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-2022-03517

January 26, 2024

Todd Tillinger
Chief, Regulatory Branch
U.S. Army Corps of Engineers, Seattle District
4735 East Marginal Way South, Bldg. 1202
Seattle, Washington 98134-2388

Re: Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the Terminal 91 Berths 6 & 8 Redevelopment Project, Elliott Bay, King County, Washington (NWS-2022-842-WRD)

Dear Mr. Tillinger:

Thank you for your May 5, 2022 letter requesting initiation of consultation with NOAA's National Marine Fisheries Service (NMFS) pursuant to section 7 of the Endangered Species Act of 1973 (ESA) (16 U.S.C. 1531 et seq.) for the U.S. Army Corps of Engineers' (COE) proposed issuance of permit NWS-2022-842-WRD for the Terminal 91 Berths 6 & 8 Redevelopment Project, Elliott Bay, King County, Washington (HUC 171100191200). Thank you, also, for your request for consultation pursuant to the essential fish habitat (EFH) provisions in Section 305(b) of the Magnuson–Stevens Fishery Conservation and Management Act (16 U.S.C. 1855(b)) for this action.

In this biological opinion (Opinion), NMFS concludes that the proposed action is not likely to jeopardize the continued existence of Puget Sound (PS) Chinook salmon (*Oncorhynchus tshawytscha*), PS steelhead (*Oncorhynchus mykiss*), Puget Sound-Georgia Basin (PS/GB) bocaccio rockfish (*Sebastes paucispinis*), or southern resident killer whales (SRKW; *Orcinus orca*). The project is also not likely to result in the destruction or adverse modification of critical habitat designated for these species.

Please contact Sara Potter (NMFS liaison, Central Puget Sound Branch of the Oregon/ Washington Coastal Office) at sara.potter@noaa.gov if you have questions concerning this consultation or require additional information.

Sincerely,

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

cc: Jacalen Printz, USACE
Andrew Shuckhart, USACE

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

Terminal 91 Berths 6 & 8 Redevelopment Project
Elliott Bay, King County, Washington
(NWS-2022-842-WRD)

NMFS Consultation Number: WCRO-2022-03517

Action Agency: U.S. Army Corps of Engineers

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 Chinook salmon (*Oncorhynchus tshawytscha*)	Threatened	Yes	No	Yes	No
Puget Sound steelhead (*Oncorhynchus mykiss*)	Threatened	Yes	No	Yes	No
Puget Sound-Georgia Basin Bocaccio rockfish (*Sebastes paucispinis*)	Endangered	Yes	No	Yes	No
Puget Sound-Georgia Basin Yelloweye rockfish (*Sebastes ruberrimus*)	Threatened	No	No	No	No
Southern Resident killer whale (*Orcinus orca*)	Endangered	Yes	No	Yes	No
Central America (CAM) DPS & Mexico DPS Humpback whale (*Megaptera novaeangliae*)	Endangered (CAM)/ Threatened (Mexico)	No	No	No	No

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 Coast 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: January 26, 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 the biological opinion (Opinion) and incidental take statement (ITS) portions of this document in accordance with section 7(b) of the Endangered Species Act (ESA) of 1973 (16 U.S.C. 1531 et seq.), as amended, and implementing regulations at 50 CFR part 402.

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.

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 the Oregon Washington Coastal Office in Lacey, Washington.

1.2. Consultation History

On May 5, 2022, NMFS received a request for formal consultation from the Seattle District U.S. Army Corps of Engineers (COE) on its proposal to authorize construction for Terminal 91 Berths 6 & 8 Redevelopment Project (proposed action) proposed by the Port of Seattle (Port; applicant).

The COE concluded that the proposed action is likely to adversely affect the Puget Sound (PS) Evolutionary Significant Unit (ESU) of Chinook salmon (*Oncorhynchus tshawytscha*) and the PS Distinct Population Segments (DPS) of steelhead (*Oncorhynchus mykiss*). The consultation request included a “not likely to adversely affect” (NLAA) determination for Puget Sound/Georgia Basin (PS/GB) DPS of *Sebastes paucispinus* (bocaccio rockfish) and PS/GB *Sebastes ruberrimus* (yelloweye rockfish), *Orcinus orca* (Southern resident killer whale [SRKW]) and Central American (CAM) and Mexico (MEX) DPS of *Megaptera noveaengliae* (humpback whale). It also made an NLAA determination on the critical habitat for PS Chinook salmon, both rockfishes, and SRKW. Following submission, the COE affirmed that NMFS should include ESA consultation for steelhead critical habitat (electronic communication dated August 25, 2023). The COE determined no effect for humpback whale critical habitat, as documented by an email received by NMFS November 16, 2023

We concur with the NLAA determination for PS/GB yelloweye rockfish and their critical habitat, and the no effect determination for humpback whale. We include our support for these NLAA determinations as in Section 2.11, “Not Likely to Adversely Affect” Determinations. This Opinion includes analysis of the COE determinations with which we did not concur (PS Chinook salmon critical habitat, bocaccio and bocaccio critical habitat, and SRKW and SRKW critical habitat), and additional analysis of PS steelhead critical habitat.

The proposed action (INQ-2022-00122) was considered for coverage under the Salish Sea Nearshore Programmatic Consultation (SNNP; WCRO-2019-04086). Having evaluated the proposed action and following a pre-consultation meeting with the applicant on March 3, 2023, NMFS determined that the complexity and scope of proposed activities are not suitable for coverage under the programmatic SSNP consultation. Consequently, and in light of the time-critical nature of this proposed action, NMFS determined the most expedient path forward to be through this individual consultation.

As such, NMFS notified COE via email on March 3, 2023 and via letter dated March 7, 2023 that individual formal consultation was proceeding for this proposed action under tracking number WCRO-2022-03517. On March 27, 2023, NMFS requested additional information from the applicant – specifically, documentation of the proposed action's essential fish habitat (EFH) analysis that was inadvertently omitted from the original permit package. After determining that we had sufficient information to complete ESA consultation, NMFS initiated formal consultation on April 18, 2023.

We reviewed the May 5, 2022 COE consultation request document and related materials, including the September 2021 biological evaluation (BE), Appendix A: EFH Assessment, and other project materials to complete this Opinion. Additional information was received electronically from the Port on May 19, July 20, August 11, and August 25, 2023 and has been reviewed and incorporated. On July 20, 2023, the Port and COE clarified final elements of the project description as written in this Opinion. On July 25, 2023, the NMFS biologist calculated final project long-term habitat impacts using the Puget Sound Nearshore Conservation Calculator (Nearshore Calculator). Tabulation of all adverse and positive long-term impacting components of the proposed action in the Nearshore Calculator indicates the proposed action will provide long-term benefits to nearshore habitat. On November 16, 2023, the COE provided NMFS with a no effect determination for humpback whale critical habitat. Where relevant, we have adopted the information and analyses provided and/or referenced only after our independent, science-based evaluation confirmed they meet our regulatory and scientific standards.

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 2 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 the biological 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 (see 50 CFR 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).

The proposed action is the issuance of permits by the COE under section 10 of the Rivers and Harbors Act, and section 404 of the Clean Water Act, to the Port of Seattle (the Port). The Port proposes to replace and reconfigure deteriorating marine industrial structures at Terminal 91 Berths 6 and 8 on the north side of Elliott Bay in Seattle, Washington. Originally built as one of the Port of Seattle's first facilities, Terminal 91 Berths 6 and 8 are the last remaining original timber pier structures at the terminal and are at the end of their service life. Approximately 30 percent of the apron at Berths 6 and 8 is currently condemned and the remaining sections are posted with load limits. Berths 6 and 8 were last rehabilitated in 1985.

We considered, under the ESA, whether or not the proposed action would cause any other activities and determined that it would cause the continuation of commercial fishing traffic, because the purpose of redevelopment of Berths 6 and 8 is ensuring long-term viability of the Port as the home to the North Pacific Fishing Fleet (Port 2022)

The North Pacific Fish Fleet of commercial fish catcher/processors has homeported at Terminal 91/Fishermen's Terminal for more than 100 years (Port 2023a). The fleet comes and goes throughout the year, heading into the Pacific Ocean during harvest times and docking at the terminal to unload harvests. To reach the terminal, vessels must travel south from the Strait of Juan de Fuca, through Admiralty Inlet, and into Elliott Bay. Commercial vessels traveling this route follow well-defined navigation lanes known as the Traffic Separation Scheme, monitored by the U.S. Coast Guard (USCG) and the Canadian Coast Guard (CCG), and recognized by the International Maritime Organization (WDOE 2009). While it is impossible to predict the exact course of each individual commercial fishing vessel utilizing the berth, it is reasonable to assume they will travel between the Strait of Juan de Fuca to Elliott Bay via Admiralty Inlet in the established TSS lanes to unload their catch.

Fish harvest conducted by the fleet is not considered a consequence of the proposed action. Harvest levels are determined by a number of federal and state decision making processes. Many of the process are themselves the subject of individual Section 7 consultations (i.e. NMFS 1994, 1995, 1999, 2009, 2012). This proposed action will repair and extend the lifespan of Pier 91, which is the homeport of the North Pacific Fishing Fleet, and therefore it is reasonably certain that there will be continued vessel traffic to and from the pier as a consequence of this action. It is reasonably certain that the fleet will operate in some capacity, including that vessels will transit between Pier 91 and the entrance to the Strait of Juan de Fuca as they travel to the Pacific Ocean. However, we cannot reasonably predict the behavior of those vessels beyond the Strait of Juan de Fuca, including where those fishing vessels are likely travel after leaving the Straight, where those vessels will harvest fish, which species will be harvest or at what level. Therefore, harvest is not an expected consequence of the proposed action.

The proposed action will include replacement of the existing creosote-treated timber pier and apron with a new wharf structure (including associated piles), relocation of a small boat storage and float system, and replacement of existing slope armoring. The exposed portion of steel sheet pile sections of the existing under-wharf bulkhead will be cut off, with portions below ground surface abandoned in place, and a new sheet pile wall installed just waterward of the existing bulkhead. Timber piles associated with the timber sections of existing bulkhead will be fully extracted to the extent practical, and above-ground timber lagging will be removed. Locations of the proposed elements are depicted on Figure 1, below.

Because of the complexity of this proposed action, we incorporate by reference Sections 2 and 5 of the BE, which contains the descriptions of:

- project location,
- timing,
- elements and construction methods, and
- conversation measures/best management practices (BMPs).

However, additional information provided by the Port (D. Butsick, electronic communication) supplements or modifies some elements. Per electronic communication with the Port, the dimensions and volumes in the BE are superseded by the final design drawings (Port 2023b), as the BE used approximations, while the design drawings have the most detailed and accurate figures to date (D. Butsick, electronic communication May 19, 2023). These are described below.

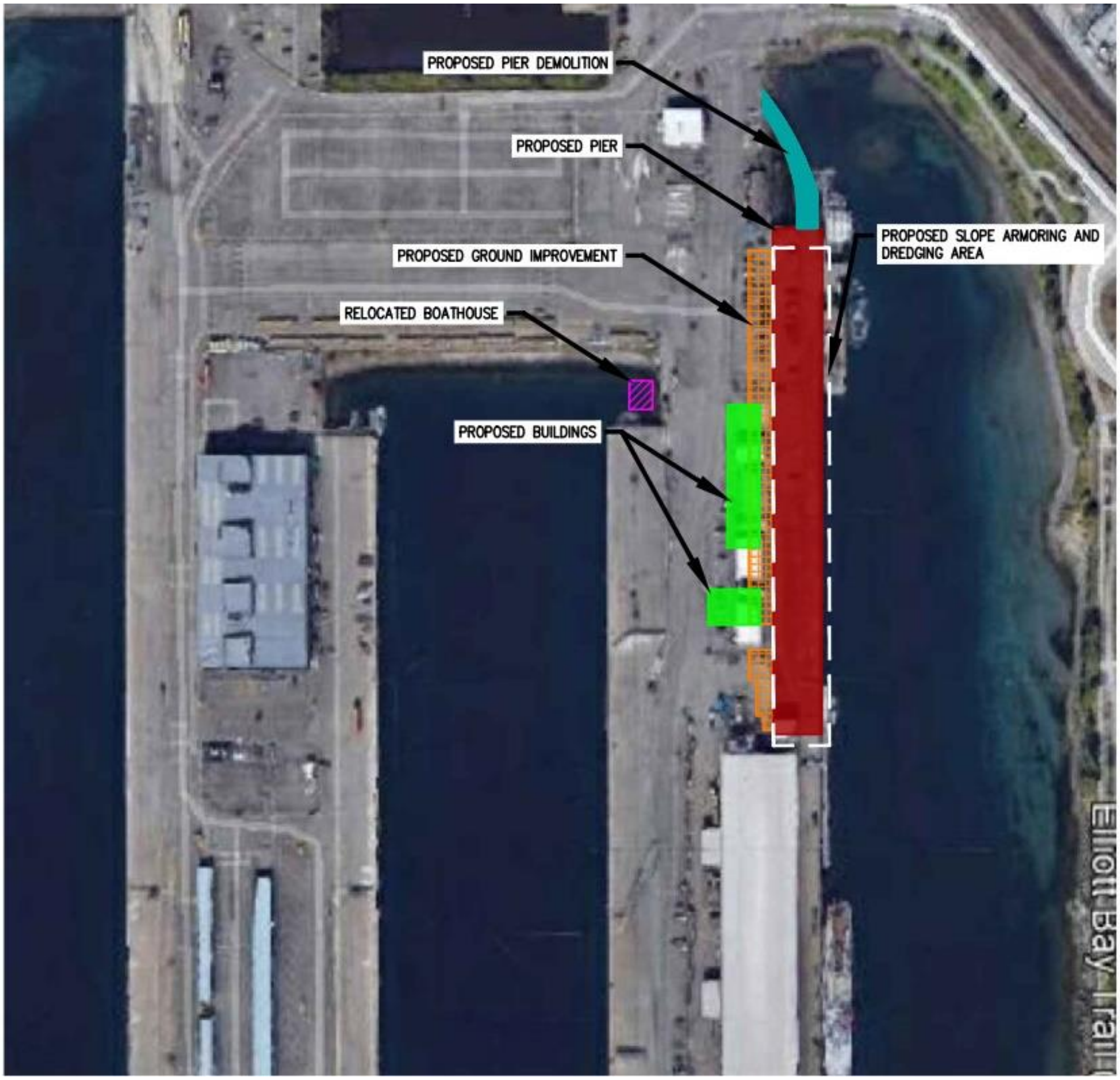

Figure 1. Terminal 91 redevelopment site map. Source: Port of Seattle 2021.

1.3.1. Proposed Action Elements and Construction Methods

Wharf Replacement

Wharf replacement will occur above the lower shore zone (LSZ; +5 feet MLLW to -10 feet MLLW) and deep shore zone (DSZ; -10 feet MLLW and deeper) in the waterway east of Pier 90. Construction is expected to occur throughout the full approved work windows. Components of the wharf replacement will include:

- remove approximately 55,042 square feet (SF) of solid existing timber wharf, 154 SF of derelict pier, and 9,640 SF of rail spur and jut-out pier areas, and

- install 53,509 SF new wharf comprised of pre-cast concrete decking.

The new concrete wharf will be 725 feet long with 25-foot spacing between cast-in-place concrete pile cap bents. The pile cap bents will support pre-cast concrete deck panels and a cast-in-place or precast concrete bull rail. The precast concrete panels will be overlain by asphalt concrete.

Small Boat Storage and Float System Removal/Relocation

The Port proposes to remove the small boat storage and float system from its existing location above LSZ and DSZ in waterway east of Pier 90 (northeast corner of Terminal 91) and relocate some components to Berth 7 above LSZ and DSZ in waterway west of Pier 90 (northwest corner of Pier 90). Construction is expected to occur throughout the full approved work windows. Removal/relocation of the small boat storage and float system would include:

- relocate the 1,590 SF solid small boat storage float to the west side of Pier 90, and
- remove 911 SF of the 100 percent grated gangway and access float system, and reconfigure/relocate 275 SF of those components on the east side of Pier 90.

The floats and small boat storage will be anchored/affixed to the existing pier and guide piles using steel pile collars with abrasion resistant surfaces.

Pile Removal/Replacement

Proposed pile work associated with the wharf replacement and small boat storage and float system removal/relocation includes the following elements:

- Remove approximately 2,489 14-inch diameter creosote-treated timber pile in one of two ways:
    - When no conflict occurs with location of new pile, creosote-treated timber pile will be cut at the top of the subgrade and removed in order to maintain slope stability.
    - Conflicting pile will be extracted by crane by using a vibratory hammer. Pile will be cut by divers equipped with chainsaws or by biting with a dredge bucket, and pile and timber decking will be removed using land-based and/or floating crane barges for disposal at an approved upland facility. A debris boom will be installed around the work area in order to contain any floating debris produced during the demolition and new construction work.
- Install a total 320 piles, including:
    - 64 20-inch steel fender pile with full-round 24-inch diameter high density polyethylene sheaths
    - 6 20-inch steel pipe guide and mooring pile
    - 240 24-inch concrete octagonal pile
    - 5 24-inch steel pipe guide pile
    - 2 24-inch steel pipe float guard pile
    - 3 36-inch steel pipe float guard pile

Prestressed concrete pile will be installed to support the new wharf apron. Steel fender pile will be primarily installed using a vibratory hammer, though impact driving may be required to achieve final tip elevation. New guide pile will primarily be installed using a vibratory hammer, though impact driving may be required to achieve final tip elevation.

Slope Excavation and Armoring Replacement

Slope excavation and armor replacement will occur below 0 feet mean lower low water (MLLW) in the waterway east of Pier 90. Armor removal is estimated to take 15 days, and armor replacement is estimated to take 45 days. Replacement of primarily under-wharf slope armoring will include the following components:

- removal of 25,000 cubic yards (CY) of existing material on the slope (riprap, sediment, and debris) within a 67,660 SF area, and
- installation of 13,000 CY of fill within a 67,660 SF area, including:
    - 1-foot thickness of quarry spalls,
    - 3-foot thickness of heavy riprap,
    - 8-inch equivalent width fish mix containing 50% sand to fill the voids (above -10 feet MLLW).

The top of the toe of the new armoring will be placed at -39 feet MLLW and will be a total of 4-feet thick to provide scour protection and stability. The armoring will be installed to a 2H:1V slope between approximately +6.16 feet and -10 feet MLLW, then to a 1.75H:1V slope between -10 and -39 feet MLLW. The area will be excavated to a subgrade depth that will allow installation to a 1-foot thickness of quarry spalls and a 3-foot thickness of riprap.

The Terminal 91 site is under an administrative cleanup order action in accordance with the Model Toxics Control Act (MTCA) regulations. A remedial investigation (RI) is being conducted under an Agreed Order between the Port and WDOE (No. DE24768) to determine a final cleanup action. The RI report is currently in progress, but studies to date have confirmed that historical activities resulted in sediment contamination in the vicinity of the piers. Polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and mercury are the primary constituents of concern in sediment in the Berth 6 & 8 project area. Thus, sediment removal for this proposed action has been approved by WDOE as an ‘interim cleanup action’.

The interim action work plan (Port 2023c) was developed to present and characterize the proposed redevelopment action through the MTCA lens in the absence of a final RI and feasibility study. The work plan specifies that after slope excavation is complete, the contractor will conduct sampling of both the newly exposed slope and the stockpiled excavated material prior to offsite disposal. The contractor will submit a Dredging and Disposal Work Plan (DDWP) to address activities associated with dredge work, including disposal means and methods. The DWWP will be submitted to the Port Engineer at least 60 days prior to dredging, and must be reviewed and approved by the Port and WDOE. Disposal options are determined by sediment quality testing (Puget Sound Dredged Disposal Analysis); clean materials are disposed of in established in-water disposal sites governed by Puget Sound DMMP (Dredged Material Management Program) regulations. Contaminated material is disposed of in upland facilities.

Sheet Pile Wall Replacement

The sheet pile wall is positioned at the top of the slope under the wharf, extending approximately 729 linear feet (LF) under the wharf and 13 LF north beyond the wharf edge. Sheet pile wall replacement will take place above 0 feet MLLW in the waterway east of Pier 90.

Removal of the exposed existing bulkhead is estimated to take 60 days, and replacement of the existing bulkhead will be performed concurrently over approximately 42 days. This replacement will include the following components:

- Remove the top approximately 4 feet of the existing bulkhead 742 LF above the mudline and capping. The existing bulkhead type varies along the length and consists of either steel sheet pile, tied back creosote treated timber, or tied back creosote treated timber with a concrete fascia. Creosote pile will be fully extracted to the extent practical, and all above-ground timber lagging will be removed.
- Install steel sheet pile with approximately 6 feet of exposed height directly adjacent (waterward) of the 742 LF existing abandoned wall.

Sheet pile driving will be conducted in the dry whenever possible. Installation of the new sheet pile wall will be conducted primarily using a vibratory hammer, though impact driving may be required to achieve final depths. Removed material will be disposed of at an approved upland facility.

Construction Vessels

Specific construction vessel support for the proposed action was considered based on the following information in the BE:

- The wharf will be constructed utilizing floating derrick barges, support barges, and assisting tugs.
- Floats will be removed and reinstalled in the new location using land-based and/or floating crane barges.
- Excavation/dredging of the excess slope material and installation of new slope armoring will be conducted using land-based and/or barge-mounted excavators or a clamshell bucket and barge derrick.
- Cutting and removal of the exposed portion of the existing bulkhead will be done by crews on upland or barge mounted equipment and land-based or crane-mounted excavators.

Based on this information, and electronic communication from the Port (D. Butsick, 2023), at least one barge and one tug are expected at the proposed action site for up to a full year in order to support both in- and overwater construction elements during the work windows and ongoing upland construction outside of in-water work window. Construction staging vessels are expected to tie off to existing infrastructure where possible; however, crane barges are expected to spud down and remain in place for the duration of the project.

Stormwater Upgrades

The Port proposes to consolidate the 8 existing stormwater conveyances discharging to the project area above 0 feet MLLW on Berths 6 & 8 wharf face. A single new 18-inch outfall will be installed to provide basic stormwater treatment in compliance with WDOE, City of Seattle, and Port stormwater treatment standards.

Offsetting Activities

A number of activities included in the proposed action can result in the loss of nearshore long-term habitat functions and values to ESA listed species and their designated critical habitat. Long-term adverse effects on nearshore habitat from the proposed activities will be offset with an equal (or greater) amount of conservation offsets (compared to project effects/debits). Offsetting activities incorporated into the proposed project include

- removal of creosote-treated timber pile and bulkhead materials (estimated 3,334 tons),
- reduction of in-water structures (i.e., pile, -1,711 SF),
- reduction of overwater cover (-11,964 SF),
- debris removal, and
- installation of basic stormwater treatment.

These offsetting activities are intended to offset the loss of long-term ecosystem functions from the project actions, with the goal of achieving a no-net-loss of long-term habitat function as a result.

The NMFS' Puget Sound Nearshore Calculator (Nearshore Calculator) can be used to ensure the proposed action balances impacts on long-term nearshore habitat function. Beneficial and detrimental attributes of the proposed federal action have been entered in the Nearshore Calculator to determine if impacts on long-term nearshore habitat function are balanced. The Nearshore Calculator summary sheet is provided in Appendix A.

If following construction, the proposed offsets are found to result in a negative value in the Nearshore Calculator (most likely due to fewer tons of creosote removed than projected), the applicant will implement a habitat improvement plan offset those remaining debits within 3 years, within the South-Central Puget Sound Partnership service area. The Port has proposed two[1] potential projects to achieve these offsets. If this becomes necessary, the Port will contact NMFS to determine the valuation of those proposed projects prior to submission for appropriate ESA consultation. It is possible, though, that any necessary offsets might also be purchased through Puget Sound Partnership or a conservation bank.

[1] Two piling removal projects are planned within the next three years – Pier 34 Pile Removal Project and Jack Block Pier Removal Project. Both will remove a substantial number of creosote-treated timber pilings and overwater structures from the East Waterway and Elliott Bay, respectively.

1.3.2. Best Management Practices

General Measures

- In-water work will occur during the designated work window when juvenile salmonids are absent or present in very low numbers.
- Care will be taken to prevent any petroleum products, chemicals, or other toxic or deleterious materials from entering the water. Fuel hoses, oil drums, oil or fuel transfer valves and fittings, etc., will be checked regularly for drips or leaks, and shall be maintained and stored properly to prevent spills into waters. Proper security shall also be maintained to prevent vandalism.
- Vegetable-based hydraulic fluid will be used in pile driving equipment.
- The contractor will have a spill containment kit, including oil-absorbent materials, on site to be used in the event of a spill or if any oil product is observed in the water.
- If a spill were to occur, work would be stopped immediately, steps would be taken to contain the material, and appropriate agency notifications would be made. The contractor is responsible for the preparation of spill response and hazardous material control plans to be used for the duration of project construction.
- Spills and/or conditions resulting in distressed or dying fish shall be reported immediately to WDOE's Northwest Regional Spill Response Office at (425) 649-7000 (a 24-hour phone number), the Washington Emergency Management Division at 1-800-OILS-911, and the National Response Center at 1-800-424-8802.
- If fish are observed in distress or a fish kill occurs, work would be stopped immediately. Washington Department of Fish and Wildlife (WDFW), WDOE and other necessary agencies would be contacted and work would not resume until further approval is given.
- A marine mammal monitoring plan will be carried out during in-water work.

Pile Removal/Installation Water Quality Measures

- The applicant's contract specifications for pile removal and disposal incorporate Best Management Practices for Pile Removal and Placement in Washington State (2016) promulgated by the EPA.
- No pile treated with AZCA, creosote, pentachloraphenol, or coal tar will be used. The project would result in a reduction of creosote-treated timber pile.
- A boom will be installed around the work area prior to removal of the timber piling and related structures to contain and collect debris. Debris will be disposed of at an approved upland location.
- Hydraulic water jets will not be used to remove or place piling.
- Every effort will be made to minimize release of adhering sediments when extracting fender piling that are pulled from the water and placed on receiving barge or on the adjacent concrete cargo pier deck.
- All treated wood will be contained on land or barge during and after removal to preclude sediments and any contaminated material from re-entering the aquatic environment.
- Treated piling will be fully extracted or cut at the mudline; holes or piling stubs will be covered with a new riprap layer.

- Piling will be replaced in same general location, and pile will not extend beyond the footprint of existing structure.

Turbidity from Pile Cutting

- Where possible, extraction equipment for vibratory extraction or lifting of cut pile will be kept out of the water to avoid "pinching" pile below the water line in order to minimize creosote release during extraction.
- The work surface on barge deck or pier shall include a containment basin for pile and any sediment removed during pulling. Any sediment collected in the containment basin will be disposed of at an appropriate upland facility, as will all components of the basin (e.g., straw bales, geotextile fabric) and all pile removed.
- All pile removed will be disposed of at an appropriate upland facility.

Pile Removal/Installation Noise Abatement

- Vibratory hammer installation is the preferred method to minimize the generation of potentially injurious sound. Impact pile driving would be limited to proofing of structural pile.
- Noise attenuation measures (i.e., bubble curtain) will be employed for impact-driving of all steel pile.
- Pile caps will be used for all driving of concrete pile.
- Sheet pile driving will be conducted in the dry (at low tide) whenever possible.
- For projects that produce underwater noise within the range known to cause ‘disturbance’ of cetaceans, qualified biologists will be stationed at appropriate points to ensure that work is stopped if marine mammals enter the project area, consistent with the proponent’s marine mammal monitoring plan.

1.3.3. Project Timing

In-water work is expected to take approximately two and a half authorized in-water work windows to complete. In Tidal Reference Area 5, the WDOE-approved work window is August 1 through February 15 (198 days) for all work except dredging, and September 1 through February 15 (167 days) for dredging in areas outside the Duwamish Waterway (such as is proposed in this action).

Estimated workdays represent the number of days in which work may occur. Work may not be consecutive, and activities may occur with breaks over the full in-water work windows.

- creosote pile removal is expected to take 50 total days, with vibratory and saw removal performed concurrently,
- concrete pile will be impact driven with an estimated installation production rate of approximately 3 pile per day over approximately 100 work days,
- steel fender pile installation estimated production rate is 8 pile per day over approximately 13 work days,
- steel guide pile estimated production rate is 8 pile per day over approximately 0.5 work days, and

- sheet pile wall installation estimated production rate is approximately 20 LF of wall per day for approximately 42 work days.

1.3.4. 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 for the proposed action includes greatest extent of the area of effects associated with the temporary construction-related effects, ongoing operational effects, and long-term effects of structures.

For the proposed action, there are short-term construction-related effects, operational effects associated with the continued use of the replacement structures, and long-term (or enduring) effects caused by the replacement of the in- and overwater structures. The most far-reaching effects of the proposed action are operational effects from perpetuation of fishing vessels that utilize the berth. Because the primary purpose of berth rehabilitation is to provide moorage for commercial fishing vessels, it is reasonably certain that the structure will generate future commercial fishing vessel operation. Intermittent biological effects (i.e., sound or collision) associated with these fishing vessels are expected to occur to listed species anywhere vessels are underway.

To reach the terminal, vessels must travel south from the entrance to the Strait of Juan de Fuca, through Admiralty Inlet, and into Elliott Bay. Commercial vessels traveling this route follow well-defined navigation lanes known as the Traffic Separation Scheme (TSS), monitored by the U.S. Coast Guard (USCG) and the Canadian Coast Guard (CCG), and recognized by the International Maritime Organization (WDOE 2009). While it is impossible to predict the exact course of each individual commercial fishing vessel utilizing the berth, it is reasonable to assume they will travel between the Strait of Juan de Fuca to Elliott Bay via Admiralty Inlet in the established TSS lanes to unload their catch. Outside of the Puget Sound navigation lanes, the location of the vessels is variable to the degree that an analysis of co-occurrence of vessels with listed species is speculative. Therefore, the Action Area for this proposed action is defined by the geographic range of the TSS in marine waters of Puget Sound between the entrance to the Strait of Juan de Fuca and Elliott Bay (Figure 2).

The action area includes Puget Sound Chinook Salmon, Puget Sound Steelhead, Southern Resident Killer Whale, bocaccio and yelloweye rockfish and critical habitat for each of these species.

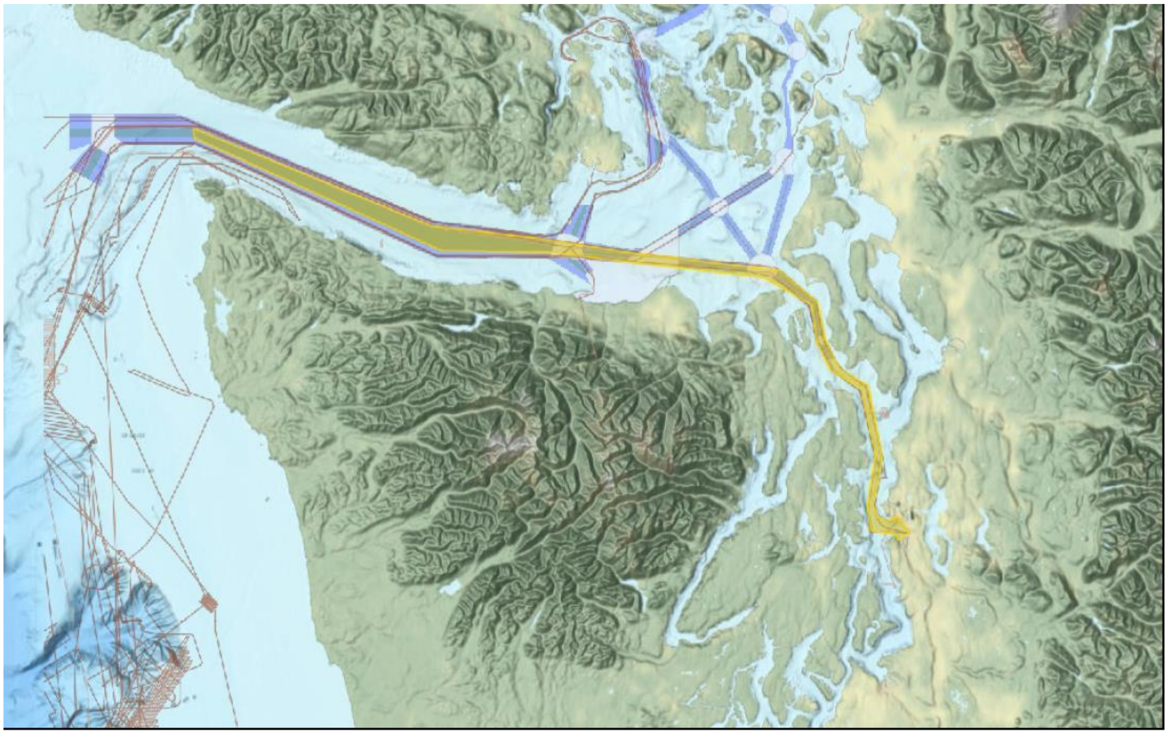

Figure 2. The approximate action area is highlighted in the yellow polygon. The geographic extent of the Action Area shown here is defined by commercial shipping lanes from Seattle to the entrance of the Strait of Juan de Fuca (purple polygons; USCG 2024) and actual commercial vessel traffic data (red lines; NOAA 2024).

Effects from temporary construction, operational stormwater treatment, and long-term impacts are more spatially constrained to the area adjacent to construction. The extent of these effects is considered to be the Terminal 91 waterway, extending into Elliott Bay approximately 4 miles south into a portion of the West Waterway at the mouth of the Lower Duwamish, as defined by the extent of the area directly affected by underwater noise from impact driving of 36-inch steel piles. This will be referred to throughout this document as the "project area". Within the project area, the Green River populations of PS Chinook and PS steelhead are expected to be the most prevalent fish populations exposed to project effects. Green River fall Chinook are a priority prey species for SRKW.

2. ENDANGERED SPECIES ACT 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 to 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.

The COE determined the proposed action is not likely to adversely affect Puget Sound-Georgia Basin DPS (PS/GB) bocaccio rockfish (*Sebastes paucispinis)*, PS/GB yelloweye rockfish (*Sebastes ruberrimus)*, and Southern Resident killer whale (SRKW; *Orcinus orca*) or their critical habitat, and humpback whale (*Megaptera novaeangliae*). No determination was provided for PS steelhead critical habitat. The COE did not indicate humpback whale DPS, but the listed entities are CAM and MEX. The COE determined no effect for humpback whale critical habitat. Our concurrence with the COE's determination on humpback whale, and yelloweye rockfish and their critical habitat, is documented in the "Not Likely to Adversely Affect" Determinations section (Section 2.13). We disagree with the COE's effect determination for SRKW and bocaccio rockfish, and on PS Chinook salmon, bocaccio, and SRKW critical habitat, which we analyze in this Opinion along with PS steelhead critical habitat.

