflows are expected to increase (Lee and Hamlet 2011, p. 110; Mauger et al. 2015, p. 3-8; Moore et al. 2015, p. 6; Mote et al. 2003, p. 56). These changes in seasonal freshwater inflows are expected to alter water circulation and stratification within Conservation Zone 1, and to affect the rate and timing of exchange of waters through the Strait of Juan de Fuca between the Puget Sound and the North Pacific Ocean (Babson et al. 2006, pp. 29-30; MacCready and Banas 2016, p. 13; Mauger et al. 2015, p. 6-2, Riche et al. 2014, pp. 37-39, 44-45, 49-50). The effect of changes in freshwater inflow on stratification is likely to vary by location within the action area, with greater potential for effect in, for example, southern Puget Sound than in well-mixed channels like Admiralty Inlet and Dana Passage (Newton et al. 2003, p. 721). When hypoxic (low dissolved oxygen) events occur in the waters of Zone 2, these waters also flow into the inland waters of Conservation Zone 1, driving down the oxygen content there as well, although there is considerable variation over time, space, and depth, due to patterns of circulation and mixing within the Salish Sea (Bassin et al. 2011, Section 3.2; Johannessen et al. 2014, pp. 214-220). Increased stratification, as is expected during winter with the larger freshwater inflows, can lead to hypoxic conditions in deeper waters (Mauger et al. 2015, p. 6-3; Whitney et al. 2007, p. 189). On the other hand, weaker stratification, as expected in the summer, may decrease the probability of low oxygen due to greater mixing, or increase the probability of low oxygen due to slower circulation (Newton et al. 2003, p. 725).

The increasing carbon dioxide emissions responsible for rising temperatures is also responsible for ocean acidification, which results when carbon dioxide in the air dissolves in surface water (IPCC 2014, pp. 41, 49). Both the surface and upwelled waters of the North Pacific Ocean have become more acidic due to carbon dioxide emissions (Feely et al. 2008, pp. 1491-1492, Murray et al. 2015, pp. 962-963), and this trend is expected not only to continue but to be irreversible at human-relevant timescales (Feely et al. 2009, pp. 40-46; Byrne et al. 2010, p. L02601; IPCC 2014, pp. 8-9, 49; IPCC 2019, pp. 1-4, 1-7, 1-14). Any increase in upwelling intensity or changes in seasonality would respectively increase acidification or change the timing of pH changes within the listed murrelet range.

Another aspect of ocean conditions that is changing is sea level, which is rising at most coastal locations in the listed range of the murrelet (Dalrymple 2012, pp. 79-81; Mauger et al. 2015, p. 4-2) and is likely to continue to do so into the future (Mote et al. 2008, p. 10; Bromirski et al. 2011, pp. 9-10; Dalrymple 2012, pp. 71, 102; Mauger et al. 2015, pp. 4-3 – 4-5; Petersen et al. 2015, pp. 21, 29, Appendix D). In near-shore ecosystems, sea level rise can lead to larger areas of suitable depth for eelgrass (*Zostera marina*) meadows, increasing eelgrass cover, biomass, and net primary production in some areas during the next 20 years (Kairis 2008, pp. 92-102).

Sea level rise, alongside changes in temperature, marine heatwaves, nutrient levels, and acidification, likely affects primary productivity by phytoplankton, macroalgae, kelp, eelgrass, and other marine photosynthesizers (Mauger et al. 2015, p. 11-5; IPCC 2019, p. 5-72). In general, warmer temperatures, higher carbon dioxide concentrations, and higher nutrient levels lead to greater productivity (Thom 1996, pp. 386-387; Newton and van Voorhis 2002, p. 10; Gao and Campbell 2014, pp. 451, 454; Roberts et al. 2014, pp. 11, 22, 108; Nagelkerken and Connell 2015, p. 13273), but these effects vary by species and other environmental conditions, such as sunlight levels or the ratios of different nutrients (Low-Decarie et al. 2011, p. 2530; Krembs 2013, p. 109; Kroeker et al. 2013, p. 1889; Gao and Campbell 2014, pp. 451, 454). Models project reductions in overall annual marine net primary productivity in the world's oceans during the 21st century, but trends will vary across the listed murrelet range, with decreases at the southern end of the range and increases at the northern end (IPCC 2019, pp. 5-31, 5-38). Changes in primary productivity are also likely to vary at smaller scales, even within a Conservation Zone (Newton and van Voorhis 2002, pp. 10-11).

