UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
West Coast Region
7600 Sand Point Way N.E., Bldg. 1
Seattle, Washington 98115

Refer to NMFS No.:
WCR-2014-1502

September 2, 2016

Michelle Walker
U.S. Army Corps of Engineers, Seattle District
Regulatory Branch CENWS-OD-RG
P.O. Box 3755
Seattle, Washington 98124-3755

Re: Endangered Species Act Section 7 Formal Biological Programmatic Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation for Shellfish Aquaculture Activities in Washington State (COE Reference Number NWS-2014-12)

Dear Ms. Walker:

The enclosed document contains a programmatic biological opinion (PBO) prepared by the National Marine Fisheries Service (NMFS) pursuant to section 7(a)(2) of the Endangered Species Act (ESA) on the effects of a proposal by the U.S. Army COE of Engineers (COE) to authorize shellfish aquaculture and harvest activities under the authority of section 10 of the Rivers and Harbors Act and section 404 of the Clean Water Act.

In this PBO, NMFS concludes that the proposed action is not likely to jeopardize the continued existence of Puget Sound/Georgia Basin distinct population segment (DPS) of canary rockfish (*Sebastes pinninger*), and is not likely to adversely affect their critical habitat. NMFS also concludes that the proposed action is likely to adversely affect Puget Sound (PS) Chinook salmon (*O. tshawytscha*), Hood Canal summer-run chum salmon (*O. keta*), North American green sturgeon (*Acipenser medirostris*) and their designated critical habitat, but is not likely to jeopardize the continued existence of these species or to adversely modify their critical habitat. NMFS also concludes that the proposed action is not likely to adversely affect the southern DPS of, Pacific eulachon (*Thaleichthys pacificus*), Columbia River chum salmon, Lower Columbia River Chinook salmon, bocaccio rockfish (*S. paucispinis*), PS steelhead (*O. mykiss*), Southern Resident killer whale (*Orcinus orca*), or adversely affect their designated critical habitat (except for critical habitat for Columbia River chum salmon and Lower Columbia River Chinook salmon for which this action has no effect). NMFS also determined the proposed action would have “no effect” on yelloweye rockfish (*S. ruberrimus*), or their designated critical habitats.

As required by section 7 of the ESA, NMFS is providing an incidental take statement with the PBO. The incidental take statement describes reasonable and prudent measures NMFS considers necessary or appropriate to minimize the impact of incidental take associated with the COE’s proposed action.

The take statement sets forth nondiscretionary terms and conditions, including reporting requirements, that the Federal action agency must comply with to carry out the reasonable and prudent measures. Incidental take from actions that meet these terms and conditions will be exempt from the ESA's prohibition against the take of ESA-listed species.

This document also includes the results of our analysis of the proposed action's likely effects on essential fish habitat (EFH) pursuant to section 305(b) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA), and includes two conservation recommendations to avoid, minimize, or otherwise offset potential adverse effects on EFH.

Section 305(b) (4) (B) of the MSA requires Federal agencies to provide a detailed written response to NMFS within 30 days after receiving our final recommendations. If the response is inconsistent with the EFH conservation recommendations, the Federal action agency must explain why the recommendations will not be followed, including the scientific justification for any disagreements