2.1. Analytical Approach

This biological 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 biological opinion also relies on the regulatory 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 PS steelhead critical habitat use(s) the term primary constituent element (PCE) or essential features. The 2016 final rule (81 FR 7414; February 11, 2016) that revised the 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 biological opinion, we use the term PBF to mean PCE or essential feature, as appropriate for the specific critical habitat.

The ESA Section 7 implementing regulations define effects of the action using the term "consequences" (50 CFR 402.02). As explained in the preamble to the final rule revising the definition and adding this term (84 FR 44976, 44977; August 27, 2019), that revision 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 critical 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.

For this consultation, NMFS also evaluated the proposed action using a Habitat Equivalency Analysis (HEA)[2] and the Puget Sound Nearshore Habitat Values Model (NHVM) that we adapted from Ehinger et al. (2015). We developed an input calculator ("Nearshore Calculator") that serves as a user-accessible interface to simplify model use. Ecological equivalency that forms the basis of HEA is a concept that uses a common currency to express and assign a value to functional habitat loss and gain. Ecological equivalency is traditionally a service-to-service approach where the ecological functions and services for a species or group of species lost from an impacting activity are fully offset by the services gained from a conservation activity. In this case, we use this approach to calculate the "cost" and "benefit" of the proposed action, as well as the effects of the existing environmental baseline into the future, using the NHVM.

The NHVM includes a debit/credit factor of two applied to new structures to account for the fact that impacts on unimpaired habitat have been found to be more detrimental than future impacts to already impaired habitat at sites with existing structures (Roni et al. 2002). To rephrase, given the current condition of nearshore habitat, impacts from new structures on relatively unimpaired habitat would be, for example, more harmful than impacts resulting from the repair or replacement of existing structures, and the model accounts for this difference.

NMFS developed the NHVM based specifically on the designated critical habitat of listed salmonids in Puget Sound, scientific literature, and our best professional judgement. The model,

[2] A common "habitat currency" to quantify habitat impacts or gains can be calculated using Habitat Equivalency Analysis (HEA) methodology when used with a tool to consistently determine the habitat value of the affected area before and after impact. NMFS selected HEA as a means to identify section 7 project related habitat losses, gains, and quantify appropriate mitigation because of its long use by NOAA in natural resource damage assessment to scale compensatory restoration (Dunford et al. 2004, Thur 2006) and extensive independent literature on the model (Milon and Dodge 2001, Cacela et al. 2005, Strange et al. 2002). In Washington State, NMFS has also expanded the use of HEA to calculate conservation credits available from fish conservation banks (NMFS 2008a, NMFS 2015), from which "withdrawals" can be made to address mitigation for adverse impacts to ESA species and their designated CH.

run by inputting project specific information into the Nearshore Calculator, produces numerical outputs in the form of conservation credits and debits. Credits (+) indicate positive environmental results to nearshore habitat quality, quantity, or function. Debits (-) indicate a loss of nearshore habitat quality, quantity, or function. The model can be used to assess credits and debits for nearshore development projects and restoration projects; in the past, we have used this approach in the Structures in Marine Waters Programmatic consultation (NMFS 2016a

Use of the NHVM requires an assumption of the amount of time the proposed structure, and thus the resulting habitat impacts, will persist. For this consultation and consistent with our application in NMFS 2020 and 2021b batched biological opinions on COE actions, we have applied an assumption that structures are serviceable for approximately 40 years[3] before requiring an additional action to maintain their structural integrity (this terminal was last rehabilitated 37 years ago) .

As explained above, model outputs for new or expanded projects account for impacts to an undeveloped environment and are calculated at a higher debit rate (2 times greater) than those calculated for replace/repair projects, that assume that some function has already been lost from the existing structure. Outputs from the NHVM account for the following consequences of the proposed action:

- Beneficial aspects of the proposed action, including any positive effects that would result from reduction of overwater coverage, in-water structures, creosote removal, and reduction of armoring.
- Minimization incorporated through project design improvements (e.g., credit is given for grating over water structures).
- Adverse effects that would occur from the replacement over water structures, the persistence of existing relocated over water structures, pile installation, and shoreline stabilization.

Appendix A contains a summary sheet of the Nearshore Calculator that displays entries for overall long-term habitat impacts (beneficial and detrimental) caused by the proposed project.

2.2. Rangewide Status of the Species and Critical Habitat

This Opinion examines the status of each species that is likely to 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' "reproduction, numbers, or distribution" for the jeopardy analysis. 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 function of the PBFs that are essential for the conservation of the species.

[3] Assumption based on available input parameters of the NHVM model.

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 2022). Long-term trends in warming have continued at global, national and regional scales. Global surface temperatures in the last decade (i.e., 2010's) were estimated to be 1.09 degrees Celsius (°C) higher than the 1850 to1900 baseline period, with larger increases over land (~1.6 °C) compared to oceans (~0.88 °C; IPCC WGI 2021). The vast majority of this warming has been attributed to anthropogenic releases of greenhouse gases (IPCC WGI 2021). Globally, 2014 to 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 to 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 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 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 2011; Crozier 2012; Crozier 2013; Crozier 2014; Crozier 2015; Crozier 2016; Crozier 2017; Crozier and Siegel 2018; Siegel and Crozier 2019; Siegel and Crozier 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 through 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 to 2015 (0.18 to 0.35°C/decade) and 1976 to 2015 (0.14 to 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 percent), while 68 percent 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. 2019a), 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. 2016a; 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. 2020). 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 Evolutionary Significant Unit or Distinct Population Segments (ESU or DPS, respectively) with early-returning (i.e. spring- and summer-run) phenotypes associated with longer freshwater holding times (Crozier et al. 2020; 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 (Burke et al. 2013; Holsman et al. 2012). 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 salmon 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 et al. 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 salmon 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 et al. 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).

2.2.1. Status of the Species

Table 1 provides a summary of listing and recovery plan information, status summaries and limiting factors for the species addressed in this opinion. More information can be found in recovery plans and status reviews for these species. Acronyms appearing in the table include DPS (Distinct Population Segment), ESU (Evolutionarily Significant Unit), ICTRT (Interior Columbia Technical Recovery Team), MPG (Multiple Population Grouping), NWFSC (Northwest Fisheries Science Center), TRT (Technical Recovery Team), and VSP (Viable Salmonid Population).

Table 1. Listing classification and date, recovery plan reference, most recent status review, status summary, and limiting factors for each species considered in this opinion. Listed documents are incorporated by reference.

Species	Listing Classification and Date	Recovery Plan Reference	Most Recent Status Review	Status Summary	Limiting Factors
Puget Sound Chinook salmon	Threatened 6/28/05 (70 FR 37159)	Shared Strategy for Puget Sound 2007 NMFS 2006	NMFS 2017a; Ford 2022	This ESU comprises 22 populations distributed over five geographic areas. All Puget Sound Chinook salmon populations continue to remain well below the TRT planning ranges for recovery escapement levels. Most populations also remain consistently below the spawner–recruit levels identified by the TRT as necessary for recovery. Across the ESU, most populations have increased somewhat in abundance since the last status review in 2016, but have small negative trends over the past 15 years. Productivity remains low in most populations. Overall, the Puget Sound Chinook salmon ESU remains at "moderate" risk of extinction.	• Degraded floodplain and in-river channel structure • Degraded estuarine conditions and loss of estuarine habitat • Degraded riparian areas 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 • Severely altered flow regime
Puget Sound steelhead	Threatened 5/11/07	NMFS 2019	NMFS 2017a; Ford 2022	This DPS comprises 32 populations. Viability of has improved somewhat since the PSTRT concluded that the DPS was at very low viability, as were all 3 of its constituent MPGs, and many of its 32 DIPs (Hard et al. 2015). Increases in spawner abundance were observed in a number of populations over the last five years within the Central & South Puget Sound and the Hood Canal & Strait of Juan de Fuca MPGs, primarily among smaller populations. There were also declines for summer- and winter-run populations in the Snohomish River basin. In fact, all summer-run steelhead populations in the Northern Cascades MPG are likely at a very high demographic risk.	• Continued destruction and modification of habitat • Widespread declines in adult abundance despite significant reductions in harvest • Threats to diversity posed by use of two hatchery steelhead stocks • Declining diversity in the DPS, including the uncertain but weak status of summer-run fish • A reduction in spatial structure • Reduced habitat quality • Urbanization • Dikes, hardening of banks with riprap, and channelization

Species	Listing Classification and Date	Recovery Plan Reference	Most Recent Status Review	Status Summary	Limiting Factors
Puget Sound/ Georgia Basin DPS of Bocaccio	Endangered 04/28/10	NMFS 2017b	NMFS 2016b	Though 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 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 bocaccio in the Main Basin and South Sound represents a further reduction in the historically spatially limited distribution of bocaccio, and adds significant risk to the viability of the DPS.	• Over harvest • Water pollution • Climate-induced changes to rockfish habitat • Small population dynamics
Southern resident killer whale	Endangered 11/18/05	NMFS 2008b	NMFS 2022a	The Southern Resident killer whale DPS is composed of a single population that ranges as far south as central California and as far north as southeast Alaska. While some of the downlisting and delisting criteria have been met, the biological downlisting and delisting 63 criteria, including sustained growth over 14 and 28 years, respectively, have not been met. The SRKW DPS has not grown; the overall status of the population is not consistent with a healthy, recovered population. Considering the status and continuing threats, the Southern Resident killer whales remain in danger of extinction.	• Quantity and quality of prey • Exposure to toxic chemicals • Disturbance from sound and vessels • Risk from oil spills

2.2.2. Status of the Critical Habitat

This section describes the status of designated critical habitat affected by the proposed action by examining the condition and trends of the essential physical and biological features (PBFs) of that habitat throughout the designated areas. These features are essential to the conservation of the ESA-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).

For most salmon and steelhead, NMFS's critical habitat analytical review teams (CHARTs) 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 ESA-listed species that they support (NMFS 2005). The conservation rankings were high, medium, or low. To determine the conservation value of each watershed to species viability, the CHARTs evaluated the quantity and quality of habitat features, 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. Even if a location had poor habitat quality, it could be ranked with a high conservation value if it were essential due to factors such as limited availability, a unique contribution of the population it served, or is serving another important role.

Critical habitat for PS Chinook salmon, PS steelhead, GB/PS bocaccio rockfish, and SRKW is designated within portions of the Action Area.

NMFS reviews effects on critical habitat by examining how the PBFs of critical habitat will be altered, 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. Whether or not habitat is designated as critical, the full range of the Action Areas provides accessible habitat to the various listed species considered in this opinion, and it is certain that the features of the habitat, will be altered either temporarily, or for the foreseeable future. Given the mixture of critical and non-critical habitat within the Action Areas, in the following section, we will review effects to all habitat features, whether or not the habitat is designated as critical, as this analysis is foundational to our review of the effects of the proposed action on the listed species themselves.

Chinook salmon critical habitat in nearshore marine area, from the line of extreme high tide out to a depth of 30 meters, is present in the Action Area. The nearshore environment supports various life stages of PS Chinook salmon including growing and sexually maturing adults, migrating spawners, and rearing and growing juveniles.

Steelhead critical habitat includes 2,031 stream miles. Nearshore and offshore marine waters were not designated for this species. Steelhead river or stream critical habitat for migration is present in a portion of the Action Area within the West Waterway, an estuary where saltwater from the sound and freshwater from the Duwamish River mix. Water levels and salinity here fluctuate with the tide and amount of water in the river. The Action Area coincides with approximately 30 acres of PS steelhead critical habitat within the final 0.41 miles of West Waterway prior to the terminus in Elliott Bay.

Cumulatively, the associated salmonid critical habitat PBFs present in portions of the Action Area that apply to these 2 species include:

4. Estuarine areas free of obstruction and excessive predation with:
(i) Water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh- and saltwater;
(ii) Natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels; and
(iii) Juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation.

5. Nearshore marine areas free of obstruction with water quality and quantity conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation; and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels.

Both marine deepwater and nearshore bocaccio critical habitat are designated in portions of the Action Area. Rockfish critical habitat features are distinguished between species and between adults and juveniles, as each species and life history stage have different location and habitat needs. Juvenile settlement habitats 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. PBFs essential to the conservation of juvenile bocaccio rockfish 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.

Benthic habitats or sites deeper than 98 feet that possess or are adjacent to areas of complex bathymetry consisting of rock and or highly rugose habitat. PBFs essential to the conservation of adult bocaccio rockfish include:

1. Quantity, quality, and availability of prey species to support individual growth, survival, reproduction, and feeding opportunities.
2. Water quality and sufficient levels of dissolved oxygen to support growth, survival, reproduction, and feeding opportunities.
3. The type and amount of structure and rugosity that supports feeding opportunities and predator avoidance.

Marine critical habitat for SRKW is present within the Action Area in depths 6.1 meters or greater relative to extreme high water. The PBFs essential to SRKW conservation and recovery existing within the Action Area 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.
3. Passage conditions to allow for migration, resting, and foraging.

A summary of the status of critical habitats considered in this Opinion is provided in Table 2 below

Table 2. Critical habitat, designation date, federal register citation, and status summary for critical habitat considered in this opinion

Species	Designation Date and Federal Register Citation	Critical Habitat Status Summary
Puget Sound Chinook salmon	9/02/2005 70 FR 52630	Critical habitat for Puget Sound Chinook salmon includes 1,683 miles of streams, 41 square mile of lakes, and 2,182 miles of nearshore marine habitat in Puget Sounds. The Puget Sound Chinook salmon ESU has 61 freshwater and 19 marine areas within its range. Of the freshwater watersheds, 41 are rated high conservation value, 12 low conservation value, and eight received a medium rating. Of the marine areas, all 19 are ranked with high conservation value.
Puget Sound steelhead	2/24/2016 81 FR 9252	Critical habitat for Puget Sound steelhead includes 2,031 stream miles. Nearshore and offshore marine waters were not designated for this species. There are 66 watersheds within the range of this DPS. Nine watersheds received a low conservation value rating, 16 received a medium rating, and 41 received a high rating to the DPS.
Puget Sound/Georgia Basin DPS of bocaccio	11/13/2014 79 FR68042	Critical habitat for bocaccio includes 590.4 square miles of nearshore habitat and 414.1 square miles of deepwater habitat. Critical habitat is not designated in areas outside of United States jurisdiction; therefore, although waters in Canada are part of the DPSs' ranges for all three species, critical habitat was not designated in that area. Based on the natural history of 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; 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 as specific threats to rockfish habitat in the Georgia Basin.
Southern resident killer whale	08/02/2021 86 FR 41668	Critical habitat includes approximately 2,560 square miles of marine inland waters of Washington: 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. Six additional areas include 15,910 square miles of marine waters between the 20-feet (6.1-meter (m)) depth contour and the 656.2-feet (200-m) depth contour from the U.S. international border with Canada south to Point Sur, California. We have excluded the Quinault Range Site. Based on the natural history of the Southern Residents and their habitat needs, NMFS identified three PCEs, or physical or biological features, essential for the conservation of Southern Residents: 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 Water quality in Puget Sound, in general, is degraded. Some pollutants in Puget Sound persist and build up in marine organisms including Southern Residents and their prey resources, despite bans in the 1970s of some harmful substances and cleanup efforts. The primary concern for direct effects on whales from water quality is oil spills, although oil spills can also have long-lasting impacts on other habitat features In regards to passage, human activities can interfere with movements of the whales and impact their passage. In particular, vessels may present obstacles to whales' passage, causing the whales to swim further and change direction more often, which can increase energy expenditure for whales and impacts foraging behavior. Reduced prey abundance, particularly Chinook salmon, is also a concern for critical habitat.

2.3. 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).

As described in Section 1.3.4, the Action Area for this proposed action is defined by the geographic range of the TSS in marine waters of Puget Sound between the entrance to the Strait of Juan de Fuca and Elliott Bay. The project area for the proposed action is considered to be the Terminal 91 waterway, extending into Elliott Bay approximately 4 miles south into a portion of the West Waterway at the mouth of the Lower Duwamish, as defined by the extent of the area directly affected by underwater noise from impact driving of 36-inch steel piles.

2.3.1 Habitat in the Action Area

Habitat in the Action Area includes portions of the Strait of Juan de Fuca (SJDF) and Salish Sea adjacent to the TSS, as well as the project area.

Habitat in the SJDF includes 217 linear miles of shoreline between Cape Flattery and Point Wilson. The waters of the SDJF link the inner Salish Sea to the Pacific Ocean, and act as an essential pathway for exchange of incoming cold, dense saltwater with freshwater from many rivers influenced by intense tidal action (Strait Ecosystem Recovery Network Local Integrating Organization [LIO] 2017). Additionally, the connectivity of the SJDF makes it critical for marine transportation since almost all vessels entering or leaving Puget Sound or Georgia Basin ports for the Pacific Ocean travel through these waters (Strait Ecosystem Recovery Network LIO 2017). Increasing commercial and residential development around urbanizing areas have introduced anthropogenic pressure on habitat in the SDJF. A total area of 65 acres of overwater structures was observed in aerial photos taken between 2013 and 2016, and armored shoreline accounts for 15.7 percent of total shoreline length (Beechie et al. 2017). Other pressure sources and stressors identified as very high priority by the Strait Ecosystem Recovery Network LIO (2017) include: marine shoreline infrastructure, including roads, railroads, and culverts; freshwater levees, floodgates, and tidegates influenced by agriculture and residential development; conversion of natural resource lands to developed areas; abstraction of surface water; onsite sewage systems; industrial infrastructure within geographically limited locations, legacy shoreline and sediment contaminants, and toxic chemicals; and, shipping lanes and oil spills.

Habitat in the Salish Sea nearshore within the Action Area, considered at the landscape scale, is generally degraded from coastal development and pollution. Throughout the Salish Sea, nearshore areas have been modified by human activity, disrupting the physical, biological, and chemical interactions that are vital for creating and sustaining the diverse ecosystems of this area. There are approximately 503,106 acres of overwater structure in the nearshore of Puget Sound (Schlenger et al. 2011) and approximately 27 percent of Puget Sound's shoreline has been modified by armoring (Simenstad et al. 2011). Habitat stressors include reduced water quality, reduced forage and prey availability, reduced quality of forage and prey communities, reduced amount of estuarine habitat, reduced quality of nearshore and estuarine habitat, and reduced condition of migration habitat due to structure noise and vessel perturbations. The input of pollutants affects water quality, sediment quality, and food resources in the nearshore and deep-water areas of critical habitat.

In the project area (i.e., the vicinity of construction), habitat conditions have been further degraded by many decades of anthropogenic modification. Terminal 91 is in a highly-modified maritime industrial area and urban waterway along the northern shoreline of Elliott Bay, Puget Sound, in Seattle, Washington. Construction will occur on easternmost Pier 90 at Berths 6 & 8, situated in the northern portion of the adjacent waterway. East to west, the waterway is approximately 87 meters (286 feet) wide at the construction area and is bound by existing infrastructure of Pier 90 to the west and the landmass adjacent to 16th Avenue West. North to south, the waterway is approximately 747 meters (0.5 miles) bound by the landmass adjacent to West Garfield Street to the north and entering Elliott Bay to the south. Deep water areas at the berth face are dredged to -28 feet (8.5 meters) MLLW. Sand, silt, and mud are the dominant substrate types.

The shoreline adjacent to the construction area is dominated by an existing wharf, riprap slopes, constructed seawalls, and bulkheads. Properties adjacent to Terminal 91 support commercial marine trade, including transportation facilities, maritime/industrial facilities, and vessel moorage. Ambient underwater noise near the facilities is estimated to be approximately 120 dB_{RMS} (Laughlin 2020).

No forage fish spawning occurs in shorelines along the construction area or are downdrift (WDOE 2023). Submerged aquatic vegetation (SAV) is not recorded within the waterway and is likely minimal (WDOE 2023). A July 2021 SAV survey showed sea lettuce around submerged debris and at approximately -40 feet MLLW, sparse *Saccharina* spp. at approximately -15 to -20 feet MLLW, and sparse bull kelp at -30 feet MLLW in the northwest portion of the project area. None of this would be disturbed by the proposed debris removal or dredging of the slope. Bull kelp and eelgrass planted as part of the Port’s 2018 Blue Carbon pilot project are present on the west side of Terminal 91, outside of the project area.

Elliott Bay is about 6 kilometers by 4 kilometers (3.7 by 2.5 miles), covering an area of about 21.4 square kilometers (8.3 square miles; Silcox et al. 1984). With the exception of Duwamish Head extending into the bay from the south, Elliott Bay has a nearly semicircular shoreline. Shoreline elevations range from 0 feet relative to the ordinary high water mark (OHWM) in unarmored areas to about -30 feet (-9 meters) relative to MLLW along the inner shoreline, which is dominated by man-made piers and seawalls. Substrate along the shoreline consists of a mix of shell hash, scattered cobbles and boulders, and silts and clays. The average tidal fluctuation is 11.3 feet (3.4 meters; NOAA 2018). The bathymetry of Elliott Bay is dominated by a submarine canyon in the center of the bay which trends in a northwest-southeast direction and debouches onto the floor of the central basin of Puget Sound (Massoth 1982). The easternmost areas of Elliott Bay are approximately 40 meters (131 feet) deep, gradually reaching depths of 200 meters (656 feet; NOAA 2011). Depths in the inner canyons range from 75 to 150 meters (246 to 492 feet). Circulation in Elliott Bay generally follows a counter-clockwise low velocity circulation pattern. Currents during flood tides tend to flow clockwise and are typically stronger than counterclockwise ebb tide currents (NOAA 2018). The principal source of freshwater is the Duwamish River, which divides into the East and West Waterways before entering the southeast corner of the bay.

Elliott Bay is contained within the major urban city of Seattle and a long-established deep-water commercial seaport. Consequently, the surrounding upland areas have been heavily impacted by more than 100 years of development. As described above, the Project Area is highly modified and developed, with over 76 percent impervious surface (WDOE 2023). The southern half of the bay is occupied by the Port of Seattle and numerous other industrial waterfront users. Nearly continuous and heavy urban and industrial development extends along the eastern shoreline of Elliott Bay north from the Duwamish Waterway to Elliott Bay Park and Trail just east of the project area. Shoreline development is classified as medium or high intensity between the western extent of the project area and the outlet of Elliott Bay (WDOE 2023). Inland land use for miles north and south of the proposed action site is nearly continuous industrial, residential, and commercial properties, as well as roads and major highways.

Water and sediment quality within the bay have been impaired by decades of urban and industrial discharges. These include sewage discharges from wastewater treatment facilities and numerous point and non-point stormwater discharges. Typical sources of noise near the project site include high levels of daily vessel traffic that include ocean-going commercial and military vessels, tug boats, commercial fishing boats, tour boats and ferries, and numerous recreational vessels. Strong tidal movement through Admiralty Inlet and Possession Sound is another contributor to ambient noise.

2.3.2 Species in the Action Area

The SJDF is utilized as a primary migration corridor for many species of fish, marine mammals, and birds that travel between the Salish Sea and the Pacific Ocean. Unique populations of raptors, marine birds, Roosevelt elk, black-tailed deer, marmots, and other mammals, as well as anadromous and resident fish, are found throughout the SJDF. The SJDF marine shoreline and nearshore contains the majority of Washington's coastal kelp resources, supporting 95 linear miles of floating kelp, 161 linear miles of non-floating kelp, and 75 linear miles of eelgrass (Strait Ecosystem Recovery Network LIO 2017). These resources, along with numerous bays and pocket estuaries, provide habitat and food for salmon, birds, marine mammals, and forage fish migrating through or otherwise inhabiting the SDJF (PSI 2023).

The Salish Sea is rich in marine, freshwater, and wetland species, including more than 100 species of seabirds, 200 species of fish, 15 marine mammal species, hundreds of plant species, and thousands of invertebrate species (Armstrong et al. 1976; Canning and Shipman 1995; Thom et al. 1976). The array of species found in the Salish Sea reflects high productivity, a wide diversity of habitats, and a unique geographic location at the interface of the northern and southern ranges for many species (Sound Science 2007).

In the project area, 1980 study found that fish abundance beneath Terminal 91 is only 20 percent as large as comparable shallow-mud sand habitats without piers (Miller et al. 1980; Nightingale and Simenstad 2001). Miller also found that riprap and pilings beneath Terminal 91 act as artificial reefs, attracting predominantly *Embiotocidae spp.* (surfperch) and *Sebastes spp*. (rockfish) with surfperch being dominant. Common fish species beneath Terminal 91 included: *Parophrys vetulus* (English sole), *Lepidopsetta bilineata* (rock sole), *Hippoglossoides elassodon* (flathead sole), *Solea* (dover sole), *Citharichthys stigmaeus* (speckled sanddab), *Cymatogaster aggregata* (shiner perch), *Rhacochilus vacca* (pile perch), *Sebastes auriculatus* (brown rockfish) and *Sebastes maliger* (quillback rockfish). Weitkamp (1982) found that fish distribution beneath Terminal 91 appeared to correlate to light availability. Juvenile salmonids feeding on the western side of the terminal (i.e., non-adjacent to the project area) were reluctant to pass under piers except where piers were open to light.

PS Chinook salmon presence is documented within West Waterway, and juveniles and adults migrate through Elliott Bay (WDFW 2023). Effects to PS Chinook salmon will most likely occur among the Green River Chinook salmon distinct independent population (DIP), specifically the fall-run Green River Chinook salmon as this population is in closest proximity to the proposed action. Despite significant investments and large-scale restoration projects, Green River Chinook salmon population abundance, productivity, diversity and spatial distribution have not improved, and in some cases have continued to decline (Water Resource Inventory Area [WRIA] 9 2021) [. Annual escapement estimates of Chinook salmon natural origin spawners returning to the Duwamish/Green River has been highly variable and decreasing since 1990 (WRIA 9 2017). The number of natural-origin spawners has been below the planning target range (1,000 to 4,200). 5 of the 10 most recent data years (WRIA 9 2021). However, the proportion of hatchery fish in the spawning grounds has ranged from 35 percent to 75 percent since 2002, and appeared to be increasing.

PS steelhead presence and migration is documented throughout the Action Area and project area (WDFW 2023). The PS steelhead DIP most likely to be present in the project area are winter or summer run steelhead from the Green River (Duwamish)DIP (WDFW 2023), which are considered ‘healthy” and “depressed”, respectively. Run timing for adult Green River winter steelhead is generally from December through mid-March, with spawning generally from early March through mid-June. Run timing for Green River summer steelhead is generally from August through December with spawning generally from mid-January through mid-March. Adult PS steelhead, like adult PS Chinook, occupy deep water and do not typically rely on nearshore habitats.

Bocaccio rockfish larvae are typically found in the pelagic zone, often occupying the upper layers of open waters, under floating algae, detached seagrass, and kelp. Rockfish larvae are thought to be mostly distributed passively by currents (Love et al. 2002), and may be broadly dispersed from the place of their birth (NMFS 2003). Therefore, rockfish larvae presence may occur in the Action Area and project area. There is no single, reliable historical or contemporary abundance estimate for the bocaccio DPS in the Puget Sound/Georgia Basin (Drake et al. 2010), and additional uncertainty in the anthropogenic and natural factors that limit their abundance (NMFS 2017b). Though bocaccio were likely never a predominant component of the multi-species rockfish abundance within the Puget Sound/Georgia Basin (Drake et al. 2010), their present-day abundance is likely a fraction of their historical abundance. In recent decades, bocaccio have been most commonly documented within the South Sound and Main Basin (Drake et al. 2010; Williams et al. 2010). Adult PS/GB bocaccio rockfish typically occupy waters deeper than 120 feet (about 36 meters) (Love et al. 2002), and prefer rocky habitats like Dalco Pass near Tacoma. This preferred habitat is scarce within the project area, and preferential use by PS/GB bocaccio rockfish is not indicated (NMFS 2016b). Because of their depth preference, adult bocaccio rockfish in the Action Area would be present at depths that attenuate many of effects, causing any exposure to impacts to occur at low intensity.

SRKW are highly mobile with an average daily travel distance of 75 miles (Center for Whale Research 2018). In Puget Sound proper, there is limited SRKW occurrence in the spring and summer and increased occurrence during the fall and early winter months (between the months of October and January; Olson et al. 2018). Their movement patterns often overlap with the occurrence and movement patterns of their primary prey base, especially Chinook salmon, but are only somewhat predictable. While there may be areas within Puget Sound and the Strait of Juan de Fuca that the whales prefer, they are capable of occupying and traveling through any area. Because of their relatively large size, they do not typically enter waters less than 30 feet deep. Thus, SRKWs could be present when proposed action work will occur, especially from October through January, but are unlikely to occur in the vicinity of construction due to limited depth and vessel traffic.

Critical habitat is designated within portions of the Action Area for PS Chinook salmon, PS steelhead, PS/GB bocaccio rockfish, and SRKW. The past and ongoing anthropogenic impacts described above have impacted ESA-listed species and their critical habitats by reducing the quantity and quality of migratory and rearing habitat, including reduced water quality caused by the introduction of pollutants related to upland development and vessel operations.

2.4. 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 (see 50 CFR 402.02). 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 the factors set forth in 50 CFR 402.17(a) and (b).

Temporary effects are typically associated with construction or maintenance activities, and in this Opinion are applicable for both proposed infrastructure and offsetting activities. Stressors to species from activities covered in this Opinion will vary depending on their location relative to a listed individual and their duration, frequency, and intensity. Because BMPs will be implemented to limit effects to noise, water quality, and benthic habitat, the analysis is for those effects that occur despite the implementation of BMPs. The following temporary stressors (habitat reductions) were analyzed:

a) underwater noise (pile work and construction vessels),
b) suspended sediment and reduced dissolved oxygen (DO),
c) contaminant exposure,
d) reduced forage, and
e) obstructions in migration areas

The temporary stressors identified with each activity are listed in Table 3. We analyze each stressor in this section based on its extent, the risk of potential exposure to individuals of each species, and their anticipated responses. For each stressor and for each species, where exposure will occur, we evaluate the response of species to that exposure.

An additional construction effect on fish that is not habitat based, entrainment, is analyzed in Section 2.1.4.f.

Table 3. Activity types causing temporary stressors (habitat reductions) (denoted by X), by activity

Proposed Action Element	Underwater Noise	Suspended Sediment / Reduced DO	Contaminant Exposure	Reduced Forage	Obstructions in Migration Areas
Wharf replacement				X	
Small boat storage and float system removal/relocation				X	
Pile removal/replacement	X	X	X	X	
Slope excavation and armoring replacement	X	X	X	X	X
Sheet pile wall replacement	X	X	X		
Construction vessels	X	X	X	X	X
Stormwater upgrades			X		
Offsetting activities	X	X	X	X	

2.4.1 Species Exposure and Response to Temporary Effects

Work can occur between August 1 through February 15 (198 days) for all work except dredging, and September 1 through February 15 (167 days) for dredging in areas outside the Duwamish Waterway (such as is proposed in this proposed action). Construction is expected to take place during two work windows, so two cohorts of juvenile ESA listed fish may be exposed if present in the project area of temporary impacts.

Temporary impacts will occur only within the project area described in Section 2.3. As summarized in Table 4, all species have some presence in the project area during some portion of the work windows, indicating exposure potential. As noted above, the salmonid DIPs mostly likely to be exposed to project effects would be fall-run Green River Chinook salmon and Green River (Duwamish) winter or summer run steelhead. It is possible that SRKWs will be present in the project area during the work window; however, we consider it unlikely in the project area that is subject to temporary construction effects.

Table 4. Summary of species and life stages potentially present in the project area during construction

Month	J	F	M	A	M	J	J	A	S	O	N	D
Proposed Action Duration	X	X						X	X	X	X	X
Adult PS Chinook salmon (fall run)						X	X	X	X	X	X	
Juvenile PS Chinook salmon (fall run)	X	X	X	X	X	X	X	X	X			
Adult PS steelhead (winter and summer run)	X	X	X	X	X	X	X	X	X	X	X	X
Juvenile PS steelhead (winter and summer run)			X	X	X	X	X	X				
Juvenile PS/GB bocaccio				X	X	X	X	X	X	X		
Adult PS/GB bocaccio	X	X	X	X	X	X	X	X	X	X	X	X
SRKW	X	X	X	X	X	X	X	X	X	X	X	X

a) Underwater Noise

Noise from Pile Installation and Removal

Table 5 summarizes the proposed pile activities and methods. Underwater sound pressure levels (SPLs) from vibratory pile-driving will be temporary and intermittent, lasting up to 8 hours per work day. Steel fender, guide, and sheet pile will be installed with a vibratory hammer to the greatest extent possible; up to 80 structural steel pile may be proofed with an impact hammer to verify loadbearing capacity. Proofing steel piles with an impact hammer, if necessary, will last approximately 90 minutes per work day. The Port will use a bubble curtain as a BMP for the proposed action (Section 1.3.2) to attenuate sound on all impact-proofed steel pile, which is estimated to have a 9-dB reduction of sound impacts.

Table 5. Proposed pile installation/removal

Activity and Method	Pile Type	Count	Pile per Day	Estimated Work Days	Vibration Minutes per Pile	Impact Strikes per Pile	Impact Strikes per Day
Fully remove via vibratory hammer	14” creosote-treated timber	599	50	50[3]	10	--	--
Remove by cutting at mudline	14” creosote-treated timber	1,890	50	50[3]	--	--	--
Install pile via vibratory hammer, and potential impact proof	20”, 24”, and 36” steel	80/ Up to 80	8	14	60	400	3,200
Install sheet pile via vibratory hammer	24” steel AZ sheet	20	20	42	60	--	--
Install via impact hammer	24” concrete octagonal	240	3	100	--	1,000	3,000

Sound levels produced and propagated from pile driving (both sound pressure and particle motion) vary depending on numerous factors such as pile type (e.g., timber, concrete, steel), pile diameter, driver size, substrate characteristics, etc. (Bellmann et al. 2020; Jimenez-Arranz et al. 2020; WSDOT 2020).