Altered prey availability, abundance, and quality. Changing physical conditions, such as increasing temperatures, hypoxia, or acidification have direct effects on some prey species and subsequently their competitors and consumers (Mackas et al. 2007, p. 249). The Pacific marine heatwave of 2014 to 2016 saw surface-water chlorophyll concentrations decrease, as did the mean cell size of phytoplankton (Suryan et al. 2021, p. 5), resulting in longer food chains with less efficient transfer of energy to higher trophic levels (Ruiz-Cooley et al. 2017, p. 3; Armengol et al. 2019, p. 5). The abundance and nutritional quality of forage fishes on the continental shelf, including capelin (*Mallotus catervarius)*, sand lance, and Pacific herring, decreased during and after this heatwave (Arimitsu et al. 2021, p. 1859; Cushing et al. 2023, p. 23). Depending on species, life stage, and other factors such as warming and hypoxia, the effects of acidification on fish include embryo mortality, delayed hatching, reduced growth rates, reduced metabolic rates, altered sensory perception, and changes in behavior (Hamilton et al. 2014, entire; Ou et al. 2015, pp. 951, 954; Nagelkerken and Munday 2016, entire; Villalobos 2018, p. 18). Fish growth and body composition may also be sensitive to sea surface temperature; for example, one-year-old sand lance were dramatically smaller and less energy-dense during warm water years (2014 to 2016) than during the immediately preceding cool years (2012 to 2013) (von Biela et al. 2019, pp. 176-179; Robinson et al. 2023, p. 7).

In the northeastern Pacific Ocean, capelin, Pacific sand lance, and rockfish (*Sebastes* spp.) abundance are all negatively correlated with seasonal sea surface temperatures (Thayer et al. 2008, p. 1616). However, it is important to note that changes in forage fish biomass may be related to overfishing and loss of spawning habitat as well. Pacific herring biomass was declining in most stocks in Puget Sound from 2013 to 2016 (Sandell et al. 2019, p. 4), but in 2020, herring spawning biomass was the highest it's been since 1980 (WDFW 2020, p. 1). In Washington, northern anchovy harvest levels have declined since 2010 (Wargo and Hinton 2016, p. 15), trawling efforts indicate significant surf smelt declines (Greene et al. 2015, p. 162), and Pacific sand lance are likely in decline (Huard 2023, p. 77). In Oregon, abundance and distribution information for Pacific herring, surf smelt, Pacific sand lance, and northern anchovy are not readily available. In California, Pacific herring stocks continue to fluctuate (California Department of Fish and Wildlife 2016, pp. 2, 4), northern anchovy were very abundant in 2021 (Kuriyama et al. 2021, p. 20; Thompson et al. 2022, p. 13), and we have no information on surf smelt and Pacific sand lance status. A model of multiple climate change effects, like acidification and deoxygenation, in the Northeast Pacific consistently projects future declines in small pelagic fish abundance (Ainsworth et al. 2011, pp. 1,219, 1,224).

When prey items decrease in abundance, their consumers are also expected to decrease, and this can also create opportunities for other species to increase. A food web model of Puget Sound shows that acidification effects are expected to cause reductions in forage fish biomass, which are in turn expected to lead to reductions in diving bird biomass (Busch et al. 2013, p. 829). However, the model also illustrates that changes in abundance of a given prey species will not always correspond directly to changes in the abundance of their consumers (Busch et al. 2013, pp. 827, 830), and increasing variance of climate drivers is leading to increased variability in abundance of prey species and corresponding variability in the demography of seabirds (Kaplan et al. 2010, pp. 1973-1976; Sydeman et al. 2013, pp. 1662, 1667-1672). Several studies have also suggested that climate change is one of several factors allowing jellyfish to increase their ecological dominance, at the expense of forage fish (Parsons and Lalli 2002, pp. 117-118; Purcell et al. 2007, pp. 154, 163, 167-168; Richardson et al. 2009, pp. 314-216).

Impacts of prey availability, abundance, and quality on individuals and populations. Altered foraging conditions such as low prey availability, abundance, and quality can result in reduced reproductive success as well as starvation. Although studies are not available that directly project the effects of marine climate change on murrelets, several studies have been conducted within and outside the listed range regarding ocean conditions and murrelet behavior and fitness. The relationships between ocean conditions, prey species, and bird demography is variable;

however, the consistent demonstration of such relationships indicates that alcids as a group are sensitive to climate-related changes in prey availability, abundance, and quality (Hyrenbach and Veit 2003, p. 2551; Hedd et al. 2006, p. 275).

In response to insufficient prey availability, adult murrelets may forego breeding (Peery et al. 2004, pp. 1094-1095). In British Columbia, there is a strong negative correlation between sea surface temperature and the number of murrelets observed at inland sites displaying behaviors associated with nesting (Burger 2000, p. 728). Murrelets lay a single egg weighing about 25 percent of their pre-breeding body mass, which suggests that egg production is energetically costly and dependent on the availability of adequate prey. In central California, murrelet diets vary depending on ocean conditions, and there is a trend toward greater reproductive success during cool water years, likely due to the abundant availability of prey items (Becker et al. 2007, pp. 273-274). The conclusion that climate change is likely to reduce murrelet breeding success via changes in prey availability is further supported by several studies of other alcid species: Common murres (*Uria aalge*), Cassin's auklets (*Ptychoramphus aleuticus*), rhinoceros auklets (*Cerorhinca monocerata*), tufted puffins (*Fratercula cirrhata*), and pigeon guillemots (*Cepphus columba*). From British Columbia to Mexico, all these species show altered reproductive rates, altered chick growth rates, or changes in the timing of the breeding season, depending on sea surface temperature or other climatic variables, prey abundance, prey type, or the timing of peaks in prey availability (Ainley et al. 1995, pp. 73-77; Bertram et al. 2001, pp. 292-301; Gjerdrum et al. 2003, pp. 9378-9380; Abraham and Sydeman 2004, pp. 239-243; Hedd et al. 2006, pp. 266-275; Sydeman et al. 2006, pp. 2-4; Albores-Barajas 2007, pp. 85-96; Borstad et al. 2011, pp. 291-299; Piatt et al. 2020, pp. 13-15).

Prey quality can also contribute substantially to the reproductive success of seabirds, which is often limited by dietary energy content (Litzow et al. 2002, p. 286). Murrelet diets appear to reflect what is most abundant and/or of the highest quality of prey available at the time (Kuletz 2005, p. 27; Becker et al. 2007, p. 274). Evidence from California and British Columbia indicates that the proportion of high-trophic level prey in murrelet diets declined strongly from the historical to the current era, while the proportion of low-trophic level prey increased, either from over-fishing or regional changes in climate (Becker and Beissinger 2006, p. 475; Norris et al. 2007, p. 879). Research on a variety of seabirds related to the murrelet (tufted puffins and pigeon guillemots) indicates reproductive success and chick survival is higher when nestling diets consist of energy-dense, high-lipid content prey (Litzow et al. 2002. p. 292; Romano et al. 2006, p. 411). When murrelet chicks are fed fewer or lower quality prey items, they shift resource allocation to high-priority body components, potentially compromising development of other body components and leading to future fitness costs, like reduced lifespan and reproductive output (Janssen et al. 2011, p. 865). In some alcid species, food limitation during nesting can result in poor growth, delayed fledging, increased mortality of chicks, and nest abandonment by adults (Øyan and Anker-Nilssen 1996, p. 836). However, murrelet nest occupancy has been recorded as being higher in years where they consumed fewer high or medium energy density prey, which indicates that murrelet breeding may be impacted by more than diet diversity (Fountain et al 2023, p. 150).

Furthermore, adult murrelets may suffer starvation in extreme warm-water conditions, as occurred with common murres during the marine heatwave of 2014 to 2016, which was likely caused by a combination of reductions in forage fish nutritional content and increases in competition with large piscivorous fish (Piatt et al. 2020, pp. 17-24; Cushing et al. 2023, p. 23). This shows that redistribution and prey-switching were insufficient to mitigate the effects of an extreme, protracted warming event (Cushing et al. 2023, p. 23). In rhinoceros auklets, higher sea surface temperature associated with higher Pacific Decadal Oscillation values resulted in poor foraging conditions that increased nutritional stress in breeding birds (Shimabukuro et al. 2023, p. 187). Counterintuitively, in the 1997 to 2003 study of radio-tagged murrelets in California, murrelet adult survival was higher during warm-water years and lower during cold-water years, likely because they did not breed and, therefore, avoided the associated physiological stresses and additional predator risk (Peery et al. 2006, pp. 83-85). From 2009 to 2017, a total of 10 dead adult and juvenile murrelets whose deaths were attributed primarily or secondarily to emaciation, likely due to reduced prey availability, were incidentally found and collected by the Service in Washington, Oregon, and California (Service 2019, p. 32).

HABs and disease. Climate change may expose adult and juvenile murrelets to health risks from HABs and disease, which will likely increase in frequency and intensity as the ocean continues to be impacted by climate change (Alava et al. 2018, p. 4; Chan et al. 2016, p. 5). HABs can result in the direct mortality or reduced fitness of murrelets, as well as a decreased quality of marine foraging habitat, across the listed range. HAB events have caused a proteinaceous foam to coat the feathers of molting alcids, ultimately resulting in hypothermia (Jessup et al. 2009, p. 2; Phillips et al. 2011, p. 120), and HAB-inflicted mortalities to fish can degrade habitat quality through altered food webs (Lopez et al. 2008, p. 22). Mortality from HABs can be very difficult to track; murrelets have rarely been specifically identified in such events. HAB-related domoic acid poisoning has been documented as the cause of death in two adult murrelets (Peery et al. 2006, pp. 83-84). It is reasonable to expect that more murrelets have been impacted by HABs than have been documented, based on the available information for other alcid species. Nestling mortalities from HAB-related paralytic shellfish poisoning have been documented in Kittlitz's murrelet (*Brachyramphus brevirostris*), a closely related species (Shearn-Bochsler et al. 2014, p. 935; Lawonn et al. 2018, pp. 11-12), and suspected in marbled murrelet (Lorenz et al. 2019, p. 162).

Increases in HABs have been documented over the past several decades, and these changes are at least partly due to climate change (IPCC 2019, pp. 5-85 through 5-86; Trainer et al. 2003, pp. 216, 222). Elevated seawater temperatures have been linked to an increase in the scope and frequency of HABs (Trainer et al. 2003, pp. 216, 222; IPCC 2019, pp. 5-85 to 5-86; van Hemert et al. 2020, p. 1). As such, HABs are likely to increase in frequency and intensity, such that larger, more toxic events like the one that occurred in 2015 may become more typical (Chan et al. 2016, p. 5; McCabe et al. 2016, p. 10374).

Climate change may also promote conditions in which alcids become exposed to novel pathogens, as occurred in Alaska during 2013, when crested auklets (*Aethia cristatella*) and thick-billed murres (*Uria lomvia*) washed ashore after dying of avian cholera (Bodenstein et al.