Because the Port has included a marine mammal monitoring plan in the proposed action as a BMP designed to avoid marine mammal exposure to construction noise, NMFS’ analysis on construction noise is on the exposure and response of fishes. Table 6 indicates lifestage of ESA-listed fishes and the likelihood of presence when pile work noise will occur.

Table 6. Fish presence and size assumptions in project area of noise impacts

Fish Species	Adult Presence	Adult Size	Juvenile Presence	Juvenile Size
PS Chinook salmon	May be present in the project area in Elliott Bay, but are unlikely to be present in the vicinity of pile installation	Larger than 2 grams	Unlikely except in late January/early February (King County 2001), as densities in Elliott Bay are approximately 18 fish per hectare in July, decreasing to below 5 fish per hectare for August through October (Rice 2011)	Larger than 2 grams
PS steelhead	Could be present in Elliott Bay when migrating to spawning areas, but are unlikely to be present in the vicinity of pile installation	Larger than 2 grams	Extremely unlikely as they move through estuarine and nearshore areas rapidly during outmigration, and move offshore rapidly	Larger than 2 grams
PS/GB bocaccio	Very unlikely since they do not occupy the nearshore within the project area	Larger than 2 grams	May be present in the nearshore during impact pile driving	Less than 2 grams

Fish Response

Based on the proposed pile work, the estimated noise levels during construction are shown in Table 7.

Table 7. Distance to fish sound threshold levels during 36-inch steel pile driving

Effect	Threshold (dB)	Unit	Peak Isopleth During Impact Driving (dB)	Impact Distance to Threshold (meters)[2]	Vibratory Distance to Threshold (meters)[3]
Single-strike injury	206	Peak SPL	196	2	--
Cumulative injury, fish ≥ 2 grams	187	SEL_{cum}	--	71	--
Cumulative injury, fish < 2 grams	183	SEL_{cum}	--	132	--
Behavior	150	RMS	--	1,359	6

The response of fish to noise associated with pile work depends on the characteristics of the sound waves and the size of the fish. NMFS uses a Sound Pressure Exposure spreadsheet to calculate the area around each pile where listed organisms would be considered at risk of injury or behavioral disruption during pile driving. In our analysis, SPLs are presented in decibels (dB) measured as root mean square (RMS) or peak with 1 microPascal (1 µPa) as the reference unit. The thresholds use SPLs when analyzing sounds of relatively long duration, such as the noise of a vibratory pile driver. These sounds are referred to as nonimpulsive or continuous sources. Shorter duration sound sources (milliseconds) are referred to as impulsive sounds and have thresholds denoted in SPLs and Sound Exposure Level (SEL). SEL is a measure of the energy of the emitted sound over a specified duration and is referenced to 1 microPascal squared second [$\mu Pa^2 \cdot s$]). For impact pile driving, the duration is a single strike (Peak SPL). Multiple strikes from an impact pile driver are assessed by integrating the sound energy across all pile strikes, which is denoted as cumulative SEL (SEL_{cum})[4].

To assess the greatest potential for harm and exposure to habitat, we evaluated a scenario in which the highest possible amount of pile driving occurs to define the distance where construction noise attenuates to threshold values. The impact pile scenario with the greatest isopleth distance is impact proofing of 3 36-inch diameter steel pile in one day. Impact driving of this pile size will last less than 30 minutes per day; the maximum duration of impact driving any steel pile is expected to last less than 80 minutes per day (for a maximum of 9 hours cumulative) when impact driving occurs, for a total 14 expected days. An attenuation of 9 dB was subtracted from the source values for impact driving to account for implementation of a bubble curtain. The number of pile strikes is estimated per continuous work period. This approach defines a work period as all the pile driving between 12-hour breaks. Reports from these calculators are provided in Appendix B.

Behavioral Response

The level for behavioral effects to fish is at/above 150 dB_{RMS}. Noise at this at this level, both from vibratory and impact pile drivers, may cause temporary behavioral changes, including a startle response or other behaviors, which may alter fish behavior in such a way as to delay migration, increase risk of predation, reduce foraging success, or reduce spawning success, indicative of stress. While SPLs of this magnitude are unlikely to lead to permanent injury, depending on a variety of factors (e.g., duration of exposure) they can still indirectly result in potentially lethal effects. NMFS' overall synthesis of the best available science leads us to our findings. Studies in which these effects have been studied for salmonids and rockfish include, Grette 1985 (on Chinook salmon and sockeye), Feist et al. 1996 (on chum salmon), Ruggerone et al. 2008 (on coho salmon), Popper 2003 (on behavioral responses of fishes), and Pearson et al. 1992, and Skalski et al. 1992 (on rockfish).

Sound can also result in masking can negatively impact reproduction, predator detection, foraging, orientation, or communication (Slabbekoorn et al. 2010; Hawkins and Picciulin 2019). Planktonic reef fishes have been found to use sound to settle into reef habitats, so masking can potentially affect this important environmental clue (see review by Putland et al. 2019). Fish hear at low frequencies (the majority of fish hearing from less than 50 Hz to 500 Hz [Popper and Hawkins 2019]) and most of the sound energy of impact pile driving in concentrated at frequencies (100 to 800 Hz) within their hearing range. However, there is a limited understanding of fish hearing because fish are primarily sensitive to particle motion with a gradient of sensitivity among species to SPL depending on if they have a swim bladder and the degree of anatomical adaptations they have to convert sound pressure into particle motion that is detectable by the inner ear (Putland et al. 2019, p.41). Fish species that lack a swim bladder (such as eulachon and sand lance) have the most limited hearing. Salmon and rockfish have a swim bladder, but little specialization, so they primarily detect particle motion. Pacific herring, an important forage species of salmon, have special anatomical adaptations to their swim bladder and can hear sound pressure up to 5 kHz (Mann et al. 2005). Even at levels far lower than those

[4] $SEL_{single\ strike} + 10\ log_{10}(N)$, where N is the number of pulses.

that might result in mortality, may result in temporary hearing impairment, physiological changes, changes in behavior and the masking of biologically important sounds; Popper et al. 2014; Erbe and McPherson 2017). There may be significant consequences to individuals and populations as a result of changes in behavior, including impairment of spawning (Popper 2019).

Noise will reach fish behavior threshold levels (150 dB_{RMS}) in areas within 6 meters (20 feet) of activity during vibratory driving and within 1,359 meters (4,460 feet) of activity during impact driving (Table 7). During impact driving, the extent of this area encompasses the total width of the waterway adjacent to construction, and extends a maximum of approximately 3,096 feet south into Elliott Bay. It should be noted that the western bound of this area of effects is equal to the western boundary of the waterway, and approximately the width of the waterway to the east for the extent of this effect due to geographic barriers.

While no studies specifically evaluate the effects of vibratory pile driving on salmonids, NMFS extrapolates from other studies to determine that vibratory pile driving can result in noise level sufficient to alter normal behavior patterns in fish. As cited in van der Knapp et al. (2022), when exposed to boat noise, wild Pacific herring and juvenile pink and chum salmon schools showed stereotyped responses that are consistent with classic vigilance behaviors associated with anti-predator tactics (Magurran 1990). During exposure trials (in the presence of boat noise) both fish groups spent more time in behaviors considered to be a response to predators. These composite response findings suggest that salmon and herring respond to boat noise as a non-lethal predator (Beale and Monaghan 2004; Frid and Dill 2002). Flight responses to predators, including perceived predators, are adaptive. Once a predator is detected, schooling behavior decreases any one individual's probability of being eaten (Pitcher 1986). But repeated responses to predation risk can carry costs. If fish are repeatedly replacing foraging activities with vigilance and anti-predator behavior, this can reduce their energetic intake and fitness. Simply living in a “landscape of fear” of predation risk can carry population-level consequences, even in the absence of actual predation (Lima and Dill 1990). In fact, fish exposed to boat noise are responding to both perceived and actual predation risk. In addition to disrupting normal behavior in response to anthropogenic disturbance, juvenile salmon and herring in the Salish Sea face a gauntlet of predators (Chasco et al. 2017).

Therefore, underwater noise, including noise from vibratory or impact pile driving, could result in masking of communication and environmental signals for PS Chinook salmon, PS steelhead, and PS/GB bocaccio, or behavioral changes that constitute harm, , but to what extent we are unsure.

Injury or Death

The level of injury for fish begins at 183 dBrms for fish below 2 grams and at 187 dBrms for fish above 2 grams (Turnpenny and Nedwell 1994; Turnpenny et al. 1994; Popper 2003; Hastings and Popper 2005).

During impact pile driving for this proposed action, the impact driving single-strike injury threshold (206 dB) will not be exceeded. The peak isopleth (196 dB) will be reached within 2 meters of impact driving; no fish will be present within this distance due to exclusion around the bubble curtain. Impact pile noise will reach SEL_{cum} injury threshold levels for fish less than 2 grams (183 dB) within 132 meters (432 feet) of installation and injury threshold levels for fish greater than 2 grams (187 dB) within 71 meters (234 feet) of installation for fish greater than 2 grams. The extent of the injury threshold exceedance for fish greater than 2 grams, including ESA-listed fish most likely present, nearly encompasses the width of the waterways, leaving the eastern and westernmost corridors unobstructed east and west of Pier 90 (respectively). The extent of injurious noise does not reach the northern or southern terminus of the of the waterway east of Pier 90, or extend into Elliott Bay due to the location and orientation of the project in the upper portion of the waterway.

During the in-water work window, all exposed PS Chinook salmon and PS steelhead are expected to be larger than 2 grams, which reduces the likelihood of injury. Adult PS Chinook and adult and juvenile PS steelhead make little use of nearshore habitats, and would likely only be exposed to injurious levels of underwater sound if they were holding in an area long enough to accumulate harmful received levels of impact pile driving noise. Because the 71-meter area to injury onset is completely within the industrial waterway and not does not extend to the broader areas of Elliott Bay that fish might use for migration to spawning areas, it is unlikely that any adult salmon or steelhead would be exposed during the 14 days when impact driving of steel pile will occur. However, juvenile PS Chinook salmon have a higher chance of sound exposure due to their extensive use of nearshore habitats and potential to overlap with the in-water work window. Early in the work window, juvenile PS Chinook salmon (weighing more than 2 grams) may seek forage or shelter in armored areas beneath the existing wharf or along the eastern shore of the waterway east of Pier 90 despite vibratory construction noise. If behavior changes from vibratory sound cause disorientation or stress and juvenile PS Chinook salmon are unable exit the waterway, they may be exposed to impact driving causing sublethal injury.

We assume juvenile and adult PS/GB bocaccio would not be present in the 71-meter distance to the onset of injury threshold because it is confined to the terminal waterway where no deepwater habitats with structure for rockfish is present. Adult PS/GB bocaccio are also expected to weigh at least 2 grams during the in-water work window, reducing the likelihood of injury. However, larval and young juvenile PS/GB bocaccio will weigh less than 2 grams and have the potential to be closer to the sound source, making them more vulnerable to injury or death.

Injury or death associated with impact pile driving appears to be positively correlated with the size of the pile (driving larger piles requires more energy than smaller piles and produces higher sound levels) but site-specific geologic conditions also influence sound propagation, as instances of driving 30-inch diameter steel piles have been observed to create higher sound levels than 36-inch diameter steel piles (WSDOT 2020). The type of pile seems to influence the severity of impacts to fishes. All observed fish-kills have been associated with impact driving of hollow steel piles ranging from 24- to 96-inches in diameter. Wood and concrete piles appear to produce lower sound pressures than hollow steel piles of a similar size, although it is not yet clear if the sounds produced by wood or concrete piles are harmful to fishes. Death from barotrauma can be instantaneous or delayed up to several days after exposure.

High sound levels can also cause sublethal injuries, and adverse effects on survival and fitness can occur even in the absence of overt injury. 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). A temporary shift in hearing sensitivity (referred to as a temporary threshold shift [TTS]) can occur with exposure to SEL_{cum} as low as 184 dB (Popper et al. 2005). TTS can last hours to days (Turnpenny et al. 1994; Hastings et al. 1996). TTS reduces the survival, growth, and reproduction of the affected fish by impeding migration, increasing the risk of predation, and reducing foraging or spawning success.

In sum, we expect a small number of juvenile and adult PS Chinook salmon, juvenile and adult PS steelhead, and juvenile PS/GB bocaccio will experience underwater sound at levels inducing sublethal effects, including disruption of normal behavior patterns. We expect a small fraction of juvenile fish that engage in disrupted behavior may have greater likelihood of being preyed upon by other species (Table 6). Based on the preference for vibratory methods over impact driving, the relatively short duration of proposed action impact noise effects (up to 8 hours per day for 14 total days of steel driving), use of sound attenuation, the small area of effects within working waterways outside of Elliott Bay, the likelihood of these effects is small but not zero for these species. We cannot predict the exact number of individual fishes among the two cohorts that will be exposed, because of high variability in species presence at any given time. Furthermore, not all exposed individuals will experience adverse effects.

SRKW Response

Modeled distances to SRKW thresholds are provided in Table 8.

Table 8. Distance to SRKW sound threshold levels during 36-inch steel pile driving

Effect	MF Threshold (dB)	Unit	Peak Isopleth During Impact Driving (dB)	MF Impact Distance to Threshold (meters)[2]	MF Vibratory Distance to Threshold (meters)[3]
Injury (onset of PTS, weighted)	230	Peak SPL	196	0	--
Injury (onset of PTS, unweighted)	185	SEL_{cum}	--	5	--
Injury (onset of PTS)	198	SEL_{cum}	--	--	0
Behavior (weighted)	160	RMS	--	293	--
Behavior (unweighted)	120	RMS	--	--	600

SRKW are unlikely to be injured or disturbed by elevated sound because the Port intends to use marine mammal monitoring and 'stop work' protocols. Experienced marine mammal observers will visually monitor the zone where acoustic levels are expected to exceed marine mammal thresholds before, during, and after pile work. Pile work will not start, or will cease, if whales enter the monitoring zones. Based on this protective measure, construction noise effects to SRKW are considered unlikely.

Although construction noise could adversely affect a small number of juvenile PS Chinook salmon, the majority of effects would be sublethal and are not of a magnitude that will measurably affect the SRKW forage base, which is of adult salmon, among other fishes.

<u>Construction Vessel Noise</u>

Vessels create noise that listed species can detect and respond to. Construction vessels (barges and tugs) will be temporarily used to build elements of the proposed action, while fleet vessel use of the completed structure is an operational activity. In this section, we analyze effects to fish from temporary construction vessel noise; impacts from ongoing fishing vessel presence are addressed in Section 2.4.2.b.

Barges and tugs used during construction will cause noise when they enter and exit the terminal and as they reposition within the terminal. Noise will be truncated by the surrounding landforms once they arrive in the waterway. Based on prior vessel noise studies in Admiralty Inlet (Bassett et al. 2012), vessel noise while transiting to and from the terminal will be detectable within the line of sight of each vessel in Puget Sound proper until it mixes with other vessel noise to reach ambient conditions. Once at the site, a vessel may remain within the waterway for up to the full proposed action duration, resulting in only one round-trip transit. While within the terminal, vessel movement will likely be infrequent, and consist of small adjustments in order to facilitate equipment access as work progresses. We anticipate construction vessels will be traveling slow, especially within the terminal, reducing their noise levels.

Fish Response

Fish that encounter construction vessel 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 as more time is spent in behavior considered to be a response to predators (van der Knaap et al. 2022).Adult bocaccio are expected to be in deeper areas where the exposure to vessel noise is unlikely. Steelhead at juvenile or adult lifestages and adult PS Chinook salmon are larger fish, and stress/startle behavior is not expected to increase adverse secondary effects because these individuals are less susceptible to predation. Taken together, it can be assumed that a small number of juvenile PS Chinook salmon and juvenile PS/GB bocaccio from two cohorts will be exposed to construction vessel noise within the waterway, and are likely to respond to episodes of boat motor noise with a stress and startle reaction that can diminish both predator and prey detection for a short period of time with each episode.

SRKW Response

SRKW are unlikely to be exposed to construction vessel noise. Construction vessels will not operate within the “high use” areas for SRKW, which were determined to be along the Washington coast, the west entrance to the Strait of Juan de Fuca, and the northern Strait of Georgia in winter (Hanson et al. 2017; Emmons et al. 2019). If SRKW are present, including when construction vessels enter or exit the project location, noise would attenuate to ambient background outside of the terminal waterway. While SRKW detect and respond to vessels, because exposure to noise from construction vessels is expected to be only brief, we expect that only brief behavioral changes (avoidance) will occur among SRKW.

The number of juvenile PS Chinook salmon expected to experience adverse sublethal construction vessel effects (stress and startle reaction) while within the waterway is not of a severity or magnitude that will measurably affect the SRKW forage base.

b) Suspended Sediment/Reduced Dissolved Oxygen

In-water sediment-disturbing activities can cause short-term and localized increases in total suspended solids resulting in increased turbidity and correlated reduced dissolved oxygen (DO). Total suspended solids are measured as nephelometric turbidity unit (NTU) and compared to background NTU values to determine the area of impact from increased suspended sediment. The types and durations of in-water work potentially disturbing sediment and corresponding areas of benthic impact expected is summarized in Table 9.

Table 9. Type and duration of proposed action activities potentially disturbing sediment

Activity	Type	Duration of Work[1] (days)	Area of Benthic Impact	Waterway Location
Pile removal via vibratory or sawing methods[2]	14" creosote	50	2,661 SF	Waterway east of Pier 90
Pile installation – wharf and float	20", 24", and 36" steel; 24" octagonal concrete	114	931 SF	Waterway east of Pier 90
Pile installation- boat house	20" and 24" steel guide piles	0.5	19 SF	Waterway west of Pier 90
Under-pier armor and debris removal	Existing armor and debris	15	67,660 SF	Waterway east of Pier 90
Under-pier armor placement	Armoring and fish rock	45	67,660 SF	Waterway east of Pier 90
Bulkhead removal[3]	Steel sheet pile, creosote-treated timber, creosote-treated timber with concrete fascia	60	742 LF[4]	Waterway east of Pier 90
Bulkhead installation[3]	Steel sheet pile	42	742 LF[4]	Waterway east of Pier 90
Construction vessels[5]	Barges used for above-, in- and overwater components	Up to 365	0	Primarily waterway east of Pier 90, but west of Pier 90 for a lesser duration

Notes:

1. Activities may be performed concurrently and non-consecutively throughout the work windows.
2. Pile removal via sawing and vibration will be performed concurrently. The total effort is expected to take 50 total days.
3. Bulkhead installation and removal will take place concurrently. Thus, time periods shown overlap, with 60 days being the maximum work estimate. Installation days are shown separately for the purposes of considering vibratory installation of sheet pile wall.
4. Linear feet along shoreline.
5. Construction vessels duration estimates include use of vessels assisting in above-water project components, outside of in-water work window. Construction vessels are expected to tie-off on existing above water infrastructure. Crane barges, if used, are likely to spud down and remain in place for the duration of the project, and sediment disturbance is therefore expected to be minimal.

As indicated in Table 9, despite the use of BMPs, elements of the proposed action will cause suspended sediment (turbidity) within discrete areas throughout the in-water work windows, and the sediment-disturbing activities may be performed concurrently and/or non-consecutively. In estuaries, aquatic life use criteria (WAC 173-201A-210) establish a point of compliance at a radius of 150 feet from the activity causing turbidity. Accordingly, the extent of suspended sediment and turbidity levels will vary within, but are not anticipated to extend more than, the 150 feet from project work. When work occurs in the dry, we expect an increase in suspended sediment and associated turbidity during the following tidal inundation, but affected area would not be expected to be extensive.

The extent of turbidity effects is equal to the total surface water area within a 150-foot radius surrounding the maximum benthic area of effects for activities in Table 9 was calculated in Google Earth (Google Earth 2022). In the waterway east of Pier 90, this is equal to aquatic areas within 150-feet from the excavation area (67,660 SF) and the 26 SF of small boat float guide piles, as all other activities overlap. The resulting extent of turbidity effects equals 237,604 SF. In the waterway west of Pier 90, the area of turbidity effects equals the aquatic area 150-feet from each pile (19 SF), or approximately 30,303 SF. High levels of turbidity can result in warmer temperatures and lower levels of dissolved oxygen (Mitchell et al. (1999)). However, given the intermittent character of the suspended sediment in any given location, we expect only minor, temporary, and localized low DO concentrations associated with resuspension of bottom sediment. Oxygen solubility will be high in Elliott Bay during the work window due to cold surface water temperatures (ranging from 12.9°C [55°F] in August to 8.2°C [47°F] in February; NOAA 2023), and moderate salinity ranges (approximately 22 to 30 practical salinity units; Eash-Louks 2014). Pile work and sheet pile wall replacement may take place during warmer water temperatures, but tidal inundation and strong currents would provide inflow from Elliott Bay and limit DO reductions. Also, sediment disturbance from dredging, which has the largest area of sediment impact, will be confined to the work window between September and February when water temperatures are coldest, which is also expected to limit reductions in DO.

Fish Response

The response to suspended sediment ranges from behavioral avoidance and/or disorientation, physiological stress (e.g., coughing), gill abrasion, and death at extremely high concentrations, and thus may be characterized as lethal, sublethal or behavioral (Bash et al. 2001; Newcombe and MacDonald 1991; Waters 1995).

- Behavioral effects that result in avoidance and loss of territoriality can have secondary effects to feeding rates and efficiency (Bash et al. 2001, p. 7). Fish that avoid elevated concentrations of suspended sediments may abandon preferred habitats and refugia and may enter less favorable conditions and/or be exposed to additional hazards (including predators).
- Sublethal effects include physiological stress reducing the ability of fish to perform vital functions (Cederholm and Reid 1987), elevated blood sugars and cough rates (Servizi and Martens 1991), increased metabolic oxygen demand and susceptibility to disease and other stressors (Bash et al. 2001), and reduced feeding efficiency (Bash et al. 2001; Berg and Northcote 1985; Waters 1995). Sublethal effects can act separately or cumulatively to reduce growth rates and increase fish mortality over time. Elevated turbidity levels can reduce the ability of salmonids to detect prey, cause gill damage (Sigler et al. 1984; Lloyd et al. 1987; Bash et al. 2001) and cause juvenile steelhead to leave rearing areas (Sigler et al. 1984). Additionally, short-term pulses of suspended sediment influence territorial, gill-flaring, and feeding behavior of salmon under laboratory conditions (Berg and Northcote 1985).
- Lethal effects include gill trauma (physical damage to the respiratory structures), severely reduced respiratory function and performance, and smothering (Bash et al. 2001).

Turbidity effects on fish rise in severity with increased sediment concentration and exposure times (Bash et al. 2001; Newcombe and Jensen 1996). Here, because the ESA-listed salmonids are not constrained to turbid areas, we expect exposed fish to respond primarily with avoidance, so that the duration of and intensity of exposure would be limited, even when turbid conditions persist several hours. Steelhead at juvenile or adult lifestages are larger fish, as are adult PS Chinook salmon, thus avoidance behavior is not expected to increase any adverse secondary effects (reduced forage success, increased predation risk) because at these lifestages these individuals readily access deeper water within their normal range of behaviors. Adult bocaccio are expected to be in deeper areas where the likelihood of exposure to increased turbidity is unlikely.

However, some juvenile PS Chinook salmon and juvenile and larval PS/GB bocaccio among two cohorts could be exposed to spatially limited, intermittent effects of suspended sediment and turbidity, which could result in adverse physiological effects and displacement from preferred habitats, increased competition for prey resources, increased bioenergetic expenditure, and reduced growth or fitness among a small subset of the exposed individuals.

SRKW Response

SRKW are not expected to be exposed to temporary increases in suspended sediment and reduced DO during construction. Exposure would require SRKW to enter the working waterway, which is extremely unlikely. Sediment-suspending activities would be halted by marine mammal observers when SRKW enter the behavioral effects area, and suspended sediment/DO effects would dissipate to levels indistinguishable from background by the time SRKW enter the zone of potential exposure (150 feet diameter from activity). Any exposure would not be of sufficient magnitude to result in a measurable change of SRKW behavior or physiology.

c) Contaminant Exposure

The proposed action could cause mobilized PAHs during removal of creosote treated timber structures (Parametrix 2011; Smith 2008). PAHs associated with creosote-treated wood can contaminate surrounding sediment up to 6.5 feet from the pile (Evans et al. 2009). Smith (2008) reported concentrations of total PAHs of 101.8 micrograms per liter (µg/L) 30 seconds after creosote-pile removal and 22.7 µg/L 60 seconds after removal, while Weston Solutions (2006) found PAH concentrations of over 134 µg/L were observed 5 minutes following pile removal and concentrations in samples did not always go down at 5 minutes after removal. In the long term, removal of creosote timber piles will reduce leaching of chemical compounds into nearshore waters and marine sediments (WDNR 2014).

The environmental fate of each type of PAH depends on its molecular weight. In surface water, PAHs can volatilize, photolyze, oxidize, biodegrade, bind to suspended particles or sediments, or accumulate in aquatic organisms, with bioconcentration factors often in the 10-10,000 range. Changes in pH and hardness may increase or decrease the toxicity of PAHs, and the variables of organic decay further complicate their environmental pathway (Santore et al. 2001). The concentration of PAHs released into surface water rapidly dilutes. Contaminants in the water column generally settle out soon after pile removal; however, PAH levels in the sediment can remain high for 6 months or more (Smith 2008). In sediments, PAHs can biodegrade or accumulate in aquatic organisms or non-living organic matter. Most do not easily dissolve in water. Some evaporate into the air from surface waters, but most stick to solid particles and settle into sediments.

The sediment disturbing activities described above could also resuspend contaminated materials and sediment during dredging. Up to 25,000 CY of sediment will be removed as a result of this proposed action. All of the sediment areas at Terminal 91 are included in a WDOE MTCA Agreed Order due to being contiguously owned property of a dangerous waste facility in the upland. Sampling conducted in 2022 indicates that chemical concentrations greater than the Sediment Cleanup Objective (SCO) for mercury, PCBs, and PAHs are present within the dredge area, with mercury concentrations in some intervals also exceeding the Cleanup Screening Level (Port 2023c). Resuspension rates of contaminated sediments have been reported ranging from less than 0.1 percent to over 5 percent dependent on a number of factors including the method of dredging, sediment properties, and site conditions (Bridges et al. 2008), and comprehensive studies indicate that when using bucket dredges without barge overflow, resuspension rates are typically less than 1 percent (Hayes and Wu 2001).

Although there is evidence that contaminant concentrations in the water column can temporarily increase during disturbance, the bioavailability, area of effects, and duration of elevated risk is likely variable. Urban et al.'s 2010 study of ecotoxicological potential of arsenic, PAHs, and PCBs during dredging observed no short-term toxicity in nearby waters, and suggested desorption of contaminants from suspended particles of sediments with a low level of contamination during a dredging operation lowers the water quality in the local water column but does not promote significant acute toxicity effects on organisms. Conversely, Schneider et al. (2007) found that after 2 hours of resuspension, 20 percent of the resuspended PCBs in sediment were released into the dissolved phase; with 1 or 2 days between resuspension events, the percentage of dissolved PCBs at steady state decreased with subsequent resuspension events. This suggests resuspension of undisturbed, highly concentrated bulk sediment could add significant amounts of dissolved PCBs to the water column, but frequent resuspension events (as would be expected during construction, and in a berth area subject to propeller wash) might result in only minimal release of dissolved PCBs per event.

The area of suspended contaminants from creosote-treated pile and sediment removal is directly related to the area of increased turbidity, totaling 267,907 SF. Benthic effects from resuspended contaminants would be applicable to this area minus the area where clean armor will be placed, totaling 200,247 SF. The duration of these activities is consistent with the time period expected for increased turbidity from pile removal or sawing (total expected duration of 50 days) and excavation of the under-pier armor and debris (15 days).

Operation of construction vessels and potentially some equipment will also introduce exhaust into the water. We expect PAHs and other contaminants to be introduced into the water column during construction when vessels are moving, which would occur only intermittently within the terminal. Because these materials can disperse quickly, they can become quite widespread at very low concentrations. As stated above, PAHs can volatilize, photolyze, oxidize, biodegrade, bind to suspended particles or sediments in surface water, or accumulate in aquatic organisms.

Fish Response

NMFS considers exposure pathway (i.e., direct contact or ingestion), duration, and specific contaminant bioavailability to determine potential effects as a result of removal of contaminated material. Aquatic species feeding in, or migrating through, contaminated habitats have been found to be vulnerable to both the near-term and delayed effects of toxic exposure (Heintz et al. 2000; Meador 2014; Johnson et al. 2013; Varanasi et al. 1993). For this proposed action, juvenile PS Chinook salmon and juvenile PS/GB bocaccio would be the species and lifestages most likely exposed to temporary elevated contaminants in the water column since they are shoreline-oriented and spend a greater amount of time within Puget Sound than other listed species.

Risk to fish exposed to contaminants during migration is influenced by interactions between chemicals in complex mixtures and the convergent impacts of other stressors, such as water temperatures and pathogens (Arkoosh et al. 2004; Goertler et al. 2016). A meta-analysis of juvenile Chinook salmon navigating through a contaminated Superfund site resulted in 3 mortality scenarios, including near-term mortality within the contaminated site, delayed mortality due to immunotoxicity and a subsequent increase in disease-related losses further downstream, and delayed mortality among migrants attributable to reduced growth (Lundin et al. 2019). Most contaminant exposures during migration are sublethal, and include such adverse health outcomes as repression of growth (Heintz et al. 2000; Meador et al. 2006, Varanasi et al. 1993), compromised immune function, and impaired reproduction (Lundin et al. 2019). For salmonids specifically, controlled exposures to PAHs, PCBs, DDTs, and TBTs have been shown to decrease the antigen response as well as decrease the proliferation and viability of immune cells (Arkoosh et al. 1994; Arkoosh et al. 2001; Bols et al. 2001; Jacobson et al. 2003; Misumi et al. 2005; Misumi et al. 2009). These types of delayed impacts may reduce the lifetime survival and reproductive success of individual fish, thereby reducing population abundance (Johnson et al. 2014).

While rare, acute mortality events have been documented in salmon habitats (e.g., Scholz et al. 2011). For example, PAHs have been documented to cause massive cardiac effects in very low concentrations, especially at early life stages and in fish with developing hearts (West et.al, 2019). Whole-body tissue PAH, PCB, and DDT concentrations in juvenile Chinook salmon were elevated throughout the Portland Harbor Superfund site relative to the upstream sites, affirming that contaminant exposures in juvenile Chinook salmon occurred within the Harbor (Lundin et al. 2021).

The probability of direct exposure to contaminants in the water column due to the proposed action is generally low given that the work windows would avoid peak presence of juvenile salmonids and because bioavailability is temporary and uncertain, juvenile PS Chinook salmon and juvenile PS/GB bocaccio are likely to avoid the construction area, and BMPs would be implemented to minimize the mobilization of sediments. However, juvenile PS Chinook salmon and PS/GB bocaccio could be exposed through ingestion of contaminated benthic prey exposed to contaminants in the 200,247 SF unarmored resuspension area. Exposure through ingestion of contaminated prey in industrial areas is a dominant pathway for aquatic organisms (Johnson et al. 2013, 2014). A measurable accumulation of contaminants in an individual organism is dependent on several factors, including levels of contaminants from the project, exposure of prey to contaminants (where and what life stage), the likelihood of detection of the contaminants in the individual, and if the contaminant bioaccumulates and/or biomagnifies. Contaminants of concern for the proposed action, including mercury (as monomethyl mercury), PAHs, and PCBs, can accumulate and biomagnify in the aquatic food web (Compeau and Bartha 1984; Dorea 2008; Yanagida et al. 2012), and bioconcentration in fish varies considerably with food chain structure and length (Barbosa et al. 2003). In order to isolate the effects of dietary exposure of PAHs on juvenile Chinook salmon, Meador et al. (2006) fed a mixture of PAHs intended to mimic those found by Varanasi et al. (1993) in the stomach contents of field-collected fish. These fish showed reduced growth compared to the control fish. Dietary DDTs, dietary PCBs, and dietary PAHs in fish were elevated relative to the stomach contents from fish upstream of a Superfund site, indicating a general correspondence between site-specific exposures to PCBs, DDTs, and PAHs via the diet and elevated tissue concentrations among subyearling Chinook that reside in these local habitats to feed, shelter, and grow (Lundin et al. 2021), consistent with earlier findings (Johnson et al. 2007; Yanagida et al. 2012).

Resuspended pollutants are absorbed at a lower efficiency by benthic organisms than those bound to particulate organic matter directly from the water column (Charles et al. 2005). We expect concentrations in benthic prey are likely minor, but may result in reduced growth and other sublethal outcomes to prey. Given the volume of available prey in undisturbed areas, it is unlikely that any juvenile fish will feed solely from the relatively small area of disturbance during recovery, causing only minor biomagnification. Additionally, habitat offsetting activities would permanently remove creosote-treated timber and contaminated sediments which release chemicals to the aquatic environment as long as they are present. We therefore expect a small temporary increase in contaminants in juvenile fish that consume benthic prey within the 200,247 SF unarmored resuspension area, but expect offsetting activities will reduce long-term fish and prey exposure to contaminants following construction.

As noted above, the duration of elevated contaminant bioavailability following sediment disturbance is highly variable. To determine an estimate for the duration of effects, we consulted the available science on the bioavailability following resuspension for the three contaminants of concern (PAHs, PCBs, and mercury). Disturbed areas may contain elevated concentrations of PAHs for 6 months following pile extraction (Smith et al. 2008). PCB concentrations in interstitial porewater decreased to below the detection limit within 50 days after resuspension, with partitioning dependent on particle size and duration of exposure, following sediment resuspension in a laboratory study (Chalhoub et al. 2012). Bioavailable metals (i.e., mercury) are soluble to overlying water for the first 20 hours after settling, and resultant concentrations in benthic prey generally show consistent but nonsignificant increases that are metal and species specific (Fetters et al. 2016). Based on existing literature, we therefore conservatively estimate that benthic prey in the turbidity settling area will be exposed to elevated soluble contaminant concentrations for up to 6 months as resuspended sediment settles and contaminants sorb to the bulk sediment.