2015, p. 935). Murrelets in Oregon may be especially susceptible to novel diseases, because these populations lack genetic diversity related to immunity (Vásquez-Carrillo et al. 2014, p. 252).

Connectivity

In the marine environment, the status of all prey species is unclear, but murrelets are foraging on lower quality prey items and may not be able to respond to shifts in prey conditions, especially during the breeding season when they need to remain closer to nesting habitat. Nesting habitat that contained more old forest and was closer to the ocean showed reduced rates of local extinction, which, given predictions of accelerated ocean warming and increased global timber demand, suggests murrelets may continue to be imperiled by deterioration of the two habitats upon which they depend (Betts et al. 2020, pp. 5-7).

Summary

In summary, environmental changes in the terrestrial and marine environments are occurring throughout the listed range of the murrelet, and changes are expected to increase in intensity into the future. The effects of these changes impact individuals and populations via loss and modification of nesting habitat, changes to forage conditions, reduced fitness, and reduced nesting success. While the magnitude of these impacts into the future is relatively uncertain and the geographic scope is highly variable, climate change is already demonstrating an impact on murrelet reproductive rates across its range.

5. **Conservation Needs of the Species**

Reestablishing an abundant supply of high-quality murrelet nesting habitat is a vital conservation need given the extensive removal during the 20th century. Following the establishment of the NWFP, higher probability habitat has decreased plan-wide between 1993 and 2017 (Lorenz et al. 2021, p. 28). This does not support the goal of the NFWP to increase high quality habitat for the marbled murrelet, for which high quality habitat is defined as higher probability habitat that is also core habitat (Lorenz et al. 2021, p. 51). Furthermore, moderate suitability habitat growth occurred primarily on Federal lands, while non-Federal lands experienced overall habitat loss (Lorenz et al. 2021, p. 48). Therefore, recovery of the murrelet will be aided if areas of currently suitable nesting habitat on non-federal lands are retained until ingrowth of habitat on federal lands provides replacement nesting opportunities (Service 2019, p. 21). The current state of nesting habitat, as a function of both historical and contemporary loss, continues to influence murrelet populations through reduction of reproduction and recruitment.

There are also other conservation imperatives. Foremost among the conservation needs are those in the marine and terrestrial environments to increase murrelet fecundity by increasing the number of breeding adults, improving murrelet nest success (increasing nestling survival and fledging rates), and reducing anthropogenic stressors that reduce individual fitness or lead to mortality. The overall reproductive success of murrelets is directly influenced by nest predation rates (reducing nestling survival rates) in the terrestrial environment and an abundant supply of high-quality prey in the marine environment before and during the breeding season (improving breeding rates, potential nestling survival, and fledging rates). Long commutes between quality nesting and quality foraging areas may also contribute to low productivity, as they exacerbate energetic bottlenecks associated with nesting and rearing chicks. Anthropogenic stressors affecting murrelet fitness and survival in the marine environment are associated with commercial and tribal gillnets, derelict fishing gear, oil spills, and high underwater sound pressure (energy) levels generated by pile-driving and underwater detonations (which can be lethal or reduce individual fitness). Anthropogenic activities, such as coastline modification and nutrient inputs in runoff, also affect prey availability and harmful algal blooms, which in turn affect murrelet fitness.

Further research regarding marine threats, general life history, and murrelet population trends in the coastal redwood zone may illuminate additional conservation needs that are currently unknown (Service 2019, p. 66).

6. **Recovery Plan**

The Marbled Murrelet Recovery Plan outlines the conservation strategy with both short- and long-term objectives. The Plan places special emphasis on the terrestrial environment for habitat-based recovery actions due to nesting occurring in inland forests.

In the short-term, specific actions identified as necessary to stabilize the populations include protecting occupied habitat and minimizing the loss of unoccupied but suitable habitat (Service 1997, p. 119). Specific actions include maintaining large blocks of suitable habitat, maintaining, and enhancing buffer habitat, decreasing risks of nesting habitat loss due to fire and windthrow, reducing predation, and minimizing disturbance. The designation of critical habitat also contributes towards the initial objective of stabilizing the population size through the maintenance and protection of occupied habitat and minimizing the loss of unoccupied but suitable habitat.

Long-term conservation needs identified in the Plan include:

- increasing productivity (abundance, the ratio of juveniles to adults, and nest success) and population size;
- increasing the amount (stand size and number of stands), quality, and distribution of suitable nesting habitat;
- protecting and improving the quality of the marine environment; and
- reducing or eliminating threats to survivorship by reducing predation in the terrestrial environment and anthropogenic sources of mortality at sea.

General criteria for murrelet recovery (delisting) were established at the inception of the Plan and they have not been met (Service 2019, p. 65). More specific delisting criteria are expected in the future to address population, demographic, and habitat-based recovery criteria (Service 1997, p. 114-115). The general criteria include:

- documenting stable or increasing population trends in population size, density, and productivity in four of the six Conservation Zones for a 10-year period and
- implementing management and monitoring strategies in the marine and terrestrial environments to ensure protection of murrelets for at least 50 years.

Thus, increasing murrelet reproductive success and reducing the frequency, magnitude, or duration of any anthropogenic stressor that directly or indirectly affects murrelet fitness or survival in the marine and terrestrial environments are the priority conservation needs of the species. The Service estimates recovery of the murrelet will require at least 50 years (Service 1997).

Survival and Recovery Role of Each Conservation Zone

The six Conservation Zones, defined in the Recovery Plan as equivalent to Recovery Units, vary not only in their population status, as described above, but also in their intended function with respect to the long-term survival and recovery of the murrelet.

Conservation Zones 1 extends inland 50 miles from the marine waters of Puget Sound and most waters of the Strait of Juan de Fuca south of the U.S.-Canadian border. The terrestrial portion of Zone 1 includes the north Cascade Mountains and the northern and eastern sections of the Olympic Peninsula. Higher probability nesting habitat in the Cascades is largely separated from high-quality marine foraging habitat by both urban development on land and highly altered coastal marine environments, leading to long commutes between nesting and foraging habitat (Lorenz et al. 2017, p. 314; Raphael et al. 2016a, p. 106; Service 1997, p. 125). In contrast, contiguous blocks of moderate and higher probability habitat remain near the coast along the Strait of Juan de Fuca, where there is a lower human footprint (Lorenz et al. 2021, p. 23; van Dorp and Merrick 2017, p. 5). This combination of large blocks of habitat close to foraging habitat is likely more conducive to successful production of young than conditions in other portions of Zone 1. Zone 1 is unique among the six Zones in that the marine environment is not a part of the California Current ecosystem, but is part of a complex system of estuaries, fjords, and straits. This means that the Zone 1 population is subject to a different set of environmental influences than the populations in the other five zones. For example, in 2005, delayed upwelling led to widespread nesting failure of seabirds, including murrelets, along the northern California Current, while above-average productivity was observed in Zone 1 (Lorenz and Raphael 2018, pp. 208-209; Peterson et al. 2006, pp. 64, 71; Ronconi and Burger 2008, p. 252; Sydeman et al. 2006, p. 3). This example illustrates the importance of Zone 1 in bolstering the rangewide resilience of murrelets. Zone 1 is one of the four Zones where increased productivity and stable or increasing population size are needed to provide redundancy and resilience that will enable recovery and long-term survival.

Conservation Zone 2 also extends inland 50 miles from marine waters. Conservation Zone 2 includes marine waters within 1.2 miles (2 km) off the Pacific Ocean shoreline, with the northern terminus immediately south of the U.S.-Canadian border near Cape Flattery along the midpoint of the Olympic Peninsula, and extending to the southern border of Washington (the Columbia River) (Service 1997, pg. 126). Although Zone 2 was defined to include only the nearshore waters, murrelets in this area are regularly found up to eight km from shore, sometimes at higher densities than in the nearshore environment, even during the breeding season (Bentivoglio et al. 2002, p. 29; McIver et al. 2021, pp. 22, 24). Zone 2 includes the rich waters of the Olympic Coast National Marine Sanctuary, which are adjacent to areas of contiguous, high-quality habitat along the coast of the Olympic Peninsula, as well as relatively large quantities of higher probability habitat farther inland (Lorenz et al. 2021, pp. 23, 26). Even more than the northern Olympic Peninsula in Zone 1, parts of the western Olympic Peninsula appear to provide one of the few remaining strongholds for murrelets in Washington. The southern portion of Zone 2 previously hosted a small but consistent subpopulation of nesting murrelets, and is now only sparsely used for nesting inland or foraging at sea. This reduction in murrelet population density in the southern portion of Zone 2 represents a widening of a gap in distribution that was described in the Recovery Plan (Service 1997, p. 126). This gap is likely a partial barrier to gene flow (Service 1997, p. 145). The eventual long-term survival and recovery of listed murrelets depends on the maintenance of a viable murrelet populations that are well distributed throughout Zone 2, along with the other three Zones where increased productivity and stable or increasing population size are needed for survival and recovery.

Conservation Zone 3 extends 35 miles inland, and includes marine waters within 1.2 miles of the Pacific Ocean shoreline between the northern border of Oregon (the Columbia River) and North Bend, Oregon (Service 1997, pp. 126-127). The terrestrial portion of Zone 3 historically experienced large-scale wildfires and timber harvest, which together likely led to a loss of nesting habitat that caused a dramatic decline in the murrelet population in this Zone (Service 1997, p. 117). In the northernmost portion of Zone 3, this lack of nesting habitat persists, and the at-sea population density of murrelets is relatively low, extending the gap in the southern portion Zone 2 (Service 1997, p. 145; McIver et al. 2022, pp. 11-17). Additionally, murrelet populations in Oregon are expected to be more susceptible to novel pathogens, due to low genetic diversity coding for important immune system peptides (Vásquez-Carrillo et al. 2014, p. 252). However, in Zone 3 as a whole, at-sea population density is high, and is trending upward, though the reason for the population increase is not well understood. Habitat modeling shows an increase in higher probability habitat in Zone 3, but most of the additional habitat is scattered or along forest edges, and some of this increase may be an artifact of the modeling process rather than reflecting actual growth of new nesting opportunities (Lorenz et al. 2021, pp. 42, 49). The murrelet population of Zone 3 is one of the two largest among the Conservation Zones. The eventual long-term survival and recovery of listed murrelets depends on the maintenance of a viable murrelet populations that is well distributed throughout Zone 3, along with the other three Zones where increased productivity and stable or increasing population size are needed for survival and recovery.