Therefore, some juvenile PS Chinook salmon and PS/GB bocaccio will experience sublethal adverse contaminant effects from prey ingested during the 6-month period following construction. This proposed action may disturb sediment for up to 2 years; thus, the maximum period for this effect is 2.5 years, which could affect three cohorts of these species. The severity of contaminant elevations is expected vary during that time period as well, as elevated concentrations peak immediately following disturbance and dissipate through time. Effects will therefore be smaller during the work window when fewer fish are likely to be present. Overall, we expect the proposed action will result in enduring reductions of contaminants in the aquatic environment following a small temporary increase, and anticipate a beneficial outcome to the fitness and survival of juvenile PS Chinook salmon and PS/GB bocaccio in the long term.

SRKW Response

Direct exposure of SRKWs to contaminants released during construction is unlikely because of the small exposure zones, their highly unlikely presence, and marine mammal monitoring/exclusion.

Concentrations of mercury, PAHs, and PCBs will increase in the water column for 6 months following disturbance of contaminated material, then decrease below current levels following the permanent removal. Juvenile fall-run Green River Chinook salmon that are present during the period of contaminant elevation (i.e., 2.5 years) may incur sublethal effects. Contamination of Chinook salmon tissue has been documented in many studies (Krahn et al. 2007; O'Neill and West 2009; Mongillo et al. 2016; Veldhoen et al. 2010), and they in fact contain higher levels of some persistent pollutants than other salmon species due to their life history, geographic distribution, lipid content, and trophic level (Mongillo et al. 2016).

SRKW could be affected by temporary increases of contaminants during construction if exposed juvenile PS Chinook salmon accumulate measurable tissue concentrations that and are subsequently consumed as adults. Predators at the top of the aquatic food chain acquire and bioconcentrate larger amounts of contaminants as a function of age or size (Nichols et al. 1999), and high levels of pollutants have been measured in sample of blubber (Krahn et al. 2007; Krahn et al. 2009; Ross et al. 2000), and feces (Lundin et al. 2015; Lundin et al. 2016). Therefore, NMFS considers toxin accumulation in SRKW a serious concern (NMFS 2008b).

Temporary contaminant increases during construction are likely to cause some sublethal effects to juvenile fall-run Green River Chinook salmon. Prey tissue elevations from this proposed action cannot be accurately quantified without site-specific analysis of the chemical composition and bioavailability, and numerous organism-specific biological factors. However, we do anticipate increases would be minor based on chemical concentrations and short exposure times, and will occur only to a small number of fish. Furthermore, the proposed action will permanently remove contaminant sources following construction, which will reduce contaminant sources to the water column and improve prey quality.

We therefore cannot determine with any accuracy if the temporary contamination impacts would result in measurable contaminant accumulations in juvenile Chinook salmon, and if those contaminants would persist in adult fish that may be consumed by SRKW. We expect prey quality diminishments to be below meaningful levels and not result in detectable consequences for any individual SRKW or at the population level. In sum, we consider direct effects to SRKW highly unlikely and effects through their forage base to be immeasurable.

d) Temporary Reduction of Forage

Juvenile PS Chinook salmon and juvenile PS/GB bocaccio depend on benthic prey communities for forage, which may be altered or diminished by temporary shade and smothering from resuspended sediment as a result of the proposed action.

Temporary shade is created by vessel propeller wash and moored construction vessels. Construction vessels propeller wash disturbs sediment and water and reduces light penetration (Eriksson et al. 2004), limiting primary productivity. Minor increased shade from propeller wash is expected for this proposed action because construction vessel movement within the waterway will primarily consist of small adjustments and work will take place over existing armor with few fines. At least one work barge with dimensions of approximately 45 feet by 100 feet (4,500 SF) is expected to be in use for the duration of the proposed action. Moored construction vessels reduce light penetration to the benthos in a manner similar to temporary infrastructure, which results in effects similar to those from permanent infrastructure, including reduced macrofauna diversity and reduced density and species richness of epibenthic organisms (which serve as prey for juvenile salmonids; Haas et al. 2002), and vary depending on their duration in water, time of placement, width, and height. Barges will be primarily situated over DSZ, where water depth limits the potential primary productivity. Based on the water depth, additional construction vessel shade is likely to result in insignificant reductions in benthic and epibenthic production and not appreciably diminish prey base.

Pile removal and installation activities, dredging/excavation, material placement, and construction vessel spudding will disrupt and diminish benthic prey communities where sediment contacts equipment and in the surrounding areas where suspended sediment will eventually settle. As bottom sediments are dislodged, benthic communities are disrupted, taking time to fully re-establish their former abundance and diversity and reducing prey availability in the footprint of the removal. This disturbance is highly local and confined to the footprint of the activity directly contacting the benthos.

For this proposed action, we expect the temporary disturbed benthic area will equal 150-feet around the footprint of shoreline excavation in the waterway east of Pier 90 (237,604 SF), and 150-feet around the guide pile installation area in the waterway west of Pier 90 (30,303 SF). Benthic communities in the footprints of the installed piles (950 SF) will be eliminated when new piles are installed, displacing benthic habitat that would provide prey for listed fishes. However, as 2,169 more pile are being removed than are being installed, 1,711 SF of additional area will be available for benthic colonization of armor following proposed action completion, potentially resulting in a net benefit in the long term.

Benthic communities are expected to fully recover with incremental improvements over baseline conditions following construction. Existing under-pier substrate includes riprap armoring, derelict piles, metal debris, and concrete debris, and is likely limited in benthic prey productivity. The proposed action will utilize fish rock atop the new armor in order to fill interstices and reduce potential predator habitat, and provide finer substrate to support a more abundant and diverse invertebrate assemblage, which supports foraging for smaller fish. Therefore, we consider the duration of recovery to current conditions to determine adverse effects on juvenile PS Chinook salmon and juvenile PS/GB bocaccio.

The speed of recovery by benthic communities is affected by several factors, including the intensity and duration of the disturbance, with greater disturbance increasing the time to recovery (Dernie et al. 2003). Based on previous pile repair at Terminal 91 and elsewhere in Elliott Bay, new structures re-populate with sessile organisms and mobile invertebrates within 2 to 3 years (Port 2021). It is anticipated that sessile organisms will recolonize the new structures in a period of months following construction, beginning with early colonizers during spring months. In the excavation and armoring area, recovery to full recruitment of prey complexity and abundance equaling baseline levels may take up to 3 years following material placement (including fish mix). Mobile organisms may begin to move back into the excavation footprint from the adjacent slope immediately following construction. Early colonizers would be followed by larger, slower growing, longer-lived species, during a recovery period that may last 2 to 3 years. Thus, for the proposed activity types and duration in the discrete work area, benthic recovery is expected to take several weeks in pile installation/removal areas, and a maximum of 3 years in the footprint of excavation for this proposed action.

Fish Response

NMFS finds it likely that juvenile PS Chinook salmon and juvenile PS/GB bocaccio, which have nearshore dependent behaviors and life history expressions that include growth, development, and maturation, would have the most significant response to reduced prey composition and abundance in the excavation area (approximately 268,000 SF). During the 3-year period of depressed prey availability, individuals among three cohorts are likely to have increased bioenergetic expenditure and increased competition as they seek areas with more prey abundance. It is likely that a small number of such individuals in each year will have reduced growth or fitness as a result of reduced forage, though that number is impossible to estimate. We expect the number of fish with reduced growth or fitness could result in decreased survival, but we expect this number of juveniles to be so low that it would not be discernable among adult abundance.

SRKW Response

Quantity and quality of prey is a factor in productivity of SRKW, and a recent study indicated that Chinook salmon were the most common prey species when averaged across SRKW fecal samples collected (51.0 percent, 67.3 percent, Puget Sound and outer coast waters, respectively). Chum salmon was the next most common species consumed in two areas of three areas surveyed (Puget Sound, 31.2 percent, Juan de Fuca/San Juan Islands 31.5 percent) but virtually nonexistent in outer coast waters (1.2 percent) (Hanson et al. 2021).

Temporary construction effects from reduced forage are likely to result in small reduced growth and fitness for juvenile Chinook salmon for up to 3 years (see above). As discussed in Section 2.3.2, the PS Chinook salmon in closest proximity to the proposed action are the Green River Chinook salmon DIP. This DIP is within the Southern Puget Sound Chinook salmon ESU/stock group, and increased abundance of their population is designated as a high-priority to benefit SRKW (NMFS and WDFW 2018). Specifically, individuals from juvenile fall-run Green River PS Chinook salmon DIP are most likely to be exposed to effects of the action due to the timing of construction and juvenile outmigration at a nearshore-dependent lifestage. The array of impacts to juvenile salmon correlate to a small, but likely, reduction in adult PS Chinook salmon quantity and quality; however, the result of these effects among PS Chinook salmon as a feature of SRKW prey are difficult to discern the level of individual SRKW, or at the population level.

NMFS does not expect SRKW to experience a meaningful prey reduction from the proposed action because effects of the proposed action occurs primarily among juvenile Chinook salmon, and we do not expect any reduction in abundance of juveniles to be of a sufficient magnitude to diminish their prey base (adult PS Chinook salmon). Temporary construction effects are likely to result in 3 years of minor reduced growth and fitness of juvenile Chinook salmon that does not result in a level of mortality that can be attributed to depressing the overall number of adult salmon available (i.e. we anticipate the reduction among juvenile Chinook salmon across 3 years to be equal to or less than 1 adult fish). However, because there could be a slight reduction in prey abundance or prey quality in Chinook salmon, critical habitat for forage may be slightly degraded. While we cannot predict any mortality or reduction in fecundity associated with this reduction, we think it possible that growth or fitness population could be incrementally affected.

e) Obstructions in Migration Area

Barriers to fish movement, including shade and the physical presence of equipment, can obstruct migration areas. Adults and subadults of PS Chinook salmon, PS steelhead, and adult and juvenile PS/GB bocaccio are not expected to be affected by this stressor because they do not migrate along the nearshore; however, outmigrating juvenile PS Chinook in the earliest periods of their marine residency prefer the protection of shallow nearshore water and are therefore vulnerable.

Migratory obstructions from shade caused by temporary structures would be expected to be similar to those effects observed on large overwater permanent structures, and vary depending on their duration in water, time of placement, width, and height (i.e., the higher a structure, the less the effect of the shadow, with structures directly on the water-surface having the greatest effect). Fishes rely on visual cues for spatial orientation, prey capture, schooling, predator avoidance, and migration. The sharp light/dark contrast between non-shaded waters and shaded water under structures affects the behavior of smaller juvenile salmon in the nearshore in two ways: 1) migrating juvenile salmon in the nearshore will avoid shaded areas and may mill along the edge, move to deeper waters, or delay migration until the light/dark contrast is reduced, 2) movement into deeper waters may increase susceptibility to predation. Therefore, the physical presence of the structures may result in juvenile salmonid delaying passage or forcing them into deeper water in an attempt to go around the structures, resulting in more vulnerability to predation.

<u>Fish Response</u>

We expect one to two barges within the waterway during construction, to take place over two in-water work windows. The effect of anchored barges on juvenile PS Chinook migration would depend on the barge location and tidal elevation. Barges supporting this proposed action will be moored inshore within the terminal waterways, contiguous or adjacent to existing structures. Typically, this may result in obstruction of the nearshore migration pathway; however, proposed action construction is located near the northernmost point of the terminal waterway, and the use of the working waterway as a migratory path is highly unlikely. Additionally, barges will not be in the same place for extended periods, although they may be present year-round. As we do not expect any interference with migration of early nearshore stages of juvenile PS Chinook salmon, shading effects from temporary mooring of barges are unlikely to adversely affect migration.

<u>SRKW Response</u>

The temporary presence of barges is extremely unlikely to adversely impact SRKW because nearshore overwater structures are not considered to be a significant obstruction to their movements. As obstructions are unlikely to affect prey base migration, no impact to SRKW prey numbers is expected.

f) Entrainment

Entrainment is a pathway of construction effects on fish that is not habitat based. Entrainment refers to the uptake of aquatic organisms by dredge equipment in this context. Mechanical (clamshell) dredges commonly entrain slow-moving and sessile benthic epifauna along with burrowing infauna that are removed with the sediments. They also entrain algae and aquatic vegetation. Organisms that become entrained or are unable to escape before contact with the substrate are likely to be buried under the sediments. The likelihood of injury or mortality would increase with proximity to the center of the discharge field, where depth and weight of the sediments would be greatest.

Carlson et al. (2001) documented the behavioral responses of salmonids to dredging activities in the Columbia River using hydroacoustics. During dredging operations, out-migrating salmon smolt (*Oncorhynchus* spp., likely fall Chinook salmon and coho salmon [*O. kisutch*]) behavioral responses ranged from (1) salmon orienting to the channel margin move inshore when encountering the dredge, (2) most out-migrating salmon passing inshore moved offshore upon encountering the discharge plume, and (3) out-migrating salmon were observed to assume their prior distribution trends within a short time after encountering both the dredging activity and dredge plume" (Kjelland et al. 2015).

The probability of fish entrainment depends on the likelihood of fish occurring within the dredge prism, dredge depth, fish densities, the entrainment zone (water column of the clamshell impact), location of dredging, type of equipment operations, time of year, and species life stage. In order to be entrained in a clamshell bucket during dredging/excavation, a fish must be directly under the bucket when it drops. Most fish in the vicinity of the dredge at the start of the operation would likely swim away to avoid the noise and activity, and the relative size of the dredge bucket in respect to organism distribution across available habitat make this situation very unlikely. Further, dredge operations move very slowly, with the barge typically staying in one location for many minutes to several hours, while the bucket is repeatedly lowered and raised within an area limited to the range of the crane arm. As a fish is most likely to move away from the disturbance during barge movement or during the first few bucket cycles, the slow progression further reduces the risk of entrainment.

Entrainment can also occur during material placement, when the sand/rock fall through the water column, and creates a plume that extends from the bottom of the vessel to the seafloor. Fish that are above the point of discharge or are otherwise not directly below a discharge plume are likely to detect the plume and attempt to evade the descending material as a perceived threat. Fish that are below a discharge plume are likely to initially dive and then initiate horizontal evasion, or to simply move laterally if already on or near the bottom.

Fish Response

There is little evidence of mechanical dredge entrainment of highly mobile organisms such as fish. If proposed action activities resulted in entrainment, demersal fish (such as sand lance, sculpins, and pricklebacks) would be 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). Evidence indicates that the risk of entrainment of any ESA listed fish during the proposed action is extremely low.

SRKW Response

While SRKW can enter shallow areas, entrainment of SRKW is extremely unlikely based on their size, migration preferences for deeper open water, and marine mammal monitoring protocols.

2.4.2. Species Exposure and Response to Operational Effects

Operational effects include ongoing activities with the potential to impact protected critical habitat and/or species that are reasonably likely to occur as a result of operation and maintenance of the rehabilitated wharf, and would not occur but-for the proposed action. We determined that the proposed action would enable the following operational effects:

a) stormwater effluent, and
b) vessel traffic.

The extent of stormwater effluent effects is limited to the project area described in Section 2.3. Outside of the project area, concentrations of contaminants that may be present in effluent are expected to be too dispersed to be meaningful. The extent of operational vessel traffic effects includes the full Action Area described in Section 2.3 (i.e., the TSS from Terminal 91 to the mouth of the Strait of Juan de Fuca).

Operational effects to listed species are analyzed below.

a) Stormwater Effluent

Stormwater effluent will be managed as an operational effect of the rehabilitated wharf. Since the proposed action extends the life of impervious surfaces on the wharf, discharge of stormwater from those surfaces are effects of the proposed action. The proposed action will consolidate eight existing stormwater outfalls into a single 18-inch outfall with basic effluent treatment, in accordance with WDOE, City of Seattle, and Port stormwater guidelines. The proposed action would not result in any new areas of pollution generating impervious surface (PGIS), but would repave the existing impervious surface and route an estimated 101,060 SF (2.32 acres) of stormwater runoff through treatment. Stormwater treatment typically reduces the amount of contaminant discharged (in the effluent) which is a positive outcome, however, effluent continues to be a source of contaminant load despite best treatment.

Per design plans, pre-treatment and treatment shall consist of media-filled filter cartridge systems to meet basic treatment as defined by the City of Seattle Stormwater Manual (2021). Stormwater from storm drains percolates through these media-filled cartridges, which trap particulates and may remove pollutants such as dissolved metals, nutrients, hydrocarbons, surface scum, and floating oil and grease (DOE 2017). Once filtered through the media, the treated stormwater is directed to a collection pipe or discharged to an open channel drainage way. Per the City of Seattle Stormwater Manual (2021), project sites discharging directly (or indirectly through a drainage system) to all marine waters, including Puget Sound, require basic treatment as defined by the City. Per the City: basic treatment BMPs are designed to achieve 80 percent removal of TSS for influent concentrations greater than 100 milligrams per liter (mg/L), but less than 200 mg/L. For influent concentrations greater than 200 mg/L, a higher treatment goal may be appropriate. For influent concentrations less than 100 mg/L, the BMPs are designed to achieve an effluent goal of 20 mg/L TSS.

Following basic treatment, the new outfall will discharge to the waterway east of Pier 90. Increased treatment is expected to reduce contaminants concentrations in stormwater effluent and improve water quality as compared to current baseline conditions. However, because no method of treatment other than full infiltration will fully remove all contaminants, stormwater effluents will continue to be a chronic source of episodic physical and chemical load into Puget Sound. It is reasonable to assume that a small number of PS Chinook salmon, PS steelhead, and juvenile PS/GB bocaccio will migrate through the project area over the 40 year period of operation, and that individuals will be exposed to treated stormwater containing dispersed concentrations of contaminants while in the water column. Although treatment and dilution will greatly reduce contaminant volumes, we expect this could contribute to some low-level, chronic behavioral or health effects that could reduce the fitness of listed fish.

The working terminal will be used for frequent industrial transport from large vessels. As a result, stormwater runoff is highly likely to contain several contaminants that have proven damaging to fish, including PAHs and microplastics such as 6PPD/6PPD-q from vehicles regularly operating on the deck. As these contaminants are of particular concern for salmonids, their effects are discussed in greater detail below. The adverse responses to toxic contaminants in stormwater effluent on PS/GB bocaccio are expected to be similar, although the magnitude and mechanism of impact may differ based on the individual contaminants present.

<u>Fish Response</u>

PAHs

A large and growing body of environmental monitoring data (analytical chemistry) has established PAHs as a ubiquitous component of stormwater-driven runoff into the Puget Sound. Whether originating from oils spills or stormwater, PAH toxicity to fish can be framed as a bottom-up approach to understanding the impacts of complex mixtures, where one or more PAH compound may share a common mechanism of action, interact with other chemicals in mixtures, and/or interact with non-chemical variables such as the thermal stress anticipated with a changing regional climate. The historical NOAA research on oils spill and urban stormwater are increasingly converging on a risk framework where certain PAHs (Figure 3) cause a well-described syndrome of involving the abnormal development of the heart, eye and jaw structure, and energy reserves of larval fish (Harding et al. 2020). Over the ensuing 30 years, combined research from NOAA's Alaska Fisheries Science Center (AFSC) and the Northwest Fisheries Science Center (NWFSC) clearly established the developing fish heart as the primary biological target organ for the toxic impacts of water-soluble chemical mixtures derived from petroleum (Incardona 2017; Incardona and Scholz 2016, 2017, 2018; Incardona et al. 2011). At the egg (developing embryo, pre-hatch) and larval stages, organ-specific detoxification pathways (e.g., cytochrome P450 enzymes in the liver) are not yet in place, and therefore do no offer the same intrinsic metabolic protections available to older fish with a fully developed hepatic function. Absent this protective metabolism in larval fish, petroleum-derived hydrophobic compounds such as PAHs bioconcentrate to high tissue levels in fertilized eggs, resulting in more severe corresponding toxicity.

Numerous controlled laboratory exposure-response studies have elucidated a toxicity syndrome with a distinctive and characteristic suite of developmental abnormalities. Severe PAH toxicity is characterized by complete heart failure, with ensuing extra-cardiac defects (secondary to loss of circulation) and mortality at or soon after hatching. More moderate forms of PAH toxicity, such as might be expected for untreated/unfiltered roadway runoff, include acute and latent alterations in subtle aspects of cardiac structure, reduced cardiorespiratory performance and latent mortality in surviving larvae and juveniles. These effects have been studied extensively and characterized in over 20 species of fish at the organismal, tissue and cellular levels (Marty et al. 1997; Carls et al. 1999; Heintz et al. 1999; Hatlen et al. 2010; Hicken et al. 2011; Incardona et al. 2013; Jung et al. 2013; Esbaugh et al. 2016; Morris et al. 2018). Unlike 6PPD-quinone, which varies in hazard across closely related salmonids (e.g., high acute toxicity to coho, low toxicity to chum; McIntyre et al., 2018, 2021), all fish species studied to date are vulnerable to PAH toxicity, with thresholds for severe developmental abnormalities often in the low parts-per-billion (µg/L) range (Figure 3).

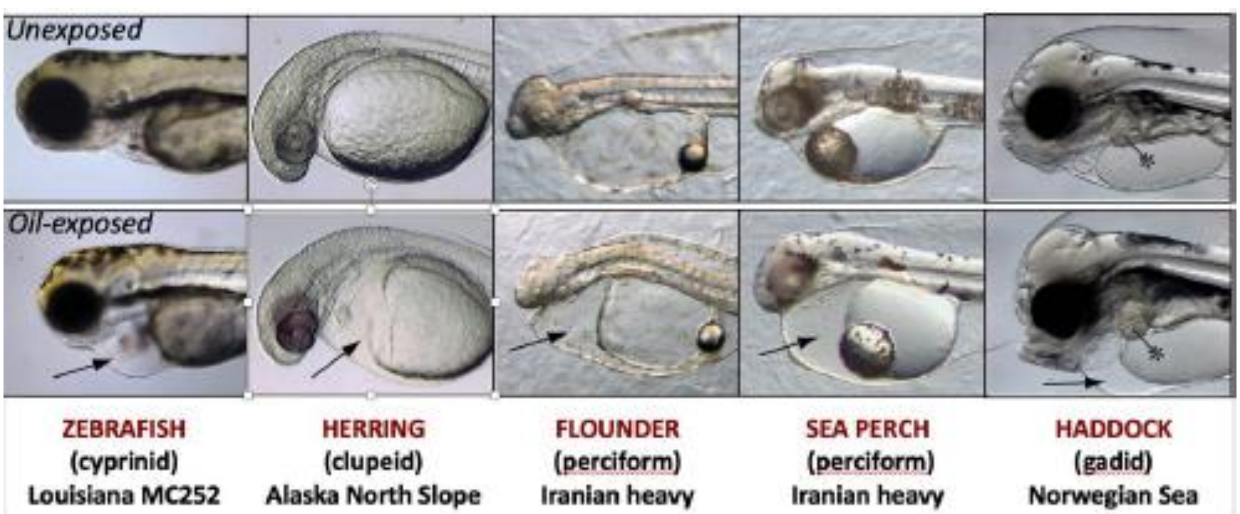

Figure 3. Examples of PAH-induced developmental abnormalities in a wide range of fish species (freshwater to marine, tropical to temperate). Our current understanding of PAH toxicity to fish embryos and larvae is drawn from several NOAA-F studies, representing major lessons learned from the Exxon Valdez and Deepwater Horizon disasters, and has been widely confirmed by independent research groups around the world. The primary form of toxicity is a loss of cardiac function, as

exemplified by circulatory failure and accumulation of fluid in the pericardial space around the heart (arrows). The pattern of excess fluid (edema) varies according to the anatomy of each species. Related abnormalities include small eyes, jaw deformities, and a dysregulation of the lipid stores, or yolk, the animal needs to survive to first feeding. This suite of defects, while sublethal, will almost invariably lead to ecological death. Consequently, “delayed-in-time” toxicity is a common risk concern for fish that spawn in PAH-contaminated habitats.

PAH toxicity in fish is often sublethal and delayed in time. The latent impacts of low-level PAH exposures – i.e., representative of the cardiotoxic PAH concentrations and discharge durations comparable with conventional Puget Sound roadway runoff – have been particularly well studied in salmonids (pink salmon, *Oncorhynchus gorbuscha*). Large-scale tagging (mark-and-recapture) studies dating back to Exxon Valdez were among the first to show that embryonic exposure to oil-derived chemical mixtures with total PAH (ΣPAH) levels in the range of 5 to 20 μg/L resulted in cohorts of salmon that survived the exposure (and appeared outwardly normal), but nevertheless displayed reduced growth and reduced survival to reproductive maturity in the marine environment. Follow-up studies at NWFSC have linked this poor survival to reduced individual fitness manifested by reduced swimming performance and subtle changes in cardiac structure. In essence, embryonic exposure to petroleum mixtures leads to juvenile fish that show signs of pathological hypertrophy of the heart (Incardona et al. 2015, 2021; Gardner et al. 2019). The latter is well known to be associated with considerable morbidity and mortality across vertebrate species in general, as evidenced by the downstream consequences of congestive heart failure in humans.

To illustrate how PAHs in runoff from the Puget Sound transportation grid align with historical NOAA research on oil spills, stormwater from the SR520 collection location at the NWFSC in Seattle shows considerable overlap with the pattern of PAHs derived from a pure oil spill (Figure 4). Notably, as an added consequence of the engine internal combustion process, the mixture in stormwater is even more complex due to the appearance of larger numbers of 4-ring and ≥ 5-ring compounds. Much of this higher molecular weight PAH mass is associated with the fine particulate matter from vehicle exhaust. The bioavailability of compounds in waters that receive highway runoff is demonstrated by uptake into passive samplers, which have properties very similar to fish eggs. Passive samples vary in design, but generally consist of a housing for a membrane material that passively accumulates lipophilic compounds such as PAHs, which can subsequently be extracted for chemical analyses. They are particularly useful for profiling patterns of bioavailable PAHs in fish spawning habitats.

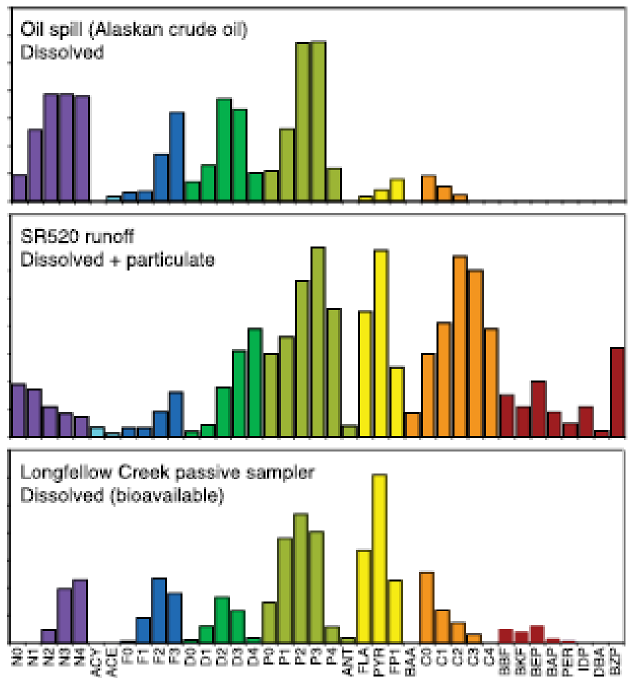

Figure 4. Patterns of PAHs in environmental samples. Top, effluent in seawater flowing over gravel coated with Alaskan crude oil (source for Exxon Valdez). Middle, runoff from the SR520 highway adjacent to NWFSC. Bottom, PAHs extracted from a polyethylene membrane device (PEMD) incubated 1 week in Longfellow Creek, West Seattle. X-axis shows proportion of total PAH, and values are omitted for simplicity to emphasize overall patterns. Abbreviations: N, naphthalenes; BP, biphenyl; AY, acenaphthylene; AE, acenaphthene; F, fluorene; D, dibenzothiophene; P, phenanthrene; ANT, anthracene; FL, fluoranthene; PY, pyrene; FP, fluoranthenes/pyrenes; BAA, benz[a]anthracene; C, chrysene; BBF, benzo[b]fluoranthene; BKF, benzo[j]fluoranthene/ benzo[k]fluoranthene; BEP, benzo[e]pyrene; BAP, benzo[a]pyrene; PER, perylene; IDY, indeno[1,2,3-cd]pyrene; DBA, dibenz[a,h]anthracene/dibenz[a,c]anthracene; BZP, benzo[ghi]perylene. Parent compound is indicated by a 0 (e.g., N0), while numbers of additional carbons (e.g. methyl groups) for alkylated homologs are indicated as N1, N2, etc.

The pattern of bioavailable PAHs in the Seattle-area urban streams depicted above in Figure 4 closely resembles a pure oil spill pattern, with the exception of a larger proportion of combustion-associated 4-ring compounds such as pyrenes and fluoranthenes. Accordingly, urban runoff is a transport pathway for PAHs, and the pattern of bioavailable PAHs closely resembles the relative enrichment of cardiotoxic phenanthrenes. Although more work is needed for Pacific salmonids (e.g., species beyond pink salmon), collected runoff from SR520 containing ΣPAH of 7.5 µg/L produced the stereotypical syndrome of heart failure and associated developmental defects in Pacific herring (Harding et al. 2020). Measured concentrations of PAH runoff from SR520 runoff are often considerably higher than the petroleum toxicity threshold for pink salmon.

6PPD-Quinone

After years of forensic investigation, the urban runoff coho mortality syndrome has now been directly linked to motor vehicle tires, which deposit the compound 6PPD and its abiotic transformation product 6PPD-q onto roads. 6PPD or [(N-(1, 3-dimethylbutyl)-N'-phenyl-p-phenylenediamine] is used to preserve the elasticity of tires. 6PPD can transform in the presence of ozone (O3) to 6PPD-q. 6PPD-q is ubiquitous to roadways (Sutton et al. 2019) and was identified by Tian et al. (2020) as the primary cause of urban runoff coho mortality syndrome described by Scholz et al. (2011). Laboratory studies have demonstrated that juvenile coho salmon (Chow et al. 2019), juvenile steelhead, and juvenile Chinook salmon are also susceptible to varying degrees of mortality when exposed to urban stormwater (French et al. 2022). Fortunately, recent literature has also shown that mortality can be prevented by infiltrating road runoff through soil media containing organic matter, which removes 6PPD-q and other contaminants (Fardel et al. 2020; Spromberg et al. 2016; McIntrye et al. 2015). Research and corresponding adaptive management surrounding 6PPD is rapidly evolving. Nevertheless, key findings to date include:

- 6PPD/6PPD-q has been killing coho in Puget Sound urban streams for decades, dating back to at least the 1980s and likely longer (McCarthy 2008; Scholz 2011).
- Wild coho populations in Puget Sound are at a very high risk of localized extinction, based on field observations of adult spawner mortality in > 50 spawning reach stream segments (Spromberg and Scholz 2011).
- Source-sink metapopulation dynamics (mediated by straying) are likely to place a significant drag on the future abundances of wild coho salmon in upland forested watersheds (the last best places for coho conservation in Puget Sound). In other words, urban mortality syndrome experienced in one part of the watershed could lead to abundance reductions in other populations because fewer fish are available to stray (Spromberg and Scholz 2011).
- Coho are extremely sensitive to 6PPD-q, more so than most other known contaminants in stormwater (Scholz et al. 2011; Chow 2019; Tian 2020).
- Coho juveniles appear to be similarly susceptible to the acutely lethal toxicity of 6PPD/6PPD-q (McIntyre et al 2015; Chow 2019).
- The onset of mortality is very rapid in coho (i.e., within the duration of a typical runoff event) (French et al., 2022).
- Once coho become symptomatic, they do not recover, even when returned to clean water (Chow 2019).
- It does not appear that dilution will be the solution to 6PPD pollution, as diluting Puget Sound roadway runoff in 95% clean water is not sufficient to protect coho from the mortality syndrome (French et al. 2022).
- Preliminary evidence indicates an uneven vulnerability across other species of Puget Sound salmon and steelhead, and a need to further investigate sublethal toxicity to steelhead and Chinook salmon. For example, McIntyre et al. (2018) indicate that chum do not experience the lethal response to stormwater observed in coho salmon.
- Following exposure, the onset of mortality is more delayed in steelhead and Chinook salmon (French et al. 2022).

- The mechanisms underlying mortality in salmonids is under investigation, but are likely to involve cardiorespiratory disruption, consistent with symptomology. Therefore, special consideration should be given to parallel habitat stressors that also affect the salmon gill and heart, and nearly always co-occur with 6PPD such as temperature (as a proxy for climate change impacts at the salmon population-scale) and PAHs.
- Simple and inexpensive green infrastructure mitigation methods are promising in terms of the protections they afford salmon and stream invertebrates, but much more work is needed (McIntyre et al. 2014, 2015, 2016a, b; Spromberg 2016).
- The long-term viability of salmon and other Puget Sound aquatic species is the foremost conservation management concern for NOAA, and thus it will be important to incorporate effectiveness monitoring into future mitigation efforts – i.e., evaluating proposed stormwater treatments not only on chemical loading reductions, but also the environmental health of salmon and other species in receiving waters (Scholz 2011).

To summarize fish response to long-term stormwater effects, there is a risk that runoff could cause lethal and sublethal toxicity, up to and including delayed mortality, in exposed ESA-listed fish and the prey available to salmon and higher-trophic species. The magnitude of this effect will be somewhat reduced by the installation of basic stormwater treatment proposed for this action, which would likely reduce contaminants to levels below lethal toxicity. However, the standards of basic treatment do not provide evidence that risks from contaminants would be entirely avoided. Thus, adverse sublethal effects from ongoing stormwater effluent discharge are expected for PS Chinook salmon, PS steelhead, and PS/GB bocaccio.

SRKW Response

As noted above, despite additional treatment, stormwater effluent produced as a result of the proposed action will likely contain chemicals that cause sublethal toxicity to individual fall Green River PS Chinook salmon which are part of a high-priority prey stock[5] for SRKW (NMFS and WDFW 2018). Proposed stormwater treatment is expected to decrease contaminant concentrations versus the current site conditions, and reduce, but do not eliminate, impacts to species.

Despite expecting only low levels of pollutants, chronic source input over the 40-year design life of the PGIS is likely to cause some sublethal effects to juvenile fall-run Green River Chinook salmon that slightly but chronically diminish SRKW prey quality. Similar to the above contaminant analysis (Section 2.4.c), we cannot predict the biomagnification of contaminants in prey tissue from stormwater effluent, but expect that reductions in prey quality are not of a magnitude that could meaningfully be detected as a consequence for any individual SRKW or at the population level. Moreover, proposed stormwater treatment is expected to reduce contaminants source input, and slightly improve pervasive degraded water quality in the project area. Given the uncertainty of meaningful exposure, and in consideration of the total quantity of prey available to SRKW, it is extremely unlikely stormwater effluent will result in measurable effects to the fitness of an individual SRKW through prey.