Conservation Zone 4 extends 35 miles inland, and includes marine waters within 1.2 miles of the Pacific Ocean shoreline between North Bend, Oregon and the southern end of Humboldt County, California (Service 1997, p. 127). Between 1993 and 2012, habitat modeling showed that this Zone experienced the majority of all nesting habitat losses on federal lands within the listed range, nearly all due to large wildfires (Raphael et al. 2016b, p. 75); however, the most recent habitat modeling effort shows a small net increase in higher probability habitat, mainly in scattered patches (Lorenz et al. 2021, p. 42). As in Zone 3, some of the modeled ingrowth may be an artifact of the modeling process rather than reflecting actual growth of new nesting opportunities (Lorenz et al. 2021, p. 49). Much of the nesting habitat within this Zone is located within National and California State Parks, and recreation likely reduces murrelet productivity in these areas, particularly via accidental food subsidies to corvid nest predators at picnic sites and camping areas (Service 1997, p. 128). Over the last decade, Redwood National and State Parks have made efforts to reduce this supplemental feeding of corvids, with some success in reducing corvid density at recreation sites, but it would be difficult to detect any population-scale benefit of these efforts (Brunk et al. 2021, pp. 7-8; McIver et al. 2021, p. 28). The murrelet population of Zone 4 is one of the two largest among the Conservation Zones, and is increasing, though the reason for the population increase is not well understood. The eventual long-term survival and recovery of listed murrelets depends on the maintenance of a viable murrelet populations that is well distributed throughout Zone 4, along with the other three Zones where increased productivity and stable or increasing population size are needed for survival and recovery.

Conservation Zone 5 extends 25 miles inland, and includes marine waters within 1.2 miles of the Pacific Ocean shoreline between the southern end of Humboldt County, California, and the mouth of San Francisco Bay (Service 1997, p. 129). Very little nesting habitat remains in this Zone, mostly in California State Parks and on private lands, and a 1 percent reduction in higher probability nesting habitat was observed between 1993 and 2017 (Lorenz et al. 2021, pp. 36-37; Service 1997, p. 129). Murrelet population estimates in Zone 5 have been correspondingly low, with population estimates of less than 100 individuals in most survey years (McIver et al. 2022, pp. 11-17). One survey, in 2017, resulted in a much higher estimate of 872 individuals, but multiple lines of evidence indicate that this increase was likely the result of unusual migratory patterns from other Zones during the breeding season (Adrean et al. 2018, p. 2; McIver et al. 2021, p. 28; Strong 2018, pp. 6-7), and the most recent estimate, from 2021, was of 42 individuals (McIver et al. 2022, pp. 16-17). Surveys in Zone 5 are now conducted only once every four years, making the status and trend of this population more difficult to discern. Given the small size of the population during most survey years, and the limited availability of nesting habitat, the ability of this population to survive over the coming decades is questionable, and Zone 5 cannot be counted on to contribute toward long-term survival or recovery of the DPS (Service 1997, pp. 129). In the best-case scenario, if nesting habitat in growth in this Zone can stimulate the restoration of a larger population in Zone 5 over the long term, this would likely improve connectivity between Zones 4 and 6, provide redundancy, and increase resiliency for the DPS as a whole.

Conservation Zone 6 extends 15 miles inland, and includes marine waters within 1.2 miles of the Pacific Ocean shoreline between the mouth of San Francisco Bay and Point Sur, in Monterey County, California (Service 1997, pp. 129-130). Zone 6 is unique among the Zones in that it is not within the NWFP area and is not included in NWFP effectiveness monitoring. Federal land is lacking in Zone 6, and all nesting habitat is located within State or County Parks or on private lands (McShane et al. 2004, p. 4-14). Murrelet population estimates for Zone 6 have averaged around 500 individuals for the period from 1999 through 2021, with a range between 174 and 699 birds across the years (Felis et al. 2022b, p. 8). The Zone 6 population is genetically differentiated from the other Zones, likely as a result of the wide gap in the range between the Zone 6 population and the populations to the north (Hall et al. 2009, p. 5078; Peery et al. 2010,

p. 703). When the Recovery Plan was written in 1997, it was anticipated that the Zone 6 population would persist long enough to contribute to recovery, but could not be relied upon to contribute to the long-term survival of the species (Service 1997, p. 116). Subsequent research has demonstrated that the population in Zone 6 is a demographic sink, with a shrinking breeding population bolstered by the presence of mainly non-breeding individuals originating from other Zones (Peery et al. 2006, p. 1523; Peery et al. 2010, p. 702; Vásquez-Carrillo et al. 2013, p. 177). Demographic effects of large-scale nesting habitat loss and degradation during the 2020 wildfires have not yet manifested, but are expected to be negative. Therefore, it remains unlikely that this population will contribute to recovery. The presence of a murrelet population in Zone 6 is necessary to ensure the future distribution of murrelets throughout their current and historical range within the DPS, but it is not clear that this will be possible over the long term, given the vulnerability of this population to stochastic or catastrophic events (Service 1997, p. 116).

The Recovery Plan identified lands that will be essential for the recovery of the murrelet, including 1) any suitable habitat in a Late Successional Reserve (LSR) in Forest Ecosystem Management Assessment Team (FEMAT) Zone 1 (not to be confused with Conservation Zone 1), as well as LSR in FEMAT Zone 2 in Washington, 2) all suitable habitat located in the Olympic Adaptive Management Area, 3) large areas of suitable nesting habitat outside of LSRs on Federal lands, such as habitat located in the Olympic National Park, 4) suitable habitat on State lands within 40 miles of the coast in Washington, or within 25 miles of the coast in Oregon and California, 5) habitat within 25 miles of the coast on county park land in San Mateo and Santa Cruz Counties, California, 6) suitable nesting habitat on Humboldt Redwood Company (formerly Pacific Lumber Company) lands in Humboldt County, California, and 5) habitat within occupied murrelet sites on private lands (Service 1997, pp. 131-133).

Marine habitat is also essential for the recovery of the murrelet. Key recovery needs in the marine environment include protecting the quality of the marine environment and reducing adult and juvenile mortality at sea (Service 1997, pp. 134-136). Marine areas identified as essential for murrelet foraging and loafing include 1) all waters of Puget Sound and the Strait of Juan de Fuca, and waters within 1.2 miles of shore 2) along the Pacific Coast from Cape Flattery to Willapa Bay in Washington, 3) along the Pacific Coast from Newport Bay to Coos Bay in Oregon, 4) along the Pacific Coast from the Oregon-California border south to Cape Mendocino in northern California, and 5) along the Pacific Coast in central California from San Pedro Point south to the mouth of the Pajaro River.

7. **Summary**

At the range-wide scale, annual estimates of murrelet populations have fluctuated, with no conclusive evidence of a positive or negative trend since 2001 (McIver et al. 2024, p. 4). The most recent extrapolated population estimate for the entire NWFP area was 19,033 murrelets (95 percent CI: 14,877 to 23,190 birds) in 2022 (McIver et al. 2024, p. 17). The largest murrelet subpopulations now occur off the Oregon and northern California coasts, while subpopulations in Washington have steadily declined since 2001 (-4.1 percent per year; 95% CI: -5.2 to -3.0 percent) (McIver et al. 2024, p. 4).

Monitoring of murrelet nesting habitat within the NWFP area indicates high probability nesting habitat has decreased from an estimated 1.51 million acres in 1993 to an estimated 1.49 million acres in 2017, a total decrease of about 1.4 percent (Lorenz et al. 2021, p. 28). Murrelet population size is strongly and positively correlated with amount of nesting habitat, suggesting that conservation of remaining nesting habitat and restoration of currently unsuitable habitat is key to murrelet recovery (Raphael et al. 2011, p. iii). Given likely future increases in forest disturbances that can cause habitat loss, conservation of remaining nesting habitat is especially important.

The species decline has been largely caused by extensive removal of late-successional and old growth coastal forest which serves as nesting habitat for murrelets. Additional factors in its decline include high nest-site predation rates, human-induced mortality in the marine environment from disturbance, and altered forage conditions resulting from climate change. Although some threats have been reduced (e.g., habitat loss on Federal lands), some threats continue, and new threats now strain murrelet survival and reproduction. Therefore, given the current status of the species and background risks facing the species, it is reasonable to assume that murrelet populations in Conservation Zones 1 and 2 and other parts of the listed range have low resilience to deleterious population-level effects and are at high risk of continuing or renewed declines. Activities that degrade the existing conditions of occupied nesting habitat or reduce adult survivorship or nest success of murrelets will be of greatest consequence to the species. Actions resulting in the loss of occupied nesting habitat, mortality to breeding adults, eggs, or nestlings will reduce productivity, contribute to continued population declines, and prolong population recovery within the listed range of the species in the coterminous United States.

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APPENDIX B - DISCRETIONARY TIDAL TURBINE ABOVE WATER MARBLED MURRELET MONITORING PLAN

APPENDIX B - Discretionary Tidal Turbine Above Water Marbled Murrelet Monitoring Plan

Guidelines are lacking on how best to use both well-established and novel survey methods to assess seabird use of tidal flow areas (Langston et al. 2011). Thus, in addition to abiding by criteria described in Sections 4.2.2 and 4.2.3, this section further details information on how to adequately conduct discretionary above water marbled murrelet monitoring for the currently proposed general deployment area for tidal turbines (Figure 8). The survey area would be that depicted in Figure 18, or any other general area selected for tidal turbine deployments. During tidal turbine research driven surveys, the focus of surveys is marbled murrelet monitoring; however, any other monitoring specific to other federally protected species could be conducted simultaneously by the same PSO.