---

[5] Here, the term "stock" is used rather than DIP for consistency with the source material cited.

b) Vessel Traffic

Here, we analyze effects from operational fishing vessel traffic noise caused by the proposed action.

Vessels used for a variety of purposes (commercial shipping, military, recreation, fishing, whale watching and public transportation) occur in inland waters of Puget Sound. Noise impacts from the vessel fleet utilizing Terminal 91 are largely analogous to impacts from construction vessel noise presented in Section 2.4.1.a; however, noise will continue after construction is complete, and will occur year-round within the Action Area. Travel in the Action Area is expected to be slow and to adhere to established USCG vessel traffic regulations, which is expected to minimize the noise. Vessel traffic is expected to be infrequent, and, as the berth is not expanding to allow a greater number of fishing vessels to call at any given time, an increase in the frequency or volume of noise from commercial fishing vessels is not anticipated in the project or Action Area. Additionally, fishing vessels and listed species within the Action Area will be temporally and spatially dispersed to the degree that the perpetuation of noise attributable to this proposed action is not measurable.

Fish Response

While NMFS cannot specifically identify fish exposure and response to the fishing vessels that use Terminal 91 we can provide a generalized presentation of response to ship noise. As described in Section 2.4.1.a., fish notice and respond to motorboat noise (Simpson et al. 2016; Voellmy et al. 2014; Whitfield and Becker 2014), and PS Chinook salmon, PS steelhead, and PS/GB bocaccio that encounter fishing vessel boat noise will likely startle and briefly move away from the area. Castellote et al. (2019) found that salmon reaction to a playback of ship noise at source level (160-170 RMS dB) was infrequent with no reaction 85 percent of the time, and that the most frequent of the responses was a minor directional change away from the source of the sound. Moreover, the authors posit that fish are less reactive to structured continuous noise than to sudden onset of noise. Because perpetuated vessel noise within the Action Area is dispersed, we consider response of ESA listed fish likely to exposed to be minor behavior changes only.. Based on the previously described research, it can be assumed that juvenile PS Chinook salmon are likely to respond to episodes of boat motor noise with a stress and startle reaction that can diminish both predator and prey detection for a short period of time with each episode.

SRKW Response

Fishing vessel use of rehabilitated berths may expose SRKW to noise from large ships that extend into frequencies used by killer whales for echolocation (Veirs et al. 2016), and affect foraging efficiency, communication, and/or energy expenditure (Ferrara et al. 2017; Holt et al. 2021). Berth traffic will remain at current operational levels and while orca whales are occasionally present in Elliot Bay, sightings have also included the unlisted transient population as well as SRKW. Vessels will adhere to speed restrictions that limit speed to below seven knots when within one-half of a nautical mile of a SRKW (RCW77.15.740). Reduced speed is suggested to limit reduce sound levels received by SRKW (Holt et al. 2017; Houghton et al. 2015; Veirs et al. 2016; Williams et al. 2021). Additionally, many commercial vessels transiting to the Port are adopting “Quiet Sound” guidelines that include increased slowdown and installation of quieter motors (Washington Maritime Blue 2022). This protocol may reduce noise from vessels using the berth or contribute to minor reductions of the ambient commercial vessel noise level in Elliott Bay, but would likely be a very minor improvement. Overall, noise from vessels utilizing Berths 6 & 8 will likely be indistinguishable from baseline underwater noise levels in Elliott Bay (approximately 120 dB), including sound pressure frequencies typical of a range of vessels.

In the remainder of the action area, SRKW exposure to vessel noise from the fishing fleet is likely. Other data on commercial vessels reveals that In the Haro Strait, which runs between Vancouver Island and the San Juan Islands, container ships produce the highest underwater source levels at 178 underwater dB. Other ship types with source levels greater than 173 underwater dB include vehicle carriers, cargo ships, tankers, and bulk carriers (Viers et al. 2016) The longest fishing vessel that utilizes Terminal 91 measures 376 feet (Port 2023a), while the average length of container and cargo ships traveling to inner Puget Sound ports is approximately 900 feet (COE 2022), so the noise levels the proposed action perpetuates are likely below those measured in this study. Current U.S. and Canadian SRKW management plans include measures to reduce disturbance from anthropogenic noise, such as mandatory minimum distances between vessels and killer whales. Scientists have found, however, that vessel speed, not distance, is the most important predictor of noise levels received by the whales (Holt et al. 2017; Houghton et al. 2015;For many ships in the Salish Sea, a 1 knot reduction in speed results in a 1 dB reduction in broadband source level (Viers et al. 2016) Williams et al. (2019b) found a 3 dB noise reduction in Haro Strait could be met by enforcing a speed limit of 11.8 knots on container ships, vehicle carriers, passenger (cruise) and cargo ships, tankers, bulk carriers, and pleasure crafts. Vessels speeds and lanes are governed by the United States Coast Guard, which is not a party to this consultation. We expect that SRKW exposure to vessel noise will be infrequent, episodic, and intermittent. We expect that only brief behavioral changes (avoidance) could occur among some SRKW if they are exposed to fishing vessel traffic noise from this proposed action, which will be indistinguishable from baseline underwater noise levels.

Finally, operational fishing vessel traffic could potentially result in collisions, known as strikes. Fatal fishing vessel interactions are infrequent for all killer whales (see Raverty et al. 2020) and while the SRKW Recovery Plan mentions vessel strikes, it does not identify them as a major threat (NMFS 2008b). Fishing vessels do not target whales, there is no record of fishing fleet vessels strikes in Puget Sound (NMFS 2023), and strikes from any vessel are a relatively rare occurrence in Puget Sound (Rockwood et al. 2017). Vessels, including fishing vessels, are subject to Washington state regulations protecting SRKWs, which include prohibition of approaching or failing to disengage transmission within 300 yards of a SRKW, positioning a vessel behind a SRKW within 400 yards, or exceeding a speed of seven knots at any point located within one-half of a nautical mile of a SRKW (RCW77.15.740; Cunningham 2023). To further reduce the risk of collision and disturbance, the Port and Quiet Sound implemented a WhaleReport Alert System that delivers alerts when a commercial vessel is within 10 nautical miles of a verified whale sighting and directs captains to slow down or alter course (B.C. Cetacean Sightings Network 2023). We consider the risk of strike extremely low and unlikely to as a result of the proposed action.

2.4.3. Species Exposure and Response to Long-term Effects

Long-term effects, or enduring effects, are a function of exposure and response to physical, chemical, or biological changes associated with the proposed action on the environmental baseline that are likely to last for months, years or decades.

The project elements for this proposed action have been evaluated using the Nearshore Calculator and are summarized in Table 10. The enduring structures result in both a long-term loss of habitat, and a reduction of current impacts that ultimately represents a net improvement in habitat quality.

Replacement of in- and overwater structures will influence habitat functions and processes that impact listed species that encounter them for the duration of their presence. Adverse effects from replacement structures, *despite their reduction in size and number* (see Table 10 below), include reduced refuge, safe migration, and reduced forage.

- Refuge –Shoreline armoring disrupts sediment transport processes that create shallow water habitat preferred for juvenile migration, removing refuge for safe migration. Shade limits growth of SAV, which reduces benthic forage opportunities and forage fish stocks; however, no rooted SAV or forage fish spawning is within the project footprint and these effects are not expected as a result of this proposed action.
- Safe migration –Swimming around replaced in-and overwater structures lengthens the migration distance and is correlated with increased mortality. There is an increased risk of juvenile salmonid predation by other fish or avian predators when they leave the relative safety of shallow water (Willette 2001), or hesitate when encountering shaded areas.
- Forage – Forage reductions are expected as a result of overwater structures that produce shade and reduce benthic productivity (Carrasquero 2001), and epibenthic prey species (Lambert et al. 2021; Munsch et al. 2017; Nightingale and Simenstad 2001). Intertidal zone primary productivity is also limited by armoring that obstructs natural upper intertidal shoreline processes that encourages invertebrates and development of suitable habitat for forage fish spawning.

Many individuals of listed species that encounter the structures will be exposed to the long-term effects of replaced structures any time of year in each year they are present. Accordingly, the Port has incorporated beneficial habitat activities into the proposed action to compensate for the enduring habitat modifications. Beneficial activities include reduction of in-and overwater structures (i.e., pile and wharf), removal of creosote-treated timber, debris removal, fish-rock habitat enhancement, and installation of basic stormwater treatment. These beneficial activities are expected to improve water quality, safe migration, and forage.

- Water quality – Removal of creosote treated material and sediment improves water quality by removing these chronic sources of contaminants.
- Safe migration – Debris removal, in-water and overwater structure reduction, and fish rock will reduce opportunities for piscine predators. Decreased in-water structures and fish rock will also reduce impediments to natural shoreline processes.
- Forage – Decreased shade, increased available benthic substrate, and removal of benthic debris are expected to positively contribute to primary productivity and forage base for

nearshore-dependent species. Use of fish-rock will provide finer substrate and support forage by encouraging a more abundant and diverse invertebrate assemblage. Productivity increases are likely minor because productivity is ultimately limited by sunlight, and the majority of habitat improvements are in deeper water.

During construction, offsetting activities will produce the same temporary effects to species in the project area as the proposed action described above. Following completion of construction, these activities are reasonably certain to lead to some degree of ecological recovery, including the establishment or restoration of environmental conditions associated with functional nearshore habitat.

Table 10. Summary of removed and replaced structures, material types, area and net change, and duration of long-term effects

Structure	Removed Overwater Material	Replaced Overwater Material	Removed Overwater Area (SF)	Replaced Overwater Area (SF)	Net Change Overwater Area (SF)	In-water Number and Material Removed	In-water Number and Material Replaced	Removed In-water Area (SF)	Replaced In-water Area (SF)	Net Change In-water Area (SF)	Duration of Effects (years)
Gangway	Grated	Grated	103	250	147	--	--	--	--	--	40
Floats	Grated	Grated	808	25	-783	--	--	--	--	--	40
Boathouse[1]	Solid	Solid	1,590	1,590	0	--	--	--	--	--	40
Derelict pier	Solid	Solid	154	0	-154	--	--	--	--	--	0
Jut-out/spur	Solid	Solid	9,640	0	-9,640	--	--	--	--	--	0
Wharf	Solid	Solid	55,042	53,509	-1,534	--	--	--	--	--	40
Pile	--	--	--	--	--	2,489 14" creosote treated wood	70 20", 247 24", and 3 36" steel, 240 24" concrete	2,661	950	-1,711	40
Slope armoring	--	--	--	--	--	Riprap, sediment, debris	Rip rap, fish mix	67,660	67,660	0	40
Sheet pile wall[2]	Steel sheet pile, creosote treated wood, concrete fascia	Steel sheet pile	3,120	4,680	1,560	--	--	--	--	--	40
Grand Total	--	--	67,337	55,374	-11,964	--	--	70,321	68,610	-1,711	--

Notes:

1. The boathouse will be relocated from the waterway east of Pier 90 to the waterway west of Pier 90, between Pier 90 and Pier 91. Thus, this single relocated structure it is included both in repair and replaced area counts.
2. The replacement sheet pile bulkhead will be within the same 742 LF as the existing bulkhead. The additional square footage indicated above is an increase only in vertical area and is omitted from totals.

Fish Response

Individuals of listed fish encountering replacement of in- and overwater structures as juveniles will experience obstructions to safe migration (PS Chinook salmon) and refuge and forage reductions (PS Chinook salmon and PS/GB bocaccio) caused by habitat modification for the duration of their presence. It is reasonable to assume that the carrying capacity of these species is constrained by limitations to forage and refuge, and incrementally reduced by predation, and abundance of these listed species will be depressed by effects of these enduring structures.

Conversely, we expect ESA listed fish will experience improved water quality, migration, and forage values, as a result of habitat improvements. Water quality improvements from permanent removal of contaminants will reduce lethal and sublethal toxicity to PS Chinook salmon, PS steelhead, and PS/GB bocaccio and exposed prey. Minor improvements in forage are expected based on increased primary productivity as a result of increased sunlight and benthic substrate, and use of fish-rock. Safe migration for juvenile PS Chinook will be improved through reduction of piscivore habitat. Over the course of the 40-year lifetime of the replacement structures, we expect minute improvements to survival of individual juvenile PS Chinook salmon and juvenile PS/GB bocaccio among some members of each cohort from improvements to the growth and fitness of individuals as a result of this proposed action. As PS steelhead are not nearshore dependent, minor improvements to this species will be primarily through improvements to water quality from contaminant removal and reduction.

Removal of contaminants, in particular, has the potential to impact listed fish, and has the potential to improve population viability by increasing subyearling survival (especially for Chinook salmon) and, by extension, adult spawner abundance (Lundin et al. 2021). Lundin et al. (2019) found that 54 percent improved juvenile survival—potentially as a result of future remediation activities—could increase adult Chinook salmon population abundance by more than 20 percent, implicating pollution remediation as a positive driver for species recovery.

Considering the proposed array of long-term adverse and beneficial activities, we expect minor long-term habitat improvements compared to current conditions that will result in populations of listed fish largely remaining static.

SRKW Response

We do not anticipate SRKW will have a discernable response to long-term project effects, positive or negative. Long-term effects to SRKW through their prey are unlikely because we expect the population abundance of Chinook salmon to remain static as a result of this action (see above).

2.4.4 Summary of Effects on Species

Individuals from PS Chinook salmon, PS steelhead, PS/GB bocaccio, and SRKW are each likely to experience temporary, operational, or long-term effects of activities of the proposed action (shown in Table 11). The temporary effects are all adverse, the operational effects do not increase the level of adverse condition but extend their duration, and the long-term effects include both negative and positive consequences for PS Chinook salmon, PS steelhead, bocaccio, and SRKW. When we add the short term, operational, and long-term effects of the proposed action, we anticipate a very slight 3-year reduction in SRKW prey, but this reduction is likely to be equivalent to less than one adult Chinook salmon in each year, so slight that it is difficult to discern the response or influence of such a reduction in any single SRKW member.

Table 11. Summary of effects to species resulting from the proposed action (denoted by X).

Species	Temporary Underwater Noise	Temporary Suspended Sediment/ Reduced DO	Temporary Contaminant Exposure	Temporary Reduction of Forage	Temporary Obstructions in Migration Areas	Temporary Entrainment	Operational Stormwater Effluent	Operational Vessel Traffic	Long-term Structures	Long-term Habitat Improvements
PS Chinook salmon	X	X	X	X			X	X	X	X
PS steelhead	X						X			X
PS/GB bocaccio	X	X	X	X			X		X	X
SRKW				X				X		X

2.4.5. Effects on Critical Habitat

In this section, we evaluate the proposed action effects on habitat described above in terms of the function of critical habitat PBFs for PS Chinook, PS steelhead, PS/GB bocaccio and SRKW. Many of the habitat modifications are well described above in the effects to species section. Here we characterize those habitat effects relative to the conservation role the features serve.

NMFS reviews effects on critical habitat by examining how the PBFs of critical habitat will be altered, 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 and marine areas, the features of designated habitat common to each of these listed species are water quality and forage or prey. For PS Chinook salmon and PS steelhead, safe migration is an additional PBF. The PBFs relevant for each species are shown in Table 12. Note that only noise effects are expected to impact PS steelhead designated critical habitat due to the distance from the project area from the extent of critical habitat mapped in the West Waterway.

Table 12. Physical and biological features of designated critical habitat

PBF of Critical Habitat	Species
Water quality	PS Chinook salmon PS steelhead PS/GB bocaccio SRKW
Forage or prey	PS Chinook salmon PS steelhead PS/GB bocaccio SRKW
Safe migration/passage	PS Chinook salmon PS steelhead SRKW

As discussed in Section 2.4.3, offsetting activities covered by this Opinion improve habitat over existing conditions, resulting in improvements to the PBFs of listed species. However, despite the full application of the planned conservation measures and BMPs, the proposed action is likely to adversely affect some of the PBFs of designated critical habitat listed in Table 12 for PS Chinook salmon, PS steelhead, PS/GB bocaccio rockfish, and SRKW. In sum, the PBFs of critical habitat for species shown in Table 12 will experience the following changes as a result of the proposed action:

- Water quality PBFs for PS Chinook salmon, PS/GB bocaccio rockfish, and SRKW will be reduced episodically by suspended sediments during construction, temporarily by resuspended contaminants for 6 months following construction (Smith et al. 2008) for up to 2.5 years, and chronically through low-level contaminants in stormwater effluent throughout the lifetime of the structure. Stormwater treatment will reduce but not eliminate nonpoint source pollutants. The extent of adverse water quality effects does not reach the mapped area of PS steelhead critical habitat. Contaminant removal will permanently eliminate sources of toxins from the sediment and water column.
- Forage/prey PBFs for PS/GB bocaccio, PS Chinook salmon, and by extension SRKW, will be diminished by benthic habitat reductions and shade in the nearshore. The spatial area of this effect does not extend to PS steelhead critical habitat, and effects are unlikely because they are not nearshore dependent. Offsetting activities are likely to improve prey/forage in other areas, so that on the whole, the baseline level of forage is retained, with only a temporary decline of up to 3 years. Sufficient quantity, quality and availability of prey, particularly Chinook salmon, are an essential feature of the critical habitat designated for SRKW. Given the total quantity of prey available to SRKWs throughout their range, the slight reduction in Chinook salmon juveniles from the short-term construction effects of the proposed action is likely to be an extremely small reduction in adult Chinook, which are the focal prey of SRKW. This reduction is unlikely to be large enough, even when aggregated over 3 years to that the reduction will reduce the conservation values of the critical habitat (i.e. growth, fitness, survival, reproduction of SRKW). However, because prey is a limiting factor for SRKW, any reduction in prey abundance or quality is likely to be meaningful to some individuals within the population.
- Migration/passage PBFs for PS Chinook salmon and PS steelhead will be temporarily diminished by noise effects during construction. Long-term passage conditions for PS Chinook salmon improve because of the reduction of in-water structures. No effects are expected to SRKW passage PBFs.

While adversely affected, PBFs are not so diminished that we would consider the role of the critical habitat to be significantly impaired. We consider the temporary effects to critical habitat not of sufficient duration, intensity, or spatial extent to impair the conservation role (survival, growth, maturation, fitness) of these species.

With implementation of the NHVM, we expect no-net-loss of shoreline long-term habitat function from the proposed action and offsetting activities covered by this Opinion. As described in Section 2.1, elements of the proposed action generate credits from the Nearshore Calculator. NMFS has determined that this proposed action would result in positive environmental results to long-term nearshore habitat quality, quantity, or function equivalent to 0 credits (Appendix A).

2.5. 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.

NMFS does not expect any new discrete non-Federal activities within the Action Area because the area is already highly developed with industrial activities, and work within the water would fall under federal authorities such as the Clean Water Act. However, at the action area-scale, future upland development activities lacking a federal nexus will continue and are expected to lead to increased impervious surface, surface runoff, and non-point discharges. NMFS expects these activities to continue in perpetuity. These activities will degrade water quality and exert a negative influence on ESA-listed species. Any future federal actions will be subject to section 7(a)(2) consultation under ESA.

Some continuing non-Federal activities are reasonably certain to contribute to climate effects within the Action Area. Because Elliott Bay and the West Waterway are expected to remain in highly industrialized and utilized for several decades, and we do expect climate change conditions to become more pronounced over time, we anticipate this may disrupt important habitat features and ecosystem functions that are critical in salmon survival and recovery.

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 conditions in the Action Area are described earlier in the discussion of environmental baseline (Section 2.4).

The human population in the Puget Sound region is experiencing a high growth rate. The central PS region (Snohomish, King, Pierce and Kitsap counties) has increased from about 1.29 million people in 1950 to over 4.2 million in 2020, and projected to reach nearly 6 million by 2050 (Puget Sound Regional Council 2020). Thus, future private and public development actions are very likely to continue in and around PS. As the human population continues to grow, demand for agricultural, commercial, and residential development and supporting public infrastructure is also likely 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 likely 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.

Several not for profit organizations and state agencies are also implementing recovery actions identified in the recovery plans for Puget Sound Chinook salmon, PS steelhead, PS/GB bocaccio, and SRKW. 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 immediately, 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 likely to have ongoing adverse effects on the listed species addressed in this Opinion, and abundance and productivity that outpace the effects of restoration activities. 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 to negate population growth and non-federal development, adverse cumulative effects may be minimized, but will probably not be completely avoided.

2.6. Integration and Synthesis

The Integration and Synthesis section is the final step in assessing the risk that the proposed action poses to species and critical habitat. In this section, we add the effects of the action (Section 2.4) to the environmental baseline (Section 2.3) and the cumulative effects (Section 2.5), 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.

Bocaccio rockfish and SRKW are endangered. Bocaccio live only in the marine environment, and the nearshore habitat of juveniles is degraded by bank armoring and impaired sediment processes. Bocaccio rockfish are long lived with late sexual maturity, which makes increasing productivity very difficult to enhance by any human endeavor. SRKWs are at risk of extinction in the foreseeable future. The SRKW 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).

Each of the other species considered in this opinion was listed as threatened with extinction because of declines in abundance, poor productivity, reduced spatial structure, and diminished diversity. Systemic anthropogenic detriments in fresh and marine habitats are also limiting the productivity for PS Chinook salmon and PS steelhead.

Throughout the Action Area and nearshore Salish Sea, the environmental baseline has been degraded by human modifications that disrupt vital physical, biological, and chemical interactions. These modifications have reduced water quality, forage and prey availability and quality, available estuarine and nearshore habitat, and condition of migration habitat. In the project area, the nearshore consists of commercial/industrial infrastructure associated with development landward of highest astronomical tide that further degrades habitat conditions for listed species in their nearshore marine life stage. There are sources of noise and shade (vessels), water quality impairments (nonpoint sources), and artificial light (marinas and fishing piers).

To this context of species status and baseline conditions, we add the temporary, operational, and long-term effects of the proposed action, together with cumulative effects (which are anticipated to be increased population growth, development of the built environment, and stressors associated with climate change), in order to determine if the proposed action's effects will appreciably diminish the value of designated critical habitat for the conservation of the listed species, and the overall effect of the proposed action on the likelihood of species' survival and recovery.

2.6.1 ESA Listed Species

Salmonids

The temporary effects on PS Chinook salmon and PS steelhead salmonids added to the baseline and considered in light of the status of the species, range from behavioral to injury or death. Some effects (noise, turbidity) will occur among individuals from two cohorts of salmonids as the construction will occur consecutively over 2 years. Prey reductions take longer to ameliorate and will expose up to 3 cohorts. However, as presented in the analysis above, the most frequent response is behavioral, when the salmonids engage in avoidance behavior, startle behavior, or expend more energy to seek more successful forage locations. This may reduce fitness or survival in some members of the populations exposed during the work windows in each of 3 years.

The long-term effects added to the baseline, and considered in light of the status of the species, are largely neutral for salmonids because when all positive and negative activities are complete, habitat conditions will be retained or slightly improved, allowing some individuals among many cohorts over the life of the structure to have greater growth and fitness.

The potential reduction in fitness or survival associated with the construction and operational impacts, when considered in the context of baseline and status of the species, is likely to result in the loss of a small number of PS Chinook and even fewer PS steelhead, but this number is insufficient to alter the population dynamics (productivity, diversity, spatial structure). When reduction is evaluated with the long-term adverse and beneficial effects,[6] and considered in respect to the anticipate slight reduction from cumulative effects, we expect that the slight reduction and the slight benefits from habitat improvements will result in the population abundance of both species remaining largely static.

---

[6] The sum of all adverse and beneficial activities within this proposed action indicate a positive output for habitat when entered in the Nearshore Calculator. This proposed action would generate a positive balance of 5,393.77 conservation credits, or 53.94 DSAYs, were the Nearshore Calculator not programmed to only return a zero balance or debit.

PS/GB Bocaccio

The 3 years of construction effects of the proposed action on individuals from three cohorts of PS/GB bocaccio, when added to the species status and baseline of poor abundance, productivity, and nearshore habitat conditions, are mostly of the same nature and magnitude as described above for salmonids. We expect an extremely small number of bocaccio to experience adverse effects that may result in reduced fitness or survival as the result of the temporary construction and operational effects, in part because their presence in the project area is expected to be very low. Long-term project effects are likely neutral to somewhat beneficial due to prey improvements anticipated from the reduction of in- and overwater structures, which could increase fitness or survival in some members of the population. We do not expect temporary reductions in abundance of larvae, juveniles or adults from construction or operational effects will alter rockfish abundance or productivity in the long term. Also, habitat benefits accruing to individuals over the long term from the project could be counterbalanced by incremental negative cumulative effects, suggesting that current levels of productivity are likely to persist.

SRKW

SRKW are listed as endangered, based on an extremely low population size, and low productivity. Their critical habitat, inclusive of the Action Area, is diminished by water quality degradation, chronic sound, and insufficient prey (both abundance and poor quality of the prey available, inferred from the high body load of contaminants of SRKW which are an apex predator). When we add the short term, operational, and long-term effects of the proposed action, we anticipate a very slight 3 year reduction in SRKW prey, but this reduction is likely to be equivalent to less than one adult Chinook salmon in each year, so slight that it is difficult to discern the response or influence of such a reduction in any single SRKW member.

When we consider cumulative effects, as described above, these are driven largely by human population growth and are likely to have an incrementally negative influence over time. However, regulatory protections designed to curtail the influence of vessel interactions with SRKW have recently increased which may yield some contemporaneous protective benefit to the species.

The proposed action's temporary effects will very slightly reduce the availability of SRKW prey over 3 years. While the anticipated temporary impacts are considered harm under the ESA, NMFS found that, in this case, the harm likely to be caused by the proposed action under the ESA did not equate to a form of take under the MMPA. .

Operationally, the ongoing fishing vessel effects perpetuated by the action are unlikely to increase the ambient noises, and collision risk from these vessels among SRKW in the Action Area is extremely low. Despite treatment, ongoing stormwater effluent will reduce but not eliminate contaminant input and contribute to diminished water quality in developed areas of Puget Sound over the lifetime of the PGIS (40 years). Given the uncertainty of effluent chemical concentration and bioavailability, and considering the beneficial offsetting activities, we cannot reasonably discern that ongoing stormwater impacts are of a sufficient intensity to have a meaningful effect on the numbers, reproduction, or distribution of SRKW, or change SRKW's viability parameters in the long term.

Long-term effects to SRKW would occur only through their prey base. We expect the population abundance of Chinook salmon to remain static in the long term as a result of offsets used to ensure sufficient conservation. Because activities occur such that the action as a whole will result in slight improvements of habitat function, as described in Section 2.1, we anticipate long-term effects to be unlikely.

Therefore, we anticipate temporary forage reductions may inhibit the growth or fitness of some individual SRKWs. While we expect impacts to be extremely minor, they will be nonetheless consequential in consideration of the SRKW status. Given the low overall level of impact to SRKW and support of prey base over time as a result of offsetting activities, we do not anticipate any change in SRKW's viability parameters, numbers, reproduction, or distribution as a result of the proposed action.

2.6.2 Critical Habitat

PS Chinook Salmon

Nearshore PS Chinook salmon critical habitat has high conservation value despite the current degraded conditions (NOAA Fisheries 2005). The proposed action would have minor localized effects, both positive and negative, to PS Chinook salmon critical habitat. The temporary negative water quality, contaminant, forage, and noise effects do not occur at an intensity or duration that will further limit critical habitat's ability to support PS Chinook salmon growth, maturation, or movement. When construction is complete, the nearshore migration PBF will be improved, and the forage PBF will be maintained or improved following benthic recovery (3 years). In the long term, long-term contaminant effects will reduce water quality while offsetting activities will result in minor water quality improvements, maintaining this PBF of critical habitat. When all positive and negative effects are considered, the proposed action will result in neutral or slightly improved critical habitat conditions which do not further reduce the conservation value of PS Chinook salmon critical habitat.

PS Steelhead

Water quality and forage effects are not expected to extend to areas of designated PS steelhead critical habitat. We expect the area of PS steelhead critical habitat within West Waterway to be temporarily diminished for the migration/passage PBF by noise during construction. Noise effects will be temporary, acute, and intermittent, for up to 198 days of each work window. Even though aspects of the baseline are degraded, mainly through development of the nearshore and upstream migration areas of the Duwamish River, and cumulative effects likely will continue to adversely affect PS steelhead critical habitat, the added adverse temporary noise effects of the proposed action do not significantly alter the conservation value of critical habitat, and long-term effects on PBFs are largely neutral to beneficial, with reductions of in and over water structures improving conditions for prey and migration.

PS/GB Bocaccio

Although loss of nearshore habitat quality is a threat to bocaccio, the recovery plan for this species list the severity of this threat as low (NMFS 2017a), and other factors, such as overfishing, are more significant threats to bocaccio rockfish (Drake et al. 2010; Palsson et al.

2009). Similar to PS Chinook salmon critical habitat (discussed above), temporary negative effects to water quality and prey PBFs are minor and localized, and do not occur at an intensity or duration that will further limit critical habitat carrying capacity. Operational and offsetting activities will maintain or improve water quality, and prey PBFs and result in maintenance or improvement of nearshore rearing habitat. Overall, when added to the degraded baseline and cumulative effects, the effects of the action do not significantly alter the conservation value of PS/GB bocaccio critical habitat at the designation scale and will result in neutral or slightly improved conditions due to the removal of in and overwater structure and an anticipated associated increase in prey communities.

SRKW

The proposed action will have some temporary negative effects on the prey/forage PBF of SRKW critical habitat through impacts to juvenile PS Chinook salmon fitness and survival for a maximum of 3 years as a result of benthic reductions. We recognize that the permanent removal of contaminated material that causes temporary depression of the water quality PBF is ultimately beneficial to species. The array of impacts to juvenile salmon correlate to a small, but likely, reduction in adult PS Chinook salmon quantity and quality; however, these effects among Chinook salmon as a feature of SRKW critical habitat are difficult to discern at the population level.

Ongoing contaminants in stormwater effluent will continue to degrade the water quality PBF (for salmonids and SRKW). We recognize here that the addition of stormwater treatment with the proposed action will reduce but not eliminate the adverse effects of degraded stormwater.

In the long term, the proposed action will result in slight improvements to PBFs of PS Chinook salmon critical habitat which may support the carrying capacity and represent slight improvements to the SRKW prey PBF. However, in light of the current SRKW status and time elapsed before positive impacts are expected for the adult PS Chinook salmon population (maximum 3 years), improvements to SRKW critical habitat prey PBF are likely neutral. Therefore, when considering the proposed action’s effects in light off SRKW population declines, and added to the degraded baseline and cumulative effects, the effects of the action on SRKW critical habitat do not diminish the conservation value of critical habitat at the designation scale.

2.7. Conclusion

After reviewing and analyzing the current status of the listed species and critical habitat, the environmental baseline within the Action Area, the effects of the proposed action, the effects of other activities caused by the proposed action, habitat conservation offsets, and the cumulative effects, it is NMFS’ biological opinion that the proposed action is not likely to jeopardize the continued existence of PS Chinook salmon, PS steelhead, PS/GB bocaccio, or SRKW, or destroy or adversely modify their designated critical habitat.

2.8. 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 applicant (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.

2.8.1. Amount or Extent of Take

The proposed action 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. The take described below cannot be accurately quantified as a number because NMFS cannot predict, using the best available science, the number of individuals of listed fish that will be exposed to these stressors. Reliable, up-to-date density information is not available and therefore it is not possible to reliably enumerate or monitor the number of individuals exposed to the action's stressors. The distribution and abundance of fish that occur within an Action Area are affected by seasonal use, life stage, habitat quality, competition, predation, and the interaction of processes that influence genetic, population, and environmental characteristics. These biotic and environmental processes interact in ways that operate across far broader temporal and spatial scales than are affected by individual activities within the proposed action.

When NMFS cannot precisely predict the number of a species that are reasonably certain to be harmed, captured, or killed, we rely on surrogate measures for take, called an extent of take. The most appropriate surrogates for take are action-related parameters that directly relate to the magnitude and duration of the expected take. In such circumstances, NMFS uses the causal link established between the activity and the likely extent and duration of changes in habitat conditions to describe the extent of take as a numerical level of habitat disturbance. The extent is readily observable, and therefore suffices to trigger reinitiation of consultation if take is exceeded. These surrogate measures provided here are valid reinitiation triggers because there will be ongoing monitoring to evaluate if the incidental take thresholds are exceeded and the action agency can take remedial action if the incidental take thresholds are exceeded based on monitoring and reporting results.

In this Opinion, NMFS has determined that incidental take is reasonably certain to occur as follows:

1. Harm and harassment of PS Chinook salmon, PS steelhead, and PS/GB bocaccio from underwater noise – The extent of take is installation of 320 piles no larger than 36 inches in diameter (harm), and removal of 2,500 piles (harassment). The number of piles driven or removed is proportional to the amount of take because the installation or removal of each pile creates sound that could harass, injure, or kill fish. The extent of take from

underwater noise produced by construction vessels is the presence of four vessels (two barges and two tugs) at any time during construction.

2. Harm of juvenile PS Chinook salmon and PS/GB bocaccio from water quality reductions caused by turbidity, reduced DO, and contaminants during construction –The extent of take is turbidity more than 5 NTU above background if natural turbidity is lower than 50 NTU, or 10 percent above background if background turbidity is higher than 50 NTU, at 150 feet from the point of disturbance. This measure is causally related to harm because the area of increased suspended sediment around sediment-disturbing activities is equivalent to the area where TSS and resuspended contaminants that can harm fish and benthic productivity are most likely to occur.

3. Harm of PS Chinook salmon, PS steelhead, and PS/GB bocaccio from water quality reductions caused by stormwater effluent – The extent of take for stormwater effluent is the area of PGIS to be repaved and diverted to the new stormwater treatment system. The fully disturbed upland area used to calculate the treatment design equals 102,000 SF (2.32 acres) of PGIS. This surrogate, a maximum of 102,000 SF, is related to the amount of take because larger areas of PGIS would contribute a greater load of contaminants, and is a valid reinitiation trigger because the spatial area of PGIS is readily observable.

4. Harm of juvenile PS Chinook salmon and PS/GB bocaccio from long-term presence of in- and overwater structures in nearshore habitat – The extent of these habitat modification impacts is directly related to the total area (SF) of pile, shoreline armor, and overwater structures installed. Thus, the extent of incidental take from exposure to in- and overwater structures is a maximum of 1,000 SF of pile, 68,000 SF of shoreline armoring, 750 LF of vertical armoring along the bulkhead, and 56,000 SF of overwater coverage for the design lifespan of each structure (40 years).

Exceeding any of these extents of take could trigger re-initiation of this consultation.

2.8.2. Effect of the Take

In this Opinion, NMFS has 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.

2.8.3. 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 COE, the applicant, or its contractor shall:

1. Minimize incidental take from underwater noise.
2. Minimize incidental take from water quality reductions.
3. Minimize incidental take associated with in- and overwater habitat modification.
4. Monitor to ensure the amount or extent of incidental take is not exceeded.

2.8.4. 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 applicant complies) with the following terms and conditions. The COE or any applicant 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. The following terms and conditions implement reasonable and prudent measure 1 (noise):
   a. Use an enclosed bubble curtain or other noise attenuation device during steel pile impact proofing unless piles are driven in the dry (not in contact with water).
   b. Perform shoreline armor removal and replacement during low-tide in the dry to the extent practicable.
   c. Ensure soft start and stop work protocols of the 2012 pile systems repair and maintenance marine mammal monitoring and minimum observer qualification specifications (Port 2012) are strictly adhered to.

2. The following terms and conditions implement reasonable and prudent measure 2 (water quality reductions):
   a. Utilize existing infrastructure to the greatest degree practicable to position and moor construction and support vessels, and limit derrick spuds or anchors for minor repositioning of equipment.
   b. Prevent grounding of all vessels, including temporary grounding of small support vessels. Grounding of vessels causes suspended sediment that reduces water quality.
   c. Direct contractors to limit engine idle time for equipment and vessels used during construction.
   d. Regularly maintain components of the new stormwater treatment system to ensure maximum efficiency.
   e. To reduce behaviors and practices that contribute to adverse stormwater impacts, distribute stormwater BMPs information to Terminal 91 tenants, such as through pamphlets or permanent signage.

3. The following terms and conditions implement reasonable and prudent measure 1-4 (monitoring):
   a. Monitor and *report at the end of each work window* used for construction information related to in-water pile installation and removal, including:
      i. Dates and start and end time.
      ii. Number, size, and material of pile installed or removed categorized by method (vibratory, impact, or vibratory with impact proofing).
      iii. Total impact hammer operation time and number of impact hammer strikes.
      iv. Total vibratory hammer operation time.
      v. Observed indicia of fish injury or death (e.g. unusual amount piscivorous bird activity).
      vi. Provide documentation of marine mammal exclusion enforcement, to include:

A. Monitoring dates and times, monitoring station locations, and construction activity at time of monitoring.
B. Species and counts of any marine mammals identified during monitoring.
C. Instances of stop work/exclusion protocols enforced and duration of time in place.

b. Monitor suspended sediment consistent with the WDOE water quality certification protocols.
   i. If exceedances occur, stop work to allow the exceedance to resolve (via settling of suspended sediment) and identify any additional measures to be employed to reduce the likelihood of re-exceedance.
   ii. Provide NMFS at the completion of each work window documentation of any exceedances of suspended sediment criteria consistent with the requirements of the WDOE water quality certification, including conditions contemporaneous with any exceedance (e.g., the specific activity occurring, the weather, tides, and measures taken to reduce sediment, and efficacy of those measures).

c. Document and report within 6 months of project completion the extent of long-term habitat modifications, including the following:
   i. Total area of all pile installed.
   ii. Total area of shoreline armor placement.
   iii. Total length of bulkhead replacement.
   iv. Total area of wharf and small boat/float system components installed.
   v. Submit dump receipts verifying the total creosote tonnage removed
   vi. Following the submission of creosote tonnage documentation, a final balance, not to exceed +0 conservation offsets, will be confirmed by NMFS.
      A. Tonnage in excess of the estimated 3,334 tons will not result in a recalculation.
      B. Tonnage less than the estimated 3,334-tons shall result in a re-calculation of conservation offsets in a NMFS-approved Calculator[7].
         I. Offset of any remaining debits must be achieved within 3 years.
         II. Offsets may be achieved by off-site conservation actions within the South-Central Puget Sound Basin. Prior to proceeding with this option, the proposed habitat improvements must be evaluated by NMFS using a NMFS-approved Calculator to determine if all necessary credits will be obtained.
         III. Alternatively, offsets may be purchased through Puget Sound Partnership or a conservation bank.

[7] The Port of Seattle has agreed to use the Nearshore Calculator for the Terminal 91 Berths 6 & 8 project because an alternative calculator for the estuarine environment has not yet been developed/approved by NMFS.

The report(s) shall be include in the regarding line the NMFS tracking number (WCRO-2022-03517) and shall be sent by electronic copy to NOAA' s reporting system email address at: projectreports.wcr@noaa.gov and sara.potter@noaa.gov.

2.9. 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).

The COE should encourage Port engagement in beneficial habitat and salmonid recovery activities, to potentially include:

1. Leverage the Port's authority over tenants to require BMPs with maximum protectiveness of aquatic habitat on Port properties, and provide educational outreach to tenants and staff.
2. Establish dedicated funding for salmon enhancement habitat development as a maritime environmental initiative, capitalizing on the Port's financial resources, public visibility, and responsibility to citizens as a special-purpose government.
3. Utilize Port facilities to perform pilot projects benefitting habitat restoration, including exploration of eco-engineering and green technologies.
4. Evaluate green and emerging technologies for contaminant removal in surface and stormwater effluent.
5. Foster a coordinated effort among Puget Sound ports in support of Washington State's pursuit of a healthier Puget Sound.
6. Continue to reduce vessel noise by investing in quiet propeller designs and incentivizing retrofitting of ships.
7. Improve the quality of riparian habitat and submerged aquatic vegetation to increase cover and forage for juvenile migration and rearing.
8. Remove existing in-water structures such as docks, floats, piles, bulkheads, or armoring that are no longer in use. To reduce contaminant loads to ESA-listed species, prioritize permanent removal of remaining creosote timber.
9. Evaluate and prioritize areas for soft shore armoring where existing bulkheads occur.

Please notify NMFS if the COE or Port carries out these recommendations so that we will be kept informed of actions that are intended to improve the conservation of listed species or their designated critical habitats.

2.10. "Not Likely to Adversely Affect" Determinations

This assessment was prepared pursuant to section 7(a)(2) of the ESA, implementing regulations at 50 CFR 402 and agency guidance for preparation of letters of concurrence.

When evaluating whether the proposed action is not likely to adversely affect listed species or critical habitat, NMFS considers whether the effects are expected to be completely beneficial, insignificant, or discountable. Completely beneficial effects are contemporaneous positive effects without any adverse effects to the species or critical habitat. Insignificant effects relate to the size of the impact and should never reach the scale where take occurs. Effects are considered discountable if they are extremely unlikely to occur. The effects analysis in this section relies heavily on the descriptions of the proposed action discussed in Sections 1.3 and on the effect analyses presented in Section 2.4.

2.11.1. PS/GB Yelloweye Rockfish and Designated Critical Habitat

Juvenile yelloweye rockfish are not known to typically occupy intertidal or shallow water habitats (Love et al. 1991). Juvenile yelloweye rockfish between 2.5 centimeters and 10 centimeters (approximately 1 and 10 inches, respectively) have been observed in areas of high relief at depths greater than 15 meters (49.5 feet) (Love et al. 2002). Accordingly, as depths in the project area are insufficient for juvenile yelloweye rockfish, exposure to construction effects other than sound are not expected for this lifestage.

Larval rock fish presence typically peaks twice, once in spring and once in late summer. Unlike PS/GB bocaccio, larval PS/GB yelloweye rockfish do not typically utilize the nearshore environment and are more likely to be found in areas with greater depth. We find the likelihood of larval or juvenile PS/GB yelloweye rockfish to be occupying the project area to be low. As yelloweye rockfish are uncommon in the Action Area, having been found to be most common in Hood Canal and less frequent in North and Central Puget Sound (Palsson et al. 2009), and larval rockfish remain in their basin of birth (Drake et al. 2010), by extension it is unlikely that larval yelloweye rockfish will be exposed to construction effects.

Only noise from construction or ongoing vessel traffic effects would potentially occur to adult yelloweye rockfish within the Action Area. Preferred habitat for the adult lifestage is very limited because the rugosity favored by this species is either not present, or, if present, is at depths habitat depths that will attenuate habitat effects (noise) to occur at a very low intensity. We consider the effects at all lifestages to be either discountable (larvae, juveniles) or insignificant (adults).

Critical habitat was designated for all species of listed rockfish in 2014 (79 Fed. Reg. 68041, November 13, 2014). Critical habitat for yelloweye rockfish includes 414.1 square miles of deepwater marine habitat in Puget Sound, all of which overlaps with areas designated for bocaccio. No nearshore component was included in the critical habitat listing for juvenile yelloweye rockfish as they, different from bocaccio, typically are not found in intertidal waters (Love et al. 1991). NMFS identified one physical or biological features, essential for their conservation:

1. Deepwater sites (>30 meters) that support growth, survival, reproduction, and feeding opportunities.

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 as specific threats to rockfish habitat in the Georgia Basin (NMFS 2017b).

The only effects of the action that may extend into these deepwater habitats are temporary noise from construction activities and water quality impacts. Temporary noise, primarily continuous noise from vibratory pile driving, that extends into deepwater habitat will be attenuated, and not measurably alter PBFs of this habitat, including prey species, water quality, and structure. The contribution of contaminants will continue at a lesser degree as a result of the proposed action, and the area of critical habitat will experience very diffuse and attenuated exposure, insufficient to degrade the role of the critical habitat. Therefore, we consider the effects insufficient to alter the function of any features of critical habitat, and the effects of the Action on designated critical habitat for PS/GB yelloweye rockfish are considered insignificant.

2.11.2. Central America and Mexico DPSs Humpback Whale

The two separate ESA-listed DPSs of humpback whales that may occur in the Action Area are the endangered Central American (CAM) DPS and threatened Mexico DPS. For our analysis, we consider humpback whales migrating or foraging in inland waters of Washington to primarily originate from the listed Mexico or non-listed Hawaii DPSs, with a smaller proportion being CAM humpback whales, following Wade (2017 and 2021).

Humpbacks may be entering the Salish Sea as a foraging or rearing opportunity along their migration from summer feeding grounds to winter breeding grounds Numbers of humpback whales have been growing annually at a rate of 6 to 7.5 percent off the U.S. West Coast (Calambokidis and Barlow 2020; Carretta et al. 2021). Humpback whale sightings in the Salish Sea have also been increasing since the early 2000s (Calambokidis et al. 2018). Sightings in recent years have most mostly occurred from May through October but occur year-round.

It is considered possible but highly unlikely that humpback whales may be in the area of noise impacts during construction. If they were to enter the zone of noise impacts during construction, the marine mammal stop-work protocols would prevent exposure, so we consider the exposure of this species to the temporary effects of the proposed action discountable.

As with SRKW (above), operational effects over the berth design life include fishing vessels that may expose humpback whales to episodic noise and/or strike risk. As analyzed above, potential exposure to vessel effects will remain episodic and transitory. Noise from vessels utilizing Berths 6 & 8 will be limited by enforced or voluntary slow-down protocols to levels indistinguishable from ambient noise, and are therefore considered insignificant to humpbacks. There are no recorded cases of a collision between a fishing vessel and humpback whales in Puget Sound, although there are 11 reports of humpback/vessel strikes within Washington waters between 2004 and 2022 (NMFS Stranding Database 2022). As detailed above, fishing vessels do not target marine mammals, operate at relatively slow speeds, remain in idle, or the engine is off when actively fishing. Required and/or recommended approach restrictions and speed reductions decrease the chance of a vessel strike occurring and the chance of a potential strike leading to a serious injury or mortality for a humpback whale (NMFS 2023). Therefore, we consider a humpback strike from a fishing vessel to be unlikely and vessel strikes effects are expected to be discountable.

Exposure of any individual humpbacks to stormwater is expected to be infrequent, brief, and at low concentration and if it were to occur, most likely to a member of the unlisted DPS. Although there has been substantial research on contaminants on individual whales, including humpbacks, no detectable or sub-lethal impact has been identified in baleen whales (NMFS 2022b).

Contaminants were not considered an important threat to the CAM or Mexico DPS in the 2015 NMFS status review of humpback whales (Bettridge et al. 2015). We consider the response to the proposed action insignificant to humpback whales.

2.11. Reinitiation of Consultation

This concludes ESA consultation for Port of Seattle Terminal 91 Berths 6 & 8 Redevelopment.

Under 50 CFR 402.16(a): "Reinitiation of consultation is required and shall be requested by the Federal agency or by the Service 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 EFH assessment provided by the COE and descriptions of EFH contained in the fishery management plans developed by the Pacific Fishery Management Council (PFMC) and approved by the Secretary of Commerce for Pacific Coast salmon (PFMC 2022a), Pacific Coast groundfish (PFMC 2022b), and coastal pelagic species (PFMC 2023).

3.1. Essential Fish Habitat Affected by the Project

The Action Area overlaps with identified EFH for Pacific Coast salmon, Pacific coast groundfish, and coastal pelagic species. Additionally, Puget Sound is a Habitat Area of Particular Concern (HAPC), based on importance of the ecological function provided by the habitat. Salmonid, groundfish, and coastal pelagic species that may be within EFH in the Action Area are listed in Table 13, Table 14, and Table 15.

Pacific salmon EFH is primarily affected by the loss of suitable spawning habitat, barriers to fish migration (habitat access), reduction in water quality and sediment quality, changes in estuarine hydrology, and decreases in prey food source. Pacific coast groundfish species are considered sensitive to overfishing, the loss of habitat, and reduction in water and sediment quality. Coastal pelagic species are considered sensitive to overfishing, loss of habitat, reduction in water and sediment quality, and changes in marine hydrology.

Table 13. Pacific salmon EFH species potentially in the Action Area

Common Name	Scientific Name
Chinook salmon	*Oncorhynchus tshawytscha*
Coho salmon	Oncorhynchus kisutch
Pink salmon	*Oncorhynchus gorbuscha*

Table 14. Pacific coast groundfish EFH species potentially in the Action Area

Common Name	Scientific Name	Common Name	Scientific Name
Arrowtooth flounder	*Atheresthes stomias*	Pacific Ocean perch	*Sebastes alutus*
Big skate	*Raja binoculata*	Pacific sanddab	*Ctlharichthys sordidus*
Black rockfish	*Sebastes melanops*	Petrale sole	*Eopsetta jordani*
Bocaccio	*Sebastes Paucispinis*	Quillback rockfish	*Sebastes maliger*
Brown rockfish	*Sebastes auriculatus*	Ratfish	*Hydrolagus colliei*
Butter sole	*Isopsetta isolepis*	Redbanded rockfish	*Sebastes proriger*
Cabezon	*Scorpaenichthys marmoratus*	Rex sole	*Glyptocephalus zachirus*
California skate	*Raja inomata*	Rock sole	*Lepidopsetta bilineata*
Canary rockfish	*Sebastes pinniger*	Rosethorn rockfish	*Sebastes helvomaculatus*
China rockfish	*Sebastes nebulosus*	Rosy rockfish	*Sebastes rosaceus*
Copper rockfish	*Sebastes caurinus*	Rougheye rockfish	*Sebastes aleutianus*
Curlfin sole	*Pleuronichthys decurrens*	Sablefish	*Anoplopoma fimbria*
Darkblotch rockfish	*Sebastes crameri*	Sand sole	*Psettichthys melanistictus*
Dover sole	*Microstomus pacificus*	Sharpchin rockfish	*Sebastes zacentrus*
English sole	*Parophrys vetulus*	Shorts pine thornyhead	*Sebastolobus alascanus*
Flathead sole	*Hippoglossoides elassodon*	Spiny dogfish	*Squalus acanthias*
Greenstriped rockfish	*Sebastes elongatus*	Splitnose rockfish	*Sebastes diploproa*
Hake	*Merluccuys productus*	Starry flounder	*Platichthys stellatus*
Kelp greenling	*Hexagrammos decagrammus*	Tiger rockfish	*Sebastes nigrocinctus*
Lingcod	*Ophiodon elongatus*	Vermilion rockfish	*Sebastes miniatus*
Longnose skate	*Raja rhina*	Yelloweye rockfish	*Sebastes ruberrimus*
Pacific cod	*Gadus macrocephalus*	Yellowtail rockfish	*Sebastes llavidus*

Table 15. Coastal pelagic species potentially in the Action Area

Common Name	Scientific Name
Market squid	*Latigo opalescens*
Northern anchovy	*Engraulis mordax*
Pacific mackerel	*Scomber japonicas*

3.2. Effects on Essential Fish Habitat

The effects of the proposed project on ESA-listed species are described in the effects analysis above (Section 2.4). The same mechanisms of effect are likely to affect Pacific coast salmon, Pacific coast groundfish, and coastal pelagic species to varying degrees. These effects include:

1. Noise – temporarily elevated underwater noise during construction.
2. Water quality – temporarily degraded water quality as a result of sound, turbidity, re-suspended contaminants, decreased dissolved oxygen, and other pollutants.
3. Migratory disruption – continued alteration of outmigration routes of juvenile salmonids, causing them to navigate around the proposed structures and move into deeper water. Juveniles encountering the structure will leave the shallow nearshore, increasing the migration route and increasing the risk of predation. Although the total overwater cover will decrease slightly, we expect this action to continue to impair the quality of the migratory corridor and hinder safe passage.
4. Forage reduction – Designated EFH will experience temporary, episodic, and long-term declines in forage or prey communities as a result of reduced primary production. Contributing project actions include temporary disturbance of benthic communities and long-term perpetuation of shading that prevents growth of submerged aquatic vegetation.
5. Offsetting/Beneficial activities – The proposed action incorporates minimization measures to avoid, reduce, and minimize adverse effects of the action on EFH. Overall, the proposed action results in slight improvements to habitat within the Action Area from reduction of structures, removal of contamination, and habitat enhancement through debris removal and use of fish rock. The Nearshore Calculator indicates a generation of conservation credits that fully offset the negative habitat effects of the proposed action.

The diminishments of EFH water quality, migration areas, shallow water habitat, forage base, and SAV will continue to incrementally degrade the function of EFH. The effects further constrain the carrying capacity for life stages (larval and juvenile) of multiple EFH species within the Action Area.

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. Therefore, NMFS recommends the following to ensure the conservation of EFH and associated marine fishery resources:

1. Preserve and enhance EFH by providing new gravel for spawning areas (i.e., incorporating fish mix and/or beach nourishment).

2. Comply with Washington state water quality standards by conducting water quality monitoring during pile activities. At point of compliance (per state permit), turbidity levels shall not exceed 5 NTU more than background turbidity when the background turbidity is 50 NTU or less, or there shall not be more than a 10 percent increase in turbidity when the background turbidity is more than 50 NTU.
3. To minimize suspended sediment during structure removal and construction, implement the best management practices and conservation measures and employ a turbidity monitoring plan. Some conservation measures include:
    a. Remove piles slowly to allow sediment to slough off at, or near, the mudline.
    b. Shake or vibrate the pile to break the bond between the sediment and pile. Doing so causes much of the sediment to slough off the pile at the mudline, thereby minimizing the amount of suspended sediment.

3.4. Statutory Response Requirement

As required by section 305(b)(4)(B) of the MSA, COE must provide a detailed response in writing to NMFS within 30 days after receiving an EFH Conservation Recommendation. 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 time frames for the Federal agency response. The response must include a description of the measures proposed by the agency for avoiding, minimizing, mitigating, or otherwise 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)].

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, you clearly identify the number of conservation recommendations accepted.

3.5. Supplemental Consultation

The COE 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 users of this opinion are COE. Other interested users could include Port of Seattle, the Northwest Seaport Alliance, citizens of affected areas, or others interested in the conservation of the affected species. Individual copies of this opinion were provided to the COE. 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 EFH consultation, if applicable*] 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, if applicable*], and reviewed in accordance with West Coast Region ESA quality control and assurance processes.

5. REFERENCES

Agne, M.C., P.A. Beedlow, D.C. Shaw, D.R. Woodruff, E.H. Lee, S.P. Cline, and R.L. Comeleo. 2018. Interactions of predominant insects and diseases with climate change in Douglas-fir forests of western Oregon and Washington, U.S.A. Forest Ecology and Management 409(1). https://doi.org/10.1016/j.foreco.2017.11.004

Alizedeh, M.R., J.T. Abatzoglou, C.H. Luce, J.F. Adamowski, A. Farid, and M. Sadegh. 2021. Warming enabled upslope advance in western US forest fires. PNAS 118(22) e2009717118. https://doi.org/10.1073/pnas.2009717118

Anderson, S. C., J. W. Moore, M. M. McClure, N. K. Dulvy, and A. B. Cooper. 2015. Portfolio conservation of metapopulations under climate change. Ecological Applications 25:559-572.

Arkoosh MR, Clemons E, Myers MS, Casillas E. 1994. Suppression of B-cell mediated immunity in juvenile Chinook salmon (*Oncorhynchus tshawytscha*) after exposure to either a polycyclic aromatic hydrocarbon or to polychlorinated biphenyls. Immunopharmacology and Immunotoxicology,16 (2):293–314. https://doi.org/10.3109/08923979409007096 PMID: 8077612.

Arkoosh, M. R., E. Clemons, A. N. Kagley, C. Stafford, A. C. Glass, K. Jacobson, P. Reno, M. S. Myers, E. Casillas, F. Loge, L. L. Johnson, and T. K. Collier. 2004. Survey of pathogens in juvenile salmon Oncorhynchus Spp. migrating through Pacific Northwest estuaries. Journal of aquatic animal health 16(4):186-196.

Arkoosh, M.R., Casillas, E., Clemons, E., McCain B.B., Varanasi, U. 1991. Suppression of immunological memory in juvenile chinook salmon (Oncorhynchus tshawytscha) from an urban estuary. Fish & Shellfish Immunology,1(4):261–77.

Armstrong, J.W., C.P. Staude, R.M. Thom, and K.K. Chew. 1976. Habitats and relative abundances of the intertidal macrofauna at five Puget Sound beaches in the Seattle area. Synthesis 9:277-290.

Bash, J., C. Berman, and S. Bolton. 2001. Effects of turbidity and suspended solids on salmonids. Center for Streamside Studies, University of Washington, Seattle, Washington.

Bassett, C., B. Polagye, M. Holt, and J. Thomson. 2012. A vessel noise budget for Admiralty Inlet, Puget Sound, Washington (USA). The Journal of the Acoustical Society of America. 132(6): 3706–3719.

Beale and Monaghan. 2004. Human disturbance: people as predation- free predators? J. Appl. Ecol., 41 (2004), pp. 335-343

Beechie, T. J., O. Stefankiv, B. Timpane-Padgham, J. E. Hall, G. R. Pess, M. Rowse, M. Liermann, K. Fresh, and M. J. Ford. 2017. Monitoring Salmon Habitat Status and Trends in Puget Sound: Development of Sample Designs, Monitoring Metrics, and Sampling

Protocols for Large River, Floodplain, Delta, and Nearshore Environments. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-137.

Beechie, T., E. Buhle, M. Ruckelshaus, A. Fullerton, and L. Holsinger. 2006. Hydrologic regime and the conservation of salmon life history diversity. Biological Conservation, 130(4), pp.560-572.

Bellmann, M. A., Brinkmann J., May A., Wendt T., Gerlach S. & Remmers P. 2020. Underwater noise during the impulse pile-driving procedure: Influencing factors on pile-driving noise and technical possibilities to comply with noise mitigation values. Supported by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit (BMU)), FKZ UM16 881500. Commissioned and managed by the Federal Maritime and Hydrographic Agency (Bundesamt für Seeschifffahrt und Hydrographie (BSH)), Order No. 10036866. Edited by the itap GmbH.

Berg, L., and T. G. Northcote. 1985. Changes in territorial, gill-flaring, and feeding behavior in juvenile coho salmon (Oncorhynchus kisutch) following short-term pulses of suspended sediment. Canadian Journal of Fisheries and Aquatic Sciences 42:1410-1417.

Bettridge, S. B., S. Baker, J. Barlow, P. J. Clapham, M. Ford, D. Gouveia, D. K. Mattila, R. M. Pace III, P. E. Rosel, G. K. Silber, P. R. Wade. 2015. Status Review of the Humpback Whale (Megaptera novaengliae) under the Endangered Species Act. March 2015. NOAA Technical Memorandum. NOAA-TM-NMFS-SWFSC-540.

Black, B.A., P. van der Sleen, E. Di Lorenzo, D. Griffin, W.J. Sydeman, J.B. Dunham, R.R. Rykaczewski, M. García-Reyes, M. Safeeq, I. Arismendi, and S.J. Bograd. 2018. Rising synchrony controls western North American ecosystems. Global change biology, 24(6), pp. 2305-2314.

Bols, N.C., J.L.Brubacher, R.C. Ganassin, L.E.J. Lee. 2001. Ecotoxicology and innate immunity in fish. Developmental & Comparative Immunology,25(8):853–73.

Braun, D.C., J.W. Moore, J. Candy, and R.E. Bailey. 2016. Population diversity in salmon: linkages among response, genetic and life history diversity. Ecography, 39(3), pp.317-328.

Bridges, T.S., S. Ells, D. Hayes, D. Mount, S.C. Nadeau, M.R. Palermo, and C. Patmont. 2008. The four Rs of environmental dredging resuspension, release, residual, and risk. US Army Corps of Engineers, Report ERDC/EL TR-08-4, Washington, DC. Feb 2008. 63 pp.

British Columbia Cetacean Sightings Network. 2023. The WhaleReport Alert System (WRAS). Vancouver Aquarium, Vancouver, B.C.

Burke, B. J., W. T. Peterson, B. R. Beckman, C. Morgan, E. A. Daly, and M. Litz. 2013. Multivariate models of adult Pacific salmon returns. PLoS One 8(1):e54134.

Cacela, D., J. Lipton, D. Beltman, J. Hansen, and R. Wolotira. 2005. Associating ecosystem service losses with indicators of toxicity in habitat equivalency analysis. Environ Manage 35(3):343-51.

Calambokidis, J. and J. Barlow. 2020. Updated abundance estimates for blue and humpback whales along the U.S. west coast using data through 2018, U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-634.

Calambokidis, J., K. Flynn, E. Dobson, J. Huggins, A. Perez. 2018. Return of the giants of the Salish Sea: increased occurrence of humpback and gray whales in inland waters. Salish Sea Ecosystem Conference. 593. https://cedar.wwu.edu/ssec/2018ssec/allsessions/593.

Canning, D. and H. Shipman. 1995, Coastal erosion management studies in Puget Sound, Washington: Executive Summary, Coastal Erosion Management Studies, Volume 1, Shorelands Program, Washington Dept. of Ecology, Olympia, DOE Report 94-74

Carls, M. G.; Rice, S. D.; Hose, J. E. 1999. Sensitivity of fish embryos to weathered crude oil: Part I. Low-level exposure during incubation causes malformations, genetic damage, and mortality in larval Pacific herring (Clupea pallasi). Environmental Toxicology and Chemistry 18:481-493.

Carlson, T. J., G. R. Ploskey, R. L. Johnson, R. P. Mueller, and M. A. Weiland. 2001. Observations of the behaviour and distribution of fish in relation to the Columbia Navigation Channel and Channel Maintenance Activities. Pacific Northwest National Laboratory, PNNL-13595.

Carretta, J.W., E.M. Olson, K.A. Forney, M.M. Muto, D.W. Weller, A.R. Lang, J. Baker, B. Hanson, A.J. Orr, J. Barlow, J.E. Moore, R.L. Brownell. 2021. U.S. Pacific Marine Mammal Stock Assessments: 2020. NOAA- TM-NMFS-SWFSC-646. https://media.fisheries.noaa.gov/2021-07/Pacific%202020%20SARs%20Final%20Working%20508.pdf?null%09

Castellote, M., Garner, C., Blakely, K., Gilstad, A., Neumann, C. A., & Wolanin, J. 2019. Exploring salmon reaction to playback noise exposures in Eagle River, Cook Inlet, AK. University of Washington Final Report.

Cederholm, C.J., and L.M. Reid. 1987. Impact of forest management on coho salmon (*Oncorhynchus kisutch*) populations of the Clearwater River, Washington: A project summary. Pages 373-398 In E.O. Salo, and T.W. Cundy, eds. Streamside management: Forestry and fishery interactions. University of Washington Institute of Forest Resource Contribution 57.

Center for Whale Research. 2018. https://www.whaleresearch.com/. Accessed on 8/13/2018.

Chalhoub, M., L. Amalric, S. Touzé, P. Gallé, P. E. Reiller, N. Doucet, B. Dlozel, and P. Bataillard. 2013. PCB partitioning during sediment remobilization—a 1D column experiment. Journal of Soils and Sediments 13(7):1284–1300.

Charles, F., S. Lopez-Legentil, A. Grémare, J. Michel Amouroux, M. Desmalades, G. Vétion, and K. Escoubeyrou. 2005. Does sediment resuspension by storms affect the fate of polychlorobiphenyls (PCBs) in the benthic food chain? Interactions between changes in POM characteristics, adsorption and absorption by the mussel *Mytilus galloprovincialis*. Continental Shelf Research, 25(19):2533–255.

Chasco, B. E., B. J. Burke, L. G. Crozier, and R. W. Zabel. 2021. Differential impacts of freshwater and marine covariates on wild and hatchery Chinook salmon marine survival. PLoS ONE 16:e0246659. https://doi.org/0246610.0241371/journal.pone.0246659.

Chasco, B., I.C. Kaplan, A. Thomas, A. Acevedo-Gutiérrez, D. Noren, M.J. Ford, M.B. Hanson, J. Scordino, S. Jeffries, S. Pearson, K.N. Marshall. 2017. Estimates of Chinook salmon consumption in Washington State inland waters by four marine mammal predators from 1970 to 2015. Can. J. Fish. Aquat. Sci., 74 (8), pp. 1173-1194.

Chow, M., et al., 2019. An urban stormwater runoff mortality syndrome in juvenile coho salmon. Aquatic Toxicology 214 (2019) 105231.

City of Seattle. 2021. City of Seattle Stormwater Manual. Seattle Public Utilities, Department of Construction & Inspections. Seattle, Washington.

COE (U.S. Army Corps of Engineers) and Port of Tacoma. 2022. Final integrated feasibility report and environmental assessment, Tacoma Harbor, WA, feasibility study, Pierce County, Washington. April 2022, Updated June 2022.

Compeau, G. C., and R. Bartha. 1985. Sulfate-Reducing bacteria: Principal methylators of mercury in anoxic estuarine sediment. Applied and Environmental Microbiology 50(2):498-502.

Cooper, M.G., J. R. Schaperow, S. W. Cooley, S. Alam,L. C. Smith, D. P. Lettenmaier. 2018. Climate elasticity of low flows in the maritime western U.S. Mountains. Water Resources Research. https://doi.org/10.1029/2018WR022816

Crozier, L. 2011. Impacts of Climate Change on Columbia River Salmon: A review of the scientific literature published in 2010. Pages D1-D50 in Endangered Species Act Section 7(a)(2) supplemental biological opinion: consultation on remand for operation of the Federal Columbia River Power System. U.S. National Marine Fisheries Service, Northwest Region (Available at https://www.researchgate.net/publication/354342662_Climate_Literature_Review_Literature_review_for_2011_citations_for_BIOP_Biological_effects_of_climate_change_Prepared_by_Lisa_Crozier_Northwest_Fisheries_Science_Center_NOAA-Fisheries).

Crozier, L. 2012. Impacts of Climate Change on Columbia River Salmon: A review of the scientific literature published in 2011. Pages D1-D50 in Endangered Species Act Section 7(a)(2) supplemental biological opinion: consultation on remand for operation of the Federal Columbia River Power System. U.S. National Marine Fisheries Service, Northwest Region (Available at http://www.nwfsc.noaa.gov/contact/display_staffprofilepubs.cfm?staffid=1471&lastname=Crozier&firstname=Lisa).

Crozier, L. 2013. Impacts of Climate Change on Columbia River Salmon: A review of the scientific literature published in 2012. Pages D1-D50 in Endangered Species Act Section 7(a)(2) supplemental biological opinion: consultation on remand for operation of the Federal Columbia River Power System. U.S. National Marine Fisheries Service, Northwest Region (Available at http://www.nwfsc.noaa.gov/contact/display_staffprofilepubs.cfm?staffid=1471&lastname=Crozier&firstname=Lisa).

Crozier, L. 2014. Impacts of Climate Change on Columbia River Salmon: A review of the scientific literature published in 2013. Pages D1-D50 in Endangered Species Act Section 7(a)(2) supplemental biological opinion: consultation on remand for operation of the Federal Columbia River Power System. U.S. National Marine Fisheries Service, Northwest Region (Available at https://repository.library.noaa.gov/view/noaa/25641).

Crozier, L. 2015. Impacts of Climate Change on Columbia River Salmon: A review of the scientific literature published in 2014. Pages D1-D50 in Endangered Species Act Section 7(a)(2) supplemental biological opinion: consultation on remand for operation of the Federal Columbia River Power System. U.S. National Marine Fisheries Service, Northwest Region (Available at http://www.nwfsc.noaa.gov/contact/display_staffprofilepubs.cfm?staffid=1471&lastname=Crozier&firstname=Lisa).

Crozier, L. 2016. Impacts of Climate Change on Columbia River Salmon: A review of the scientific literature published in 2015. Pages D1-D50 in Endangered Species Act Section 7(a)(2) supplemental biological opinion: consultation on remand for operation of the Federal Columbia River Power System. U.S. National Marine Fisheries Service, Northwest Region (Available at http://www.nwfsc.noaa.gov/contact/display_staffprofilepubs.cfm?staffid=1471&lastname=Crozier&firstname=Lisa).

Crozier, L. 2017. Impacts of Climate Change on Columbia River Salmon: A review of the scientific literature published in 2016. Pages D1-D50 in Endangered Species Act Section 7(a)(2) supplemental biological opinion: consultation on remand for operation of the Federal Columbia River Power System. U.S. National Marine Fisheries Service, Northwest Region (Available at http://www.nwfsc.noaa.gov/contact/display_staffprofilepubs.cfm?staffid=1471&lastname=Crozier&firstname=Lisa).