The Discretionary Tidal Turbine Above Water Marbled Murrelet Monitoring Plan is not mandatory for a specific tidal turbine deployment (mandatory requirements for such are covered in Section 4.2). PNNL may choose to monitor, which could occur in anticipation of and would be independent of sponsor-supported tidal turbine research. This section is considered optional at this time, based on the PNNL adoption of underwater monitoring with an AMP or similar integrated platform (Section 4.2.4).

Tidal Stages

At Sequim Bay high and low tides occur twice in any given 24-hr period. Four tidal stages surveyed will include low, high, rising (flood), and falling (ebb). Low and high tide periods are generally classified as the 1-hour period before and after a low or high tide (Haynes et al. 2008) and typically encompass the slack tide stage. These tidal stages will be considered as part of monitoring plan design.

Survey Times

Daytime surveys during the breeding season (April – August [Ralph et al. 1995] but for purposes of monitoring would also include September) would take place during various times of day, categorized as follows: (1) dawn; (2) morning, (3) afternoon, and (4) dusk (Haynes et al. 2008). Daytime surveys during the non-breeding season (October – March) would take place as follows: (1) morning, (2) noon, and (3) afternoon. Nighttime surveys would also be conducted during the breeding and non-breeding season.

Survey Frequency

Survey frequency is based on adequately covering the tidal stages and times of day indicated above. Based on the tidal stage and duration information provided above under Tidal Stages, high and low tides comprise about one-third of each 24-hr period or about 8 hrs. The remainder of each 24-hr period, about 16 hours, comprises rising and falling tides. An example scheduling of daytime surveys to occur each time of day each Friday of each week from April through September 2022 and from October 2022 through March 2023 (using Washington State Tides and

Currents Pro software) resulted in unequal representation of tidal stages, i.e., a disproportionately greater number of rising and falling tide surveys and relatively few high and low tide surveys during each season, and some combinations of time of day by tidal stage sparsely represented (1 survey) or not represented at all (0 surveys) during both the breeding and non-breeding season. Therefore, a planned sampling schedule must consider both tidal predictions and time of day to adequately characterize use of the deployment area by marbled murrelets during the breeding season and non-breeding season.

There are 16 tidal-stage by time-of-day combinations during the breeding season (4 times of day and 4 tidal stages) and 12 tidal-stage by time-of-day combinations during the non-breeding season (2 times of day and 4 tidal stages). The four tidal stages each occur at different times during the 24-hr clock throughout the year. Based on a preliminary review of the times when tide stages which occurred in 2022, it is noteworthy that some of the above tidal-stage by time-of-day combinations are disproportionately limited in number and tend to occur in only some months (e.g., dawn and dusk high and low tides). Thus, providing complete survey coverage of all tidal-stage by time-of-day combinations within any given month is not feasible. Consequently, providing complete survey coverage for the four tidal stages at the required times of day is presented on a monitoring-season basis.

Though the number of surveys is subject to change, the current example addresses 2 surveys per monitoring season, time of day and tidal stage. Note that surveys would be conducted during each month, but the 6-month monitoring season is anticipated to allow enough flexibility to adequately cover the following number of surveys for each tidal-stage by time-of-day combination. Thirty-two surveys and 24 surveys would be required to cover each tidal-stage by time-of-day combination 2 times during the breeding season and 2 times during the non-breeding monitoring season, respectively (Table 28). Daytime surveys will be scheduled in advance to occur during the tidal stages using predicted tide cycles.

Table 28. Targeted number of daytime surveys by time of day and tidal stage to be completed within the breeding and non-breeding monitoring seasons.

Monitoring Season	**Time of Day**	**Tidal Stage**				**Total**
		High	Low	Rise	Fall	
Breeding (April–September)	Dawn	2	2	2	2	8
	Morning	2	2	2	2	8
	Afternoon	2	2	2	2	8
	Dusk	2	2	2	2	8
	Total	8	8	8	8	32
Non-Breeding (October–March)	Morning	2	2	2	2	8
	Noon	2	2	2	2	8
	Afternoon	2	2	2	2	8
	Total	6	6	6	6	24
Annual Total						**56**

In addition, nighttime monitoring surveys would be conducted but will not be restricted to a particular time of night. The four tidal stages will each be covered 2 times during the breeding season and 2 times during the non-breeding monitoring season (Table 29). Nighttime surveys will be scheduled in advance using predicted tide cycles.

Table 29. Number of nighttime surveys by tidal stage and monitoring season.

	Tidal Stage				
Monitoring Season	High	Low	Rise	Fall	**Total**
Breeding	2	2	2	2	8
Non-Breeding	2	2	2	2	8
Total					**16**

Survey Area

Adequate coverage of the currently proposed general deployment area for tidal turbines depicted in Figure 8 would require six approximate polygons delineated to cover the survey area, the width of each polygon being based roughly on the distance of maximum observer visibility (50 m) from either side of the survey vessel (Section 4.2.3.2). The approximate path of the survey vessel would bisect these polygons. If a different general deployment area for tidal turbines is selected, this would change to appropriately capture that area.

Figure 18. Approximate tentative vessel path (blue lines) and observation/data recording polygons (6 red polygons) for marbled murrelet surveys in the example deployment area for tidal turbines. The spit located just north of Travis Spit is Gibson Spit.