Crozier, L. G., and J. Siegel. 2018. Impacts of Climate Change on Columbia River Salmon: A review of the scientific literature published in 2017. Pages D1-D50 in Endangered Species Act Section 7(a)(2) supplemental biological opinion: consultation on remand for operation of the Federal Columbia River Power System. U.S. National Marine Fisheries Service, Northwest Region (Available at http://www.nwfsc.noaa.gov/contact/display_staffprofilepubs.cfm?staffid=1471&lastname=Crozier&firstname=Lisa).

Crozier, L., R.W. Zabel, S. Achord, and E.E. Hockersmith. 2010. Interacting effects of density and temperature on body size in multiple populations of Chinook salmon. Journal of Animal Ecology. 79:342-349.

Crozier, L.G. and R.W. Zabel. 2006. Climate impacts at multiple scales: evidence for differential population responses in juvenile Chinook salmon. Journal of Animal Ecology. 75:1100-1109.

Crozier, L.G., B.J. Burke, B.E. Chasco, D.L. Widener, and R.W. Zabel. 2021. Climate change threatens Chinook salmon throughout their life cycle. Communications biology, 4(1), pp.1-14.

Crozier, L.G., M.M. McClure, T. Beechie, S.J. Bograd, D.A. Boughton, M. Carr, T. D. Cooney, J.B. Dunham, C.M. Greene, M.A. Haltuch, E.L. Hazen, D.M. Holzer, D.D. Huff, R.C. Johnson, C.E. Jordan, I.C. Kaplan, S.T. Lindley, N.Z. Mantua, P.B. Moyle, J.M. Myers, M.W. Nelson, B.C. Spence, L.A. Weitkamp, T.H. Williams, and E. Willis-Norton. 2019. Climate vulnerability assessment for Pacific salmon and steelhead in the California Current Large Marine Ecosystem. PLoS ONE 14(7): e0217711. https://doi.org/10.1371/journal.pone.0217711

Cunningham, K. 2023. Washington Department of Fish and Wildlife. Personal communication, letter to Lynne Barre, National Marine Fisheries Service, regarding Actions taken in development of WDFW managed fishery season for 2023-2024 beneficial for Southern Resident killer whales.

Department of Fisheries and Oceans Canada. 1999. Fraser River Chinook salmon. DFO science stock status report D6-11. Nanaimo, BC, Canada.

Dernie, K. M., M. J. Kaiser, and R. M. Warwick. 2003. Recovery rates of benthic communities following physical disturbance. Journal of Animal Ecology 72(6):1043-1056.

Dorea, J. G. 2008. Persistent, bioaccumulative and toxic substances in fish: Human health considerations. The Science of the total environment 400(1):93-114.

Dorner, B., M.J. Catalano, and R.M. Peterman. 2018. Spatial and temporal patterns of covariation in productivity of Chinook salmon populations of the northeastern Pacific Ocean. Canadian Journal of Fisheries and Aquatic Sciences, 75(7), pp.1082-1095.

Dunford, R., T. Ginn, and W. Desvousges. 2004. The use of habitat equivalency analysis in natural resource damage assessments. Ecological Economics 48:49-70.

Eash-Louks, W. 2014. Influence of the Duwamish River on water quality in Elliott Bay, Seattle, WA. King County Marine & Sediment Assessment Group, King County, Washington.

Ehinger, S. I., J.P. Fisher, R. Macintosh, D. Molenaar and J. Walters. 2015. Working Draft, April 2015: Use of The Puget Sound Nearshore Habitat Values Model with Habitat Equivalency Analysis for characterizing impacts and avoidance measures for projects that adversely affect critical habitat of ESA-Listed Chinook and chum salmon. Pages 66 in. NMFS, Lacey, WA.

Ehinger, S. I., L. Abernathy, M. Bhuthimethee, L. Corum, N. Rudh, D. Price, J. Lim, O. C. Monette, S. Smith, and J. Quan. 2023. Puget Sound Nearshore Habitat Conservation Calculator User Guide. NOAA, editor.

Emmons, C.K., M.B. Hanson, and M.O. Lammers. 2019. Monitoring the occurrence of Southern resident killer whales, other marine mammals, and anthropogenic sound in the Pacific Northwest. Prepared for: U.S. Navy, U.S. Pacific Fleet, Pearl Harbor, HI. Prepared by: National Oceanic and Atmospheric Administration, Northwest Fisheries Science Center under MIPR N00070-17-MP-4C419. 25 February 2019. 23p.

Erbe, C. and C. McPherson. 2017. Underwater noise from geotechnical drilling and standard penetration testing. The Journal of the Acoustical Society of America 142(3):EL281.

Eriksson, B. K., A. Sandström, M. Isæus, H. Schreiber, and P. Karås. 2004. Effects of boating activities on aquatic vegetation in the Stockholm archipelago, Baltic Sea. Estuarine, Coastal and Shelf Science 61(2):339-349.

Esbaugh, A.J., Mager, E.M., Stieglitz, J.D., Hoenig, R., Brown, T.S., French, B.L., Linbo, T.L., Scholz, N.L., Incardona, J.P., Benetti, D.D., and Grosell, M. 2016. The effects of weathering and chemical dispersion on Deepwater Horizon crude oil toxicity to mahi (Coryphaena hippurus) early life stages. Science of the Total Environment, 543:644-651.

Evans, M., K. Fazaka, and J. Keating. 2009. Creosote contamination in sediments of the Grey Owl Marina in Prince Albert National Park, Saskatchewan, Canada. Water Air Soil Pollut 201:23.

Fardel, A.. et al., 2020. Performance of two contrasting pilot swale designs for treating zinc, polycyclic aromatic hydrocarbons and glyphosate from stormwater runoff. Science Total Env. 743:140503.

Feist, B. E., J. J. Anderson, and R. Miyamoto. 1996. Potential impacts of pile driving on juvenile pink (Oncorhynchus gorbuscha) and chum (O. keta) salmon behavior and distribution. Fisheries Research Institute Report No. FRI-UW-9603. 67p.

Ferrara, G. A., T. M. Mongillo, and L. M. Barre. 2017. Reducing disturbance from vessels to Southern Resident Killer Whales: Assessing the effectiveness of the 2011 federal regulations in advancing recovery goals. December 2017. NOAA Technical Memorandum NMFS-OPR-58. 82p.

Fetters, K. J., D. M. Costello, C. R. Hammerschmidt, and G. A. Burton Jr. 2016. Toxicological effects of short-term resuspension of metal-contaminated freshwater and marine sediments. Environmental Toxicology and Chemistry 35(3):676-686.

FitzGerald, A.M., S.N. John, T.M. Apgar, N.J. Mantua, and B.T. Martin. 2020. Quantifying thermal exposure for migratory riverine species: Phenology of Chinook salmon populations predicts thermal stress. Global Change Biology 27(3).

Ford, M. J. (editor). 2022. Biological viability assessment update for pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-171.

French, B.F., Baldwin, D.H., Cameron, J., Prat, J., King, K., Davis, J.W., McIntyre, J.K. and Scholz, N.L. 2022. Urban roadway runoff is lethal to juvenile coho, steelhead, and chinook salmonids, but not congeneric sockeye. Environmental Science & Technology Letters, 9(9), pp.733-738.

Freshwater, C., S. C. Anderson, K. R. Holt, A. M. Huang, and C. A. Holt. 2019. Weakened portfolio effects constrain management effectiveness for population aggregates. Ecological Applications 29(7):14.

Frid and Dill. 2002. Human-caused disturbance stimuli as a form of predation risk.

Gardner, L.D., Peck, K.A., Goetz, G.W., Linbo, T.L., Cameron, J., Scholz, N.L., Block, B.A., and Incardona, J.P. 2019. Cardiac remodeling in response to embryonic crude oil exposure involves unconventional NKX family members and innate immunity genes. Journal of Experimental Biology, 222:jeb205567.

Gliwicz, Z.M., E. Babkiewicz, R. Kumar, S. Kunjiappan, and K. Leniowski, 2018. Warming increases the number of apparent prey in reaction field volume of zooplanktivorous fish. Limnology and Oceanography, 63(S1), pp.S30-S43.

Goertler, P. A. L., C. A. Simenstad, D. L. Bottom, S. Hinton, and L. Stamatiou. 2016. Estuarine habitat and demographic factors affect juvenile Chinook (Oncorhynchus tshawytscha) growth variability in a large freshwater tidal estuary. Estuaries and Coasts 39(2):542-559.

Google Earth. 2022. Google Earth Pro Version 7.36.9345. Seattle, Washington, U.S.A. 47°37'45.54"N, 122°22'44.66"W, Eye altitude 4,587 feet. Maxar Technologies, 2023. Available at: http://www.earth.google.com (accessed July 15, 2023).

Gosselin, J. L., Buhle, E. R., Van Holmes, C., Beer, W. N., Iltis, S., & Anderson, J. J. 2021. Role of carryover effects in conservation of wild Pacific salmon migrating regulated rivers. Ecosphere, 12(7), e03618.

Gourtay, C., D. Chabot, C. Audet, H. Le Delliou, P. Quazuguel, G. Claireaux, and J.L. Zambonino-Infante. 2018. Will global warming affect the functional need for essential fatty acids in juvenile sea bass (Dicentrarchus labrax)? A first overview of the consequences of lower availability of nutritional fatty acids on growth performance. Marine Biology, 165(9), pp.1-15.

Greenbusch Group, Inc. 2019. Colman Dock season 2 hydroacoustic monitoring report. As reported in WSDOT 2020.

Grette, G.B. 1985. Fish monitoring during pile driving at Hiram H. Chittenden Locks, August-September 1985. Seattle District Army Corps of Engineers. Evans-Hamilton, Inc.

Haas, M. E., C. A. Simenstad, J. R. Cordell, D. A. Beauchamp, and B. S. Miller. 2002. Effects of large overwater structures on epibenthic juvenile salmon prey assemblages in Puget Sound, WA.

Halofsky, J.E., Peterson, D.L. and B. J. Harvey. 2020. Changing wildfire, changing forests: the effects of climate change on fire regimes and vegetation in the Pacific Northwest, USA. Fire Ecology 16(4). https://doi.org/10.1186/s42408-019-0062-8

Halofsky, J.S., D.R. Conklin, D.C. Donato, J.E. Halofsky, and J.B. Kim. 2018. Climate change, wildfire, and vegetation shifts in a high-inertia forest landscape: Western Washington, U.S.A. PLoS ONE 13(12): e0209490. https://doi.org/10.1371/journal.pone.0209490

Hanson, M.B., E.J. Ward, C.K. Emmons, M.M. Holt and D.M. Holzer. 2017. Assessing the movements and occurrence of Southern Resident Killer Whales relative to the U.S. Navy's Northwest Training Range Complex in the Pacific Northwest. Prepared for: U.S. Navy, U.S. Pacific Fleet, Pearl Harbor, HI. Prepared by: National Oceanic and Atmospheric Administration, Northwest Fisheries Science Center under MIPR N00070- 15-MP-4C363. 30 June 2017. 23 pp

Hard, J.J., J.M. Myers, E.J. Connor, R.A. Hayman, R.G. Kope, G. Lucchetti, A.R. Marshall, G.R. Pess, and B.E. Thompson. 2015. Viability criteria for steelhead within the Puget Sound distinct population segment. U.S. Dept. of Commerce, NOAA Tech. Memo. NMFS-NWFSC-129. May 2015. 367 pp.

Harding, L.B., Tagal, M., Ylitalo, G.M., Incardona, J.P., Scholz, N.L., and McIntyre, J.K. 2020. Urban stormwater and crude oil injury pathways converge on the developing heart of a shore-spawning marine forage fish. Aquatic Toxicology, 229:105654.

Hastings, M. C., and A. N. Popper. 2005. Effects of sound on fish. Prepared by Jones and Stokes for the California Department of Transportation.

Hastings, M.C., A.N. Popper, J.J. Finneran, and P. Lanford. 1996. Effects of low-frequency underwater sound on hair cells of the inner ear and lateral line of the teleost fish Astronotus ocellatus. Journal of the Acoustical Society of America, 99(3):1759–1766.

Hatlen, K., Sloan, C.A., Burrows, D.G., Collier, T.K., Scholz, N.L., and Incardona, J.P. 2010. Natural sunlight and residual fuel oils are a lethal combination for fish embryos. Aquatic Toxicology, 99:56-64.

Hawkins, A. D., and Picciulin, M. 2019. The importance of underwater sounds to gadoid fishes. J. Acoust. Soc. Am. 146(5), 3536–3551

Hayes, D., and P.-Y. Wu. 2001. Simple approach to TSS source strength estimates. In Proceedings of the WEDA XXI Conference, Houston, TX, June 25-27, 2001.

Healey, M., 2011. The cumulative impacts of climate change on Fraser River sockeye salmon (Oncorhynchus nerka) and implications for management. Canadian Journal of Fisheries and Aquatic Sciences, 68(4), pp.718-737.

Heintz, R. A., S. D. Rice, A. C. Wertheimer, R. F. Bradshaw, F. P. Thrower, J. E. Joyce, and J. W. Short. 2000. Delayed effects on growth and marine survival of pink salmon Oncorhynchus gorbuscha after exposure to crude oil during embryonic development. Marine ecology. Progress series (Halstenbek) 208:205-216.

Heintz, R. A.; Short, J. W.; Rice, S. D. 1999. Sensitivity of fish embryos to weathered crude oil: Part II. Increased mortality of pink salmon (Oncorhynchus gorbuscha) embryos incubating downstream from weathered Exxon Valdez crude oil. Environmental Toxicology and Chemistry 18:494-503.

Herring, S. C., N. Christidis, A. Hoell, J. P. Kossin, C. J. Schreck III, and P. A. Stott, Eds., 2018: Explaining extreme events of 2016 from a climate perspective. Bull. Amer. Meteor. Soc., 99 (1), S1–S157.

Hicken, C.L., Linbo, T.L., Baldwin, D.W., Willis, M.L., Myers, M.S., Holland, L., Larsen, M., Stekoll, M.S., Rice, S.D., Collier, T.K., Scholz, N.L., and Incardona, J.P. 2011. Sublethal exposure to crude oil during embryonic development alters cardiac morphology and reduces aerobic capacity in adult fish. Proceedings of the National Academy of Sciences, 108:7086-7090.

Holden, Z.A., A. Swanson, C.H. Luce, W.M. Jolly, M. Maneta, J.W. Oyler, D.A. Warren, R. Parsons and D. Affleck. 2018. Decreasing fire season precipitation increased recent western US forest wildfire activity. PNAS 115(36). https://doi.org/10.1073/pnas.1802316115.

Holsman, K. K., M. D. Scheuerell, E. Buhle, and R. Emmett. 2012. Interacting effects of translocation, artificial propagation, and environmental conditions on the marine survival of Chinook salmon from the Columbia River, Washington, USA. Conservation Biology 26(5):912-922.

Holt, M. M., M. B. Hanson, D. A. Giles, C. K. Emmons, and J. T. Hogan. 2017. Noise levels received by endangered killer whales (Orcinus orca) before and after vessel regulations. Endanger. Spec. Res. 34:15-26.

Houghton, J., M. M. Holt, D. A. Giles, M. B. Hanson, C. K. Emmons, J. T. Hogan, T. A. Branch, and G. R. VanBlaricom. 2015. The relationship between vessel traffic and noise levels received by killer whales (Orcinus orca). PLoS One. DOI:10.1371/journal.pone.0140119.

Incardona, J. P. 2017. Molecular mechanisms of crude oil developmental toxicity in fish. Archives of Environmental Contamination and Toxicology, 73:19-32.

Incardona, J. P. and Scholz, N. L. 2016. The influence of heart developmental anatomy on cardiotoxicity-based adverse outcome pathways in fish. Aquatic Toxicology 177:15-525.

Incardona, J. P.; Scholz, N. L. 2017. Environmental pollution and the fish heart. In Fish Physiology, The cardiovascular system: phenotypic and physiological responses, Gamperl, A. K.; Gillis, T. E.; Farrell, A. P.; Brauner, C. J., Eds. Elsevier: London, 2017; Vol. 36B.

Incardona, J. P.; Scholz, N. L. 2018. Case study: the 2010 Deepwater Horizon oil spill. In Development, Physiology, and Environment: A Synthesis, Burggren, W.; Dubansky, B., Eds. Springer: London.

Incardona, J.P., Carls, M.G., Holland, L., Linbo, T.L., Baldwin, D.H., Myers, M.S., Peck, K.A., Tagal, M., Rice, S.D., and Scholz, N.L. 2015. Very low embryonic crude oil exposures cause lasting cardiac defects in herring and salmon. Scientific Reports, 5:13499.

Incardona, J.P., Linbo, T.L., French, B.L., Cameron, J., Peck, K.A., Laetz, C.A., Hicks, M.B., Hutchinson, G., Allan, S.E., Boyd, D.T., Ylitalo, G.M., and Scholz, N.L. 2021. Low-level embryonic crude oil exposure disrupts ventricular ballooning and subsequent trabeculation in Pacific herring. Aquatic Toxicology, 235:105810.

Incardona, J.P., Swarts, T.H., Edmunds, R.C., Linbo, T.L., Aquilina-Beck, A., Sloan, C.A., Gardner, L.D., Block, B.A., and Scholz, N.L. 2013. Exxon Valdez to Deepwater Horizon: comparable toxicity of both crude oils to fish early life stages. Aquatic Toxicology, 142-143:303-316.

IPCC WGI. 2021. Climate Change 2021: The physical science basis. contribution of working group i to the sixth assessment report of the Intergovernmental Panel on Climate Change. V. Masson-Delmotte, P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou editor. Cambridge University Press (https://www.ipcc.ch/report/ar6/wg1/#FullReport).

IPCC. 2022. Climate Change 2022: Impacts, adaptation and vulnerability: contribution of working group ii to the sixth assessment report of the Intergovernmental Panel on Climate Change.

Isaak, D.J., C.H. Luce, D.L. Horan, G. Chandler, S. Wollrab, and D.E. Nagel. 2018. Global warming of salmon and trout rivers in the northwestern U.S.: Road to ruin or path through purgatory? Transactions of the American Fisheries Society. 147: 566-587. https://doi.org/10.1002/tafs.10059

Jacobson, K.C., Arkoosh, M.R., Kagley, A.N., Clemons, E.R., Collier, T.K., Casillas E. 2003. Cumulative effects of natural and anthropogenic stress on immune function and disease resistance in juvenile Chinook salmon. Journal of Aquatic Animal Health; 15(1):1–12.

Jacox, M. G., Alexander, M. A., Mantua, N. J., Scott, J. D., Hervieux, G., Webb, R. S., & Werner, F. E. 2018. Forcing of multi-year extreme ocean temperatures that impacted California Current living marine resources in 2016. Bull. Amer. Meteor. Soc, 99(1)

Jimenez-Arranz, G., Banda, N., Cook, S., & Wyatt, R. 2020. Review on existing data on underwater sounds from pile driving activities. In A report prepared by Seiche Ltd for the Joint Industry Programme (JIP) on E&P Sound and Marine Life. Retrieved from https://www.seiche.com/wp-content/uploads/2020/10/Review_on_Pile_Driving.pdf.

Johnson, B.M., G.M. Kemp, and G.H. Thorgaard. 2018. Increased mitochondrial DNA diversity in ancient Columbia River basin Chinook salmon Oncorhynchus tshawytscha. PLoS One, 13(1), p.e0190059.

Johnson, L. L., B. F. Anulacion, M. R. Arkoosh, D. G. Burrows, D. A. da Silva, J. P. Dietrich, M. S. Myers, J. A. Spromberg, and G. M. Ylitalo. 2014. Organic chemical toxicology of fishes. Elsevier/AP, Amsterdam.

Johnson, L. L., G. M. Ylitalo, C. A. Sloan, B. F. Anulacion, A. N. Kagley, M. R. Arkoosh, T. A. Lundrigan, K. Larson, M. Siipola, and T. K. Collier. 2007. Persistent organic pollutants in outmigrant juvenile chinook salmon from the Lower Columbia Estuary, USA. Sci. Total Environ. 374:342−366.

Johnson, L., B. Anulacion, M. Arkoosh, O. P. Olson, C. Sloan, S. Y. Sol, J. Spromberg, D. J. Teel, G. Yanagida, and G. Ylitalo. 2013. Persistent organic pollutants in juvenile Chinook salmon in the Columbia River Basin: Implications for stock recovery. Transactions of the American Fisheries Society (1900) 142(1):21-40.

Jung, J.-H.; Hicken, C. E.; Boyd, D.; Anulacion, B. F.; Carls, M. G.; Shim, W. J.; Incardona, J. P. 2013. Geologically distinct crude oils cause a common cardiotoxicity syndrome in developing zebrafish. Chemosphere 91:1146-1155.

Keefer, M.L., T.S. Clabough, M.A. Jepson, E.L. Johnson, C.A. Peery, C.C. Caudill. 2018. Thermal exposure of adult Chinook salmon and steelhead: Diverse behavioral strategies in a large and warming river system. PLoS ONE 13(9): e0204274. https://doi.org/10.1371/journal.pone.0204274

Kilduff, D. P., L.W. Botsford, and S.L. Teo. 2014. Spatial and temporal covariability in early ocean survival of Chinook salmon (Oncorhynchus tshawytscha) along the west coast of North America. ICES Journal of Marine Science, 71(7), pp.1671-1682.

King County. 2001. Elliott Bay and the Duwamish River estuary. State of the Nearshore Ecosystem. King County, Seattle, Washington.

Kjelland, M.E., C.M. Woodley, T.M. Swannack, D.L. Smith 2015. A review of the potential effects of suspended sediment on fishes: potential dredging-related physiological, behavioral, and transgenerational implications. Environ Syst Decis 35:334–350.

Koontz, E.D., E.A. Steel, and J.D. Olden. 2018. Stream thermal responses to wildfire in the Pacific Northwest. Freshwater Science, 37, 731 - 746.

Krahn, M. M., M.B. Hanson, G.S. Schorr, C.K. Emmons, D.G. Burrows, J.L. Bolton, R.W. Baird, and Gina Ylitalo. 2009. Effects of age, sex and reproductive status on persistent organic pollutant concentrations in "Southern Resident" killer whales. Marine Pollution Bulletin 58:1522-1529.

Krahn, M. M., M.B. Hanson, R.W. Baird, R.H. Boyer, D.G. Burrows, C.K. Emmons, J.K.B. Ford, L.L. Jones, D.P. Noren, P.S. Ross, G.S. Schorr, and T.K. Collier. 2007. Persistent organic pollutants and stable isotopes in biopsy samples (2004/2006) from Southern Resident killer whales. Marine Pollution Bulletin 54:1903-1911.

Krosby, M. D.M. Theobald, R. Norheim, and B.H. McRae. 2018. Identifying riparian climate corridors to inform climate adaptation planning. PLoS ONE 13(11): e0205156. https://doi.org/10.1371/journal.pone.0205156

Laughlin, J. 2020. Compendium of background sound levels for ferry terminals in Puget Sound. WSF Underwater Background Monitoring Project. Washington State Department of Transportation. October 2020.

Lima, S.L., and L.M. Dill. 1990. Behavioral decisions made under the risk of predation: a review and prospectus. Can. J. Zool., 68, pp. 619-640.

Lindley, S.T., C.B. Grimes, M.S. Mohr, W. Peterson, J. Stein, J.T. Anderson, et al. 2009. What caused the Sacramento River fall Chinook stock collapse? NOAA Fisheries West Coast Region, Santa Cruz, CA. U.S. Department of Commerce NOAA-TM-NMFS-SWFSC-447.

Lloyd, D.S., J.P. Koenings, and J.D. LaPerriere. 1987. Effects of turbidity in fresh waters of Alaska. North American Journal of Fisheries Management 7: 18-33.

Love, M. S., M. Carr, and L. Haldorson. 1991. The ecology of substrate-associated juveniles of the genus Sebastes. Environmental Biology of Fishes. Volume 30, pages 225 to 243.

Love, M. S., M. Yoklavich, and L. Thorsteinson. 2002. The rockfishes of the northeast Pacific. University of California Press, Berkeley, California.

Lundin, J. I., G. M. Ylitalo, R. K. Booth, B. F. Anulacion, J. Hempelmann, K. M. Parsons, D. A. Giles, E. A. Seely, M. B. Hanson, C. K. Emmons, and S. K. Wasser. 2016. Modulation in persistent organic pollutant level and profile by prey availability and reproductive status in Southern Resident killer whale scat samples. Environmental Science & Technology 50:6506-6516.

Lundin, J. I., J. A. Spromberg, J. C. Jorgensen, J. M. Myers, P. M. Chittaro, R. W. Zabel, L. L. Johnson, R. M. Neely, and N. L. Scholz. 2019. Legacy habitat contamination as a limiting factor for Chinook salmon recovery in the Willamette Basin, Oregon, USA. PLoS One 14(3).

Lundin, J. I., P. M. Chittaro, G. M. Ylitalo, J. W. Kern, D. R. Kuligowski, S. Y. Sol, K. A. Baugh, D. T. Boyd, M. C. Baker, R. M. Neely, K. G. King, and N. L. Scholz. 2021. Decreased growth rate associated with tissue contaminants in juvenile chinook salmon out-migrating through an industrial waterway. Environmental Science & Technology 55(14).

Lundin, J. I., R. L. Dills, G. M. Ylitalo, M. B. Hanson, C. K. Emmons, G. S. Schorr, J. Ahmad, J. A. Hempelmann, K. M. Parsons, and S. K. Wasser. 2015. Persistent organic pollutant determination in killer whale scat samples: Optimization of a gas 3 chromatography/mass spectrometry method and application to field samples. Archives of Environmental Contamination and Toxicology 70:9-19.

Magurran, 1990. The adaptive significance of schooling as an anti-predator defence in fish. JSTOR, pp. 51-66

Malek, K., J.C. Adam, C.O. Stockle, and R.T. Peters. 2018. Climate change reduces water availability for agriculture by decreasing non-evaporative irrigation losses. Journal of Hydrology 561:444-460.

Mann, D.A. A.N. Popper, and B. Wilson. 2005. Pacific herring hearing does not include ultrasound. Biology Letters. 1(2):158-161.

Marty, G. D., Short, J. W. Dambach, D. M.,Willits, N. H., Heintz, R. A., Rice, S. D., Stegeman, J. J., Hinton, D. E. 1997. Ascites, premature emergence, increased gonadal cell apoptosis, and cytochrome P4501A induction in pink salmon larvae continuously exposed to oil-contaminated gravel during development. Canadian Journal of Zoology 75:989-1007.

Massoth, G. J. 1982. Elemental composition of suspended particulate matter in the Lower Duwamish River and Elliott Bay, Washington. Boulder, Colo: National Oceanic and Atmospheric Administration, Office of Marine Pollution Assessment. Print.

McCarthy, S. G., J. Spromberg, J. Incardona, B. Feist, J. Labenia, Myers, L. Rhodes, G. Ylitalo, T. K. Collier, N. L. Scholz, J. McIntyre, L. Reed, K. Lynch, and T. Davis. 2008. Impacts of stormwater runoff on Coho Salmon in restored urban streams.

McIntyre, J.K., Anulacion, B.F., Davis, J.W., Edmunds, R.C., Incardona, J.P., Stark, J.D., and Scholz, N.L. 2016b. Severe coal tar sealcoat runoff toxicity to fish is reversed by bioretention filtration. Environmental Science and Technology, 50:1570-1578.

McIntyre, J.K., Davis, J., Hinman, C., Macneale, K.H., Anulacion, B.F., Scholz, N.L., and Stark, J.D. 2015. Soil bioretention protects juvenile salmon and their prey from the toxic effects of urban stormwater runoff. Chemosphere, 132:213-219.

McIntyre, J.K., Davis, J.W., Incardona, J.P., Anulacion, B.F., Stark, J.D., and Scholz, N.L. 2014. Zebrafish and clean water technology: assessing the protective effects of bioinfiltration as a treatment for toxic urban runoff. Science of the Total Environment, 500:173-180.

McIntyre, J.K., Edmunds, R.C., Mudrock, E., Brown, M., Davis, J.W., Stark, J.D., Incardona, J.P. and Scholz, N.L. 2016a. Confirmation of stormwater bioretention treatment effectiveness using molecular indicators of cardiovascular toxicity in developing fish. Environmental Science and Technology, 50:1561-1569.

Meador, J. P. 2014. Do chemically contaminated river estuaries in Puget Sound (Washington, USA) affect the survival rate of hatchery-reared Chinook salmon? Canadian journal of fisheries and aquatic sciences 71(1):162-180.

Meador, J. P., F. C. Sommers, G. M. Ylitalo, and C. A. Sloan. 2006. Altered growth and related physiological responses in juvenile Chinook salmon (Oncorhynchus tshawytscha) from dietary exposure to polycyclic aromatic hydrocarbons (PAHs). Canadian journal of fisheries and aquatic sciences 63(10):2364-2376.

Miller, B., C. Simenstad, J. N. Cross, K. Fresh, and S. N. Steinfort. 1980. Nearshore fish and macroinvertebrate assemblages along the Strait of Juan De Fuca including food habitat of the common nearshore fish, EPA-600/7-80-027.

Milon, J. W., and R. E. Dodge. 2001. Applying habitat equivalency analysis for coral reef damage assessment and restoration. Rosenstiel School of Marine and Atmospheric Science, [URL:http://www.rsmas.miami.edu/bms/].

Misumi, I., Vella, A.T., Leong, J.C., Nakanishi, T., Schreck, C.B.. 2005. p, p0-DDE depresses the immune competence of chinook salmon (Oncorhynchus tshawytscha) leukocytes. Fish & Shellfish Immunology19 (2):97–114.

Misumi, I., Yada, T., Leong, J.C., Schreck, C.B. 2009. The effect of in vitro exposure to tributyltin on the immune competence of chinook Salmon (*Oncorhynchus tshawytscha*) leukocytes. Archives of environmental contamination and toxicology. 56(2):229–37. https://doi.org/10.1007/s00244-008-9187-5 PMID: 18629429

Mongillo, T. M., G. M. Ylitalo, L. D. Rhodes, S. M. O’Neill, D. P. Noren, M. B. Hanson. 2016. Exposure to a mixture of toxic chemicals: Implications to the health of endangered Southern Resident killer whales. U.S. Dept. Commer., NOAA Tech. Memo. NMFS- NWFSC-X8.

Morris, J.M., Gielazyn, M., Krasnec, M.O., Takeshita, R., Forth, H.P., Labenia, J.S., Linbo, T.L., French, B.L., Gill, J.A., Baldwin, D.H., Scholz, N.L., and Incardona, J.P. 2018.

Deepwater Horizon crude oil toxicity to red drum early life stages is independent of dispersion energy. Chemosphere, 213:205-214

Munsch, S. H., C. M. Greene, N. J. Mantua, and W. H. Satterthwaite. 2022. One hundred-seventy years of stressors erode salmon fishery climate resilience in California's warming landscape. Global Change Biology.

Myers, J.M., J. Jorgensen, M. Sorel, M. Bond, T. Nodine, and R. Zabel. 2018. Upper Willamette River life cycle modeling and the potential effects of climate change. Draft Report to the U.S. Army Corps of Engineers. Northwest Fisheries Science Center. 1 September 2018.

Newcombe, C. P., and J. O. Jensen. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management 16:693-727.

Newcombe, C.P., and D.D. MacDonald. 1991. Effects of suspended sediments on aquatic ecosystems. North American Journal of Fisheries Management 11(1):72-82

Nightingale, B., and C. A. Simenstad. 2001. Overwater structures: Marine issues. University of Washington, Washington State Transportation Center.

NMFS (National Marine Fisheries Service). 1991. Recovery plan for the humpback whale (Megaptera novaeangliae). Prepared by the Humpback Whale Recovery Team for the National Marine Fisheries Service, Silver Spring, Maryland.

NMFS Stranding Database. 2022. NMFS Stranding Database, at https://mmhsrp.nmfs.noaa.gov/mmhsrp/.

NMFS. 1994. Endangered Species Act Section 7 - Reinitiation of consultation biological opinion groundfish fisheries conducted under the Bering Sea and Aleutian Islands and Gulf of Alaska Fishery Management Plans of the North Pacific Fishery Management Council Agencies.

NMFS. 1995. Groundfish fisheries conducted under the Bering Sea and Aleutian Islands and Gulf of Alaska Fishery Management Plans of the North Pacific Fishery Management Council National Marine Fisheries Service, Northwest and Alaska Region.

NMFS. 1999. Endangered Species Act- Reinitiated Section 7 Consultation biological opinion. Take of listed salmon in groundfish fisheries conducted under the Bering Sea and Aleutian Islands and Gulf of Alaska Fishery Management Plans of the North Pacific Fishery Management Council North Pacific Fishery Management Council and National Marine Fisheries Service.

NMFS. 2003. Alaska Fishery Science Center, processed report 2003-10. Marine protected areas and early life-history of fishes.

NMFS. 2005. Final assessment of NOAA Fisheries' critical habitat analytical review teams for 12 evolutionarily significant units of West Coast salmon and steelhead. P. R. Division, editor, Portland, Oregon.

NMFS. 2006. Final supplement to the Shared Strategy's Puget Sound salmon recovery plan. National Marine Fisheries Service, Northwest Region. Seattle

NMFS. 2008a. Endangered Species Act Section 7 Consultation biological opinion and Magnuson-Stevens Fishery Conservation and Management Act essential fish habitat consultation for the Blue Heron Slough Conservation Bank, Snohomish County, WA. National Marine Fisheries Service Northwest Region.

NMFS. 2008b. Recovery plan for Southern Resident killer whales (*Orcinus orca*). National Marine Fisheries Service, Northwest Region. Seattle, Washington.

NMFS. 2009. Endangered Species Act (ESA) Section 7 consultation — Supplemental biological opinion reinitiating consultation on the January 11, 2007 biological opinion regarding authorization of Bering Sea/Aleutian Islands (BSAI) Groundfish Fisheries NMFS, Sustainable Fisheries Division, Northwest Region.

NMFS. 2012. Re-initiation of Endangered Species Act (ESA) Section 7 consultation on incidental catches of Chinook salmon in the Gulf of Alaska (GOA) groundfish fisheries.

NMFS. 2015. Endangered Species Act Section 7(a)(2) informal consultation and Magnuson-Stevens Fishery Conservation and Management Act essential fish habitat consultation for the Coweeman Habitat Bank. 6th Field HUC 1708000508, Lower Columbia. Cowlitz County, Washington. WCR-2015-3100. 32pp.

NMFS. 2016a. Endangered Species Act Section 7(a)(2) biological opinion, and Magnuson-Stevens Fishery Conservation and Management Act essential fish habitat response [and Fish and Wildlife Coordination Act Recommendations] for the Regional General Permit 6 (RGP-6): Structures in inland marine waters of Washington State. Pages 115 in Department of Commerce, editor, Portland, OR.

NMFS. 2016b. 5-Year Review: Summary and evaluation, yelloweye rockfish (Sebastes ruberrimus), canary rockfish (Sebastes pinniger), and bocaccio (Sebastes paucispinis) of the Puget Sound/Georgia Basin. Pages 131 in Resources, editor, Seattle, Washington.

NMFS. 2017a. 2016 5-Year Review: Summary & evaluation of Puget Sound Chinook salmon, Hood Canal summer-run chum salmon, Puget Sound steelhead. 2017. URL: https://repository.library.noaa.gov/view/noaa/17015

NMFS. 2017b. Rockfish recovery plan: Puget Sound / Georgia Basin yelloweye rockfish (*Sebastes ruberrimus*) and bocaccio (*Sebastes paucispinis*). National Marine Fisheries Service. Seattle, WA.

NMFS. 2019. ESA recovery plan for the Puget Sound steelhead distinct population segment (*Oncorhynchus mykiss*). National Marine Fisheries Service. Seattle, WA. December 30, 2019.

NMFS. 2020. Endangered Species Act Section 7(a)(2) Jeopardy Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act essential fish habitat response for the Issuance of Permits for 39 Projects under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act for Actions related to structures in the nearshore environment of Puget Sound. NMFS, editor, West Coast Region.

NMFS. 2021a. Multi-species pile driving calculator. Office of Protected Resources.

NMFS. 2021b. Endangered Species Act Section 7(a)(2) jeopardy biological opinion and Magnuson-Stevens Fishery Conservation and Management Act essential fish habitat response for the issuance of permits for 11 projects under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act for actions related to structures in the nearshore environment of Puget Sound. NMFS, West Coast Region.

NMFS. 2022a. 2021 Southern Resident Killer Whales (Orcinus orca) 5-Year Review: Summary and evaluation. January 04, 2022.

NMFS. 2022b. Endangered Species Act Section 7(a)(2) Biological Opinion, and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the Salish Sea Nearshore Programmatic Consultation (SSNP). NMFS, editor, West Coast Region.

NMFS. 2023. Endangered Species Act Section 7(a)(2) Biological Opinion, and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the Impacts of the Role of the BIA Under its Authority to Assist with the Development of the 2023-2024 Puget Sound Chinook Harvest Plan, the Role of the U.S. Fish and Wildlife Service in Activities Carried out under the Hood Canal Salmon Management Plan and in Funding the Washington Department of Fish and Wildlife under the Sport Fish Restoration Act in 2023-24, and the Role of the National Marine Fisheries Service in authorizing fisheries consistent with management by the Fraser Panel and Funding Provided to the Washington Department of Fish and Wildlife for Activities Related to Puget Sound Salmon Fishing in 2023-2024. Sustainable Fisheries, West Coast Region, National Marine Fisheries Service. NMFS Consultation Number: WCRO-2023-00552.

NOAA (National Oceanographic and Atmospheric Administration). 2018. Navigational chart for Puget Sound – Northern part. Chart No. 18441 48th Ed., Jan. 2017. Last Correction: October 24, 2018. Accessed November 13, 2018 at: http://www.charts.noaa.gov/OnLineViewer/18441.shtml.

NOAA NCEI (National Centers for Environmental Information) . 2022. State of the Climate: Global Climate Report for Annual 2021, published online January 2022, retrieved on February 28, 2022 from https://www.ncdc.noaa.gov/sotc/global/202113.

NOAA. 2023. National Weather Service National Data Buoy Center- Climatic summary table and plots of sea temperature for Station EBSW1 - 9447130 - Seattle, WA. U.S. Dept of Commerce, editor, Seattle, WA. Accessed at: https://www.ndbc.noaa.gov/data/climatic/EBSW1.txt

NOAA. 2024. Line layer. Access via Ship Tracks - NOAA Ocean Exploration Data/OER_tracklines_joined. Available at: https://services2.arcgis.com/C8EMgrsFcRFL6LrL/arcgis/rest/services/OER_Cruise_Tracklines/FeatureServer/0.

O'Neill, S. M. and J.E. West. 2009. Marine Distribution, Life History Traits, and the Accumulation of Polychlorinated Biphenyls in Chinook Salmon from Puget Sound, Washington. Transactions of the American Fisheries Society 138: 616-632.

Ohlberger, J., E.J. Ward, D.E. Schindler, and B. Lewis. 2018. Demographic changes in Chinook salmon across the Northeast Pacific Ocean. Fish and Fisheries, 19(3), pp.533-546.

Olmos, M., M.R. Payne, M. Nevoux, E. Prévost, G. Chaput, H. Du Pontavice, J. Guitton, T. Sheehan, K. Mills, and E. Rivot. 2020. Spatial synchrony in the response of a long range migratory species (Salmo salar) to climate change in the North Atlantic Ocean. Glob Chang Biol. 26(3):1319-1337. doi: 10.1111/gcb.14913. Epub 2020 Jan 12. PMID: 31701595.

Olson, J.K., J. Wood, R.W. Osborne, L. Barrett-Lennard, and S. Larson. 2018. Sightings of southern resident killer whales in the Salish Sea 1976−2014: The importance of a long-term opportunistic dataset. Endang. Species Res. Col 37: 105-118.

Ou, M., T. J. Hamilton, J. Eom, E. M. Lyall, J. Gallup, A. Jiang, J. Lee, D. A. Close, S. S. Yun, and C. J. Brauner. 2015. Responses of pink salmon to CO2-induced aquatic acidification. Nature Climate Change 5:950-955.

Palsson, W. A., T. Tsou, G. G. Bargmann, R. M. Buckley, J. E. West, M. L. Mills, Y. W. Cheng, and R. E. Pacunski. 2009. The biology and assessment of rockfishes in Puget Sound. Washington Department of Fish and Wildlife.

Parametrix. 2011. Creosote release from cut/broken piles, Asarco smelter site. t. A. N. Parametrix, Suite 1800, Bellevue, Washington 98004-5571, editor. Prepared for Department of Natural Resources, 1111 Washington Street SE, Olympia, Washington 98504-7000.

Pearson, W.H., J.R. Skalski, and C.I. Malme. 1992. Effects of sound from a geophysical survey devise on behavior of captive rockfish (Sebastes spp.). Canadian Journal of Fisheries and Aquatic Science 49:1343–1356.

PFMC (Pacific Fishery Management Council). 2022a. Appendix A to the Pacific Coast Salmon Fishery Management Plan, as modified by Amendment 18. Identification and description of essential fish habitat, adverse impacts, and recommended conservation measures for salmon.

PFMC. 2022b. Amendment 18 (bycatch mitigation program), Amendment 19 (essential fish habitat) to the Pacific Coast Groundfish Fishery Management Plan for the California, Oregon, and Washington groundfish fishery. Pacific Fishery Management Council, Portland, Oregon. November.

PFMC. 2023. Description and identification of essential fish habitat for the Coastal Pelagic Species Fishery Management Plan. Appendix D to Amendment 8 to the Coastal Pelagic Species Fishery Management Plan. Pacific Fishery Management Council, Portland, Oregon. December.

Pitcher, T.J. 1986. Functions of shoaling behaviour in teleosts. The Behaviour of Teleost Fishes, Springer (1986), pp. 294-337.

Popper, A. N. & Hawkins, A. D. 2019. An overview of fish bioacoustics and the impacts of anthropogenic sounds on fishes. Journal of fish biology. [Online] 94 (5), 692–713.

Popper, A.N. 2003. Effects of anthropogenic sounds on fishes. Fisheries 28(10): 24-31. doi: 10.1577/1548-8446(2003)28[24:EOASOF]2.0.CO;2

Popper, A.N., A.D. Hawkins, R.R. Fay, D.A. Mann, S. Bartol, T.J. Carlson, S. Coombs, W.T. Ellison, R.L. Gentry, M.B. Halvorsen, S. Løkkeborg, P.H. Rogers, B.L. Southall, D.G. Zeddies, and W.N. Tavolga. 2014. Sound exposure guidelines for fishes and sea turtles: A technical report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI. Part of the Springer Briefs in Oceanography Book Series

Port (Port of Seattle). 2011. Marine mammal monitoring specifications. Environmental Programs, Port of Seattle, Seattle, Washington.

Port. 2021. Terminal 91 berths 6 & 8 redevelopment biological evaluation. Prepared for Port of Seattle, Seattle, Washington. September 2021.

Port. 2023a. All about the fishing fleet at Terminal 91. Webpage. Available at: https://www.portseattle.org/blog/all-about-fishing-fleet-terminal-91, accessed July 19, 2023.

Port. 2023b. Terminal 91 berths 6 & 8 redevelopment permit set revision 1. Environmental Programs, Port of Seattle, Seattle, Washington. May 2023.

Port. 2023c. Final berths 6 & 8 interim action work plan. Environmental Programs, Port of Seattle, Seattle, Washington. May 2023.

PSI. 2023. Encyclopedia of Puget Sound: Strait of Juan de Fuca. Published by the Puget Sound Institute at the UW Tacoma Center for Urban Waters. Available at: https://www.eopugetsound.org/terms/46#:~:text=The%20Strait%20serves%20as%20a,marine%20mammals%2C%20and%20forage%20fish(accessed December 14, 2023).

Puget Sound Regional Council. 2020. Region data profile: Population and households. https://www.psrc.org/rdp-population. Accessed November 10, 2020.

Putland, R.L., J.C. Montgomery, C.A. Radford. 2019. Ecology of fish hearing. Journal of Fish Biology. Special Issue: The Sensory Ecology of Fishes. Volume 95, Issue 1.

Raverty, S., J. S. Leger, D. P. Noren, K. B. Huntington, D. S. Rotstein, F. M. D. Gulland, J. K. B. Ford, M. B. Hanson, D. M. Lambourn, J. Huggins, M. A. Delaney, L. Spaven, T. Rowles, L.Barre, P. Cottrell, G. Ellis, T. Goldstein, K. Terio, D. Duffield, J. Rice, and J. K. Gaydos. 2020a. Pathology findings and correlation with body condition index in stranded killer whales (*Orcinus orca*) in the Northeastern Pacific and Hawaii from 2004 to 2013. PLoS One 15(12):1-31.

REEF (Reef Environmental Education Foundation). 2023. Reef Environmental Education Foundation Volunteer Fish Survey Project Database. Fish and invertebrate survey reports for Elliott Bay and Smith Cove: https://www.reef.org/db/reports/

Rice, C. A., C. M. Greene, P. Moran, D. J. Teel, D. R. Kuligowski, R. R. Reisenbichler, E. M. Beamer, J. R. Karr, and K. L. Fresh. 2011. Abundance, stock origin, and length of marked and unmarked juvenile Chinook salmon in the surface waters of greater Puget Sound. Transactions of the American Fisheries Society 140(1):170-189.

Rockwood, R.C., Calambokidis, J., and J. Jahncke. 2017. High mortality of blue, humpback and fin whales from modeling of vessel collisions on the U.S. West Coast suggests population impacts and insufficient protection. PLOS ONE 12, e0183052. https://doi.org/10.1371/journal.pone.0183052

Roni, P., T. J. Beechie, R. E. Bilby, F. E. Leonetti, M. M. Pollock, and G. R. Pess. 2002. A review of stream restoration techniques and a hierarchical strategy for prioritizing restoration in Pacific Northwest watersheds. North American Journal of Fisheries Management 22(1):1-20.

Ross, P. S., G. M. Ellis, M. G. Ikonomou, L. G. Barrett-Lennard, and R. F. Addison. 2000. High PCB concentrations in free-ranging Pacific killer whales, Orcinus orca: effects of age, sex, and dietary preference. Marine Pollution Bulletin 40(6):504-515.

Ruckelshaus and McClure. 2007. Sound Science: Synthesizing ecological and socioeconomic information about the Puget Sound ecosystem. Prepared in cooperation with the Sound Science collaborative team. U.S. Dept. of Commerce, National Oceanic & Atmospheric Administration (NMFS), Northwest Fisheries Science Center. Seattle, Washington. 93 p.

Ruggerone, G. T., T. S. Nelson, J. Hall, and E. Jeanes. 2005. 2005 Juvenile Chinook Duwamish River studies: Habitat utilization, migration timing, growth , and diet of juvenile Chinook salmon in the Duwamish River and estuary. Prepared for WRIA 9 Technical Committee.

Ruggerone, G.T., S. Goodman, and R. Miner. 2008. Behavioral response and survival of juvenile coho salmon exposed to pile driving sounds. Prepared for the Port of Seattle, Seattle, Washington.

Santore, R.C., D.M. Di Toro, P.R. Paquin, H.E. Allen, and J.S. Meyer. 2001. Biotic ligand model of the acute toxicity of metals. 2. Application to acute copper toxicity in freshwater fish and Daphnia. Environmental Toxicology and Chemistry 20(10):2397-2402.

Schindler, D. E., J. B. Armstrong, and T. E. Reed. 2015. The portfolio concept in ecology and evolution. Frontiers in Ecology and the Environment 13(5):257-263.

Schlenger, P., A. MacLennan, E. Iverson, K. Fresh, C. Tanner, B. Lyons, S. Todd, R. Carman, D. Myers, S. Campbell, and A. Wick. 2011. Strategic Needs Assessment: Analysis of Nearshore Ecosystem Process Degradation in Puget Sound. Prepared for the Puget Sound Nearshore Ecosystem Restoration Project.

Schneider, A. R., E. T. Porter, and J. E. Baker. 2007. Polychlorinated biphenyl release from resuspended Hudson River sediment. Environmental Science & Technology 41(4):1097-1103.

Scholz, N. L., M. S. Myers, S. G. McCarthy, J. S. Labenia, J. K. McIntyre, G. M. Ylitalo, L. D. Rhodes, C. A. Laetz, C. M. Stehr, B. L. French, B. McMillan, D. Wilson, L. Reed, K. D. Lynch, S. Damm, J. W. Davis, and T. K. Collier. 2011. Recurrent die-offs of adult coho salmon returning to spawn in Puget Sound lowland urban streams. PLoS One 6(12):e28013.

Servizi, J. A., and D. W. Martens. 1991. Effect of temperature, season, and fish size on acute lethality of suspended sediments to coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences 48(3):493-497.

Siegel, J., and L. Crozier. 2019. Impacts of climate change on salmon of the Pacific Northwest. A review of the scientific literature published in 2018. Fish Ecology Division, NWFSC. December 2019.

Siegel, J., and L. G. Crozier. 2020. Impacts of climate change on Columbia River salmon: A review of the scientific literature published in 2019. U.S. National Marine Fisheries Service, Northwest Region. https://doi.org/10.25923/jke5-c307.

Sigler, J.W., T.C. Bjornn, and F.H. Everest. 1984. Effects of chronic turbidity on density and growth of steelheads and coho salmon. Transactions of the American Fisheries Society. 113: 142-150.

Silcox, R.L., Geyer, W.R., Cannon, G.A. 1981. Physical transport processes and circulation in Elliott Bay. NOAA technical memorandum. Office of Marine Pollution Assessment, Pacific Marine Environmental Laboratory (https://repository.library.noaa.gov/view/noaa/2761)

Simenstad, C.A., M. Ramirez, J. Burke, M. Logsdon, H. Shipman, C. Tanner, J. Toft, B. Craig, C. Davis, J. Fung, P. Bloch, K. Fresh, S. Campbell, D. Myers, E. Iverson, A. Bailey, P. Schlenger, C. Kiblinger, P. Myre, W. Gerstel, and A. MacLennan. 2011. Historical Change of Puget Sound Shorelines: Puget Sound Nearshore Ecosystem Project Change Analysis. Puget Sound Nearshore Report No. 2011-01. Published by Washington Department of Fish and Wildlife, Olympia, Washington, and U.S. Army Corps of Engineers, Seattle, Washington.

Simpson, S.D., A.N Radford, S.L. Nedelac, M.C.O. Ferrari, D.P Chivers, M.I. McCormick and M.G. Meekan. 2016. Anthropogenic noise increases fish mortality by predation. Nat. Commun 7, 10544. https://doi.org/10.1038/ncomms10544

Skalski, J.R., W.H. Pearson, and C.I. Malme 1992. Effects of sounds from a geophysical survey device on catch-per-unit-effort in a hook-and-line fishery for rockfish (Sebastes spp.). Canadian Journal of Fisheries and Aquatic Science 49:1357–1365.

Slabbekoorn, H., Bouton, N., Opzeeland, I. V., Coers, A., Cate, C. T., and Popper, A. N. 2010. A noisy spring: The impact of globally rising underwater sound levels on fish. Trends Ecol. Evol. 25(7), 419–427.

Smith, P. T. 2008. Risks to human health and estuarine ecology posed by pulling out creosote-treated timber on oyster farms. Aquatic Toxicology 86(2):287-298.

Spromberg, J.A. and Scholz, N.L. 2011. Estimating the decline of wild coho salmon populations due to premature spawner mortality in urbanizing watersheds of the Pacific Northwest. Integrated Environmental Assessment and Management, 4:648-656.

Spromberg, J.A., Baldwin, D.H., Damm, S.E., McIntyre, J.K., Huff, M., Davis, J.W., and Scholz, N.L. 2016. Widespread adult coho salmon spawner mortality in western U.S. urban watersheds: lethal impacts of stormwater runoff are reversed by soil bioinfiltration. Journal of Applied Ecology (Editor’s Choice), 53:398-407

Sridhar, V., M.M. Billah, J.W. Hildreth. 2018. Coupled surface and groundwater hydrological modeling in a changing climate. Groundwater Vol. 56, Issue 4. https://doi.org/10.1111/gwat.12610

Stachura, M.M., N.J. Mantua, and M.D. Scheuerell. 2014. Oceanographic influences on patterns in North Pacific salmon abundance. Canadian Journal of Fisheries and Aquatic Sciences, 71(2), pp.226-235.

Strait Ecosystem Recovery Network Local Integrating Organization. 2017. Strait Ecosystem Protection And Recovery Plan, Strait Action Area. Effective Date: June 30, 2017. Available at: https://pspwa.app.box.com/s/nxli7o61pnjxx4rkmo7nokcjh9huc0kf/file/293112924959 (accessed December 14, 2023).

Strange, E., H. Galbraith, S. Bickel, D. Mills, D. Beltman, and J. Lipton. 2002. Determining ecological equivalence in service-to-service scaling of salt marsh restoration. Environ Manage 29(2):290-300.

Sturrock, A.M., S.M. Carlson, J.D. Wikert, T. Heyne, S. Nusslé, J.E. Merz, H.J. Sturrock and R.C. Johnson. 2020. Unnatural selection of salmon life histories in a modified riverscape. Global Change Biology, 26(3), pp.1235-1247.

Sutton, R., et al., 2019. Understanding Microplastic Levels, Pathways, and Transport in the San Francisco Bay Region, SFEI-ASC Publication #950, October 2019, 402 pages, https://www.sfei.org/sites/default/files/biblio_files/Microplastic%20Levels%20in%20SF%20Bay%20-%20Final%20Report.pdf

Thom, R.M., J.W. Armstrong, C.P. Staude, K.K. Chew and R. Norris. 1976. A survey of the attached marine flora at five beaches in the Seattle, Washington area. Syesis 9:267-275.

Thorne, K., G. MacDonald, G. Guntenspergen, R. Ambrose, K. Buffington, B. Dugger, C. Freeman, C. Janousek, L. Brown, J. Rosencranz, J. Holmquist, J. Smol, K. Hargan, and J. Takekawa. 2018. U.S. Pacific coastal wetland resilience and vulnerability to sea-level rise. Science Advances 4(2). DOI: 10.1126/sciadv.aao3270

Thur, S. M. 2006. Resolving oil pollution liability with restoration-based claims: the United States' experience. Institut oceanographique, Paris (France).

Tian, Z., and 28 others. 2020. A ubiquitous tire rubber-derived chemical induces acute mortality in coho salmon. Science 10.1126/science.abd6951.

Turnpenny, A., and J. Nedwell. 1994. The effects on marine fish, diving mammals, and birds of underwater sound generated by seismic surveys. Fawley Aquatic Research Laboratories Limited, Marine and Freshwater Biology Unit, Southampton, Hampshire, UK. 48 p.

Turnpenny, A., K.P. Thatcher, and J.R. Nedwell. 1994. The effects on fish and other marine animals of high-level underwater sound. Fawley Aquatic Research Laboratory, Ltd., Report FRR 127/94, United Kingdom. October.

U.S. Coast Guard (USCG). 2024. Feature layer: Shipping Lanes and Regulations layer. Available at: https://encdirect.noaa.gov/arcgis/rest/services/NavigationChartData/MarineTransportation/FeatureServer/0

Urban, S. R., A. X. R. Corrêa, C. A. F. Schettini, P. R. Schwingel, R. M. Sperb, and C. M. Radetski. 2010. Physicochemical and ecotoxicological evaluation of estuarine water quality during a dredging operation. J Soils Sediments 10(1):65-76.

USFWS (U.S. Fish and Wildlife Service) and NMFS. 1998. Consultation Handbook: Procedures for conducting consultation and conference activities under Section 7 of the Endangered Species Act.

van der Knaap, I., E. Ashe, D. Hannay, A. G. Bergman, K. A. Nielsen, C. F. Lo, and R. Williams. 2022. Behavioural responses of wild Pacific salmon and herring to boat noise. Marine Pollution Bulletin 174.

Varanasi, U., E. Casillas, M. R. Arkoosh, T. Horn, D. A. Misitano, D. W. Brown, S.-L. Chan, T. K. Collier, B. B. McCain, J. E. Stein, NMFS, and USFWS Center. 1993. Contaminant exposure and associated biological effects in juvenile Chinook salmon (Oncorhynchus tshawytscha) from urban and nonurban estuaries of Puget Sound.

Veilleux, H.D., Donelson, J.M. and Munday, P.L. 2018. Reproductive gene expression in a coral reef fish exposed to increasing temperature across generations. Conservation physiology, 6(1), p.cox077.

Veirs, S., V. Veirs, and J. D. Wood. 2016. Ship noise extends to frequencies used for echolocation by endangered killer whales. PeerJ. 4: 1-35.

Veldhoen, N., M.G. Ikonomou, C. Dubetz, N. MacPherson, T. Sampson, B.C. Kelly, and C.C. Helbing. 2010. Gene expression profiling and environmental contaminant assessment of migrating Pacific salmon in the Fraser River watershed of British Columbia. Aquatic Toxicology 97(3):212-225.

Voellmy, I.K., J. Purser, D Flynn, P. Kennedy, S.D. Simpson, A.N. Radford. 2014. Acoustic Noise reduces foraging success in two sympatric fish species. Animal Behavior 89, 191-198.

Wade, P. R. 2021. Estimates of abundance and migratory destination for North Pacific humpback whales in both summer feeding areas and winter mating and calving areas. Paper SC/68c/IA03 submitted to the Scientific Committee of the International Whaling Commission

Wade, P.R. 2017. Estimates of abundance and migratory destination for North Pacific humpback whales in both summer feeding areas and winter mating and calving areas revision of estimates in SC/66b/IA21. IWC Scientific Committee Report SC/A17/NP/11

Wainwright, T.C. and L.A. Weitkamp. 2013. Effects of climate change on Oregon Coast coho salmon: habitat and life-cycle interactions. Northwest Science, 87(3), pp.219-242.

Ward, E.J., J.H. Anderson, T.J. Beechie, G.R. Pess, M.J. Ford. 2015. Increasing hydrologic variability threatens depleted anadromous fish populations. Glob Chang Biol. 21(7):2500–9. Epub 2015/02/04. pmid:25644185.

Washington Maritime Blue. 2022. Program. Available at: https://quietsound.org/program (accessed July 7, 2023).

Waters, T.F. 1995. Sediment in streams: Sources, biological effects, and control. American Fisheries Society, Monograph 7, Bethesda, Maryland.

WDFW (Washington Department of Fish and Wildlife). 2021. SalmonScape online GIS salmonid distribution mapper. Available at http://apps.wdfw.wa.gov/salmonscape/. Accessed June 15, 2021. As reported in Port of Seattle 2021.

WDNR (Washington State Department of Natural Resources). 2014. Removing creosote-treated wood from Puget Sound and its beaches.

WDOE (Washington State Department of Ecology). 2009. Traffic Separation Scheme and Puget Sound Vessel Traffic Service. Spill Prevention, Preparedness, & Response Program. Safety Advisory Bulletin 99-01. Lacey, Washington.

WDOE (Washington State Department of Ecology). 2017. General use level designation for basic (TSS) treatment for CONTECH Engineered Solutions stormwater management StormFilter® with ZPG media at 1 gpm/sq ft media surface area. CONTECH - StormFilter® GULD Maintenance Update (November 2012). WDOE.

WDOE . 2018. Water quality assessment. https://apps.ecology.wa.gov/waterqualityatlas/wqa/proposedassessment

WDOE. 2023. Washington Coastal Atlas Map. Available at: https://apps.ecology.wa.gov/coastalatlas/tools/Map.aspx

Weitkamp, D. 1982. Juvenile chum and chinook salmon behavior at Terminal 91, Seattle, WA. Parametrix, Seattle, WA.

Weitkamp, L. A. 2010. Marine distributions of Chinook salmon from the west coast of North America determined by coded wire tag recoveries. Trans. Am. Fish. Soc. 139:147–170.

West, J.E., A.J. Carey, G.M. Ylitalo, J.P. Incardona, R.C. Edmunds, C.A. Sloan, L.A. Niewolny, J.A. Lanksbury, and S.M. O'Neill. 2019. Polycyclic aromatic hydrocarbons in Pacific herring (Clupea pallasii) embryos exposed to creosote-treated pilings during a piling-removal project in a nearshore marine habitat of Puget Sound, Marine Pollution Bulletin, Volume 142, 2019, Pages 253-262.

Whitfield, A.K., and A. Becker. 2014. Impacts of recreational motorboats on fishes: A review. Marine Pollution Bulletin 83, 24-31

Williams, C. R., A. H. Dittman, P. McElhany, D. S. Busch, M. T. Maher, T. K. Bammler, J. W. MacDonald, and E. P. Gallagher. 2019a. Elevated CO2 impairs olfactory-mediated neural and behavioral responses and gene expression in ocean-phase coho salmon (Oncorhynchus kisutch). 25:963-977.

Williams, G. D., P.S. Levin, and W. A. Palsson. 2010. Rockfish in Puget Sound: An ecological history of exploitation. Marine Policy. Volume 34, pages 1,010-1,020.

Williams, R., E. Ashe, L. Yruretagoyena, N. Mastick, M. Siple, J. Wood, R. Joy, R. Langrock, S. Mews, and E. Finne. 2021. Reducing vessel noise increases foraging in endangered killer whales. Marine Pollution Bulletin 173:112976.

Williams, R., Veirs, S., Veirs, V., Ashe, E., & Mastick, N. 2019b. Approaches to reduce noise from ships operating in important killer whale habitats. Marine Pollution Bulletin, 139, 459–469. https://doi.org/10.1016/j.marpolbul.2018.05.015.

Williams, T.H., B.C. Spence, D.A. Boughton, R.C. Johnson, L.G. Crozier, N.J. Mantua, M.R. O'Farrell, and S.T. Lindley. 2016. Viability assessment for Pacific salmon and steelhead listed under the Endangered Species Act: Southwest. NOAA Fisheries Southwest Fisheries Science Center, Santa Cruz, CA: U.S. Dep Commerce NOAA Tech Memo NMFS SWFSC 564.

WRIA 9 (Water Resource Inventory Area 9). 2017. A synthesis of changes in our knowledge of Chinook salmon productivity and habitat uses in WRIA 9 (2004 – 2016). WRIA 9 Salmon Habitat Recovery Team, Seattle, Washington.

WRIA 9. 2021. Green/Duwamish and Central Puget Sound watershed salmon habitat plan 2021 Update. Approved by the WRIA 9 Watershed Ecosystem Forum on February 11, 2021.

WSDOT (Washington State Department of Transportation). 2020. Biological assessment manual. Chapter 7 construction noise impact assessment. Chapter 7.0 Construction Noise Impact Assessment. https://wsdot.wa.gov/engineering-standards/design-topics/environment/environmental-disciplines/fish-wildlife/endangered-species-act-and-essential-fish-habitat/biological-assessment-preparation-manual-template

Yan, H., N. Sun, A. Fullerton, and M. Baerwalde. 2021. Greater vulnerability of snowmelt-fed river thermal regimes to a warming climate. Environmental Research Letters 16(5). https://doi.org/10.1088/1748-9326/abf393

Yanagida, G. K., B. F. Anulacion, J. L. Bolton, D. Boyd, D. P. Lomax, O. Paul Olson, S. Y. Sol, M. Willis, G. M. Ylitalo, and L. L. Johnson. 2012. Polycyclic aromatic hydrocarbons and risk to threatened and endangered Chinook salmon in the Lower Columbia River estuary. Arch Environ Contam Toxicol 62(2):282-95.

6. APPENDIX A. NEARSHORE CALCULATOR SUMMARY

Blue cells contain section headings			
Rose cells contain questions that need to be answered to fill out calculator			
Grey cells contain units requested for entry			
Yellow cells indicate user entry fields			
Green cells contain additional explanations and resource links			
Maroon cells contain summary values			
Action Agency Reference #	**NWS-2022-842-WRD**		
FWS or NMFS #	**WCRO-2022-03517**		
Project Name:	Terminal 91 Berths 6&8 Redevelopment		
Prepared on and by:	SP and Nissa Rudh 4/3/2023, SP updated 5/18/2023, 7/25/2023		
Puget Sound Nearshore Habitat Conservation Calculator			
	Version 1.5		**2/24/2023**
This tool determines long-term habitat impacts and benefits for projects in the Salish Sea nearshore. Details about the use of this Conservation Calculator can be found in the User Guide, FAQs, and training materials, which are all available on the Puget Sound Nearshore Habitat Conservation Calculator Webpage			
		Conservation Credits/Debits	**DSAYs (Discounted Service Acre Years)**
Overwater Structures	Debit	-2254	**-22.54**
	Credit (includes creosote removal)	8638	**86.38**
	Balance	**6385**	**63.85**
Shoreline Armoring	Debit	-851	**-8.51**
	Credit from Armor Removal	282	**2.82**
	Credit from Creosote Removal	0	**0.00**
	Balance	**-569**	**-5.69**
Maintenance Dredging	**Balance**	**0**	**0.00**
Boatramps, Jetties, Rubble	Debit	-888	**-8.88**
	Credit	373	**3.73**
	Balance	**-514**	**-5.14**
Beach Nourishment	**Conservation Offsets**	**0**	**0.00**
Riparian Enhancement/Degradation	**Balance**	**0**	**0.00**
SAV Planting	**Conservation Credit**	**0**	**0.00**
Habitat Loss / Remaining Conservation Offsets Needed		**0**	**0.00**
Is this a standalone restoration project?*	**No**		

* Standalone restoration actions are actions that can be executed outside of a replacement or construction of new structures. They have no negative long term habitat impacts. A standalone restoration action solely restores or improves habitat functions. It does not introduce new or temporally extend adverse effects aside from construction-related effects. Standalone restoration projects include removal of a structure (that has adverse effects) without its replacement.

7. APPENDIX B. SOUND PRESSURE EXPOSURE SUMMARIES

IMPACT PILE DRIVING REPORT

PRINT IN LANDSCAPE TO CAPTURE ENTIRE SCREEN

(if OTHER INFO or NOTES get cut-off, please include information elsewhere)

Terminal 91 Impact Report

PROJECT INFORMATION	PEAK	SELss	RMS
Attenuated Single strike level (dB)	196	169	182
Distance associated with single strike level (meters)	10	10	10
Transmission loss constant	15		
Number of piles per day	3		
Number of strikes per pile	400		
Number of strikes per day	1200		
Cumulative SEL at measured distance	200		

OTHER INFO	3 36-inch steel pipe
NOTES	Greenbusch 2019
Attenuation	9

RESULTANT ISOPLETHS

FISHES

	ONSET OF PHYSICAL INJURY			BEHAVIOR
	Peak Isopleth	SEL_{cum} Isopleth		RMS Isopleth
		Fish ≥ 2 g	Fish < 2 g	
ISOPLETHS (meters)	2	71	132	1359

SEA TURTLES

	PTS ONSET		BEHAVIOR
	Peak Isopleth	SEL_{cum} Isopleth	RMS Isopleth
ISOPLETHS (meters)	0	5	29

MARINE MAMMALS

	LF Cetacean	MF Cetaceans	HF Cetaceans	PW Pinniped	OW Pinnipeds
PTS ONSET (Peak isopleth, meters)	0	0	4	0	0
PTS ONSET (SEL_{cum} isopleth, meters)	131	5	157	70	5
	ALL MM				
Behavior (RMS isopleth, meters)	293				

VIBRATORY PILE DRIVING REPORT

PRINT IN **LANDSCAPE** TO CAPTURE ENTIRE SCREEN

(if OTHER INFO or NOTES get cut-off, please include information elsewhere)

Terminal 91 Vibratory Sound Report

PROJECT INFORMATION	RMS
Attenuated Sound pressure level (dB)	150
Distance associated with sound pressure level (meters)	6
Transmission loss constant	15
Number of piles per day	8
Duration to drive pile (minutes)	60
Duration of sound production in day	28800
Cumulative SEL at measured distance	195

OTHER INFO: 36-inch steel pile

NOTES: Noise data collected at Edmonds Ferry Terminal, collected in Laughlin 2017b as

Attenuation: 0

RESULTANT ISOPLETHS

FISHES

	BEHAVIOR
	RMS Isopleth
ISOPLETHS (meters)	6

SEA TURTLES

	PTS ONSET	BEHAVIOR
	SEL_{cum} Isopleth	RMS Isopleth
ISOPLETHS (meters)	0	0

MARINE MAMMALS

	LF Cetacean	MF Cetaceans	HF Cetaceans	PW Pinniped	OW Pinnipeds
PTS ONSET (SELcum isopleth, meters)	3	0	4	2	0
	ALL MM				
Behavior (RMS isopleth, meters)	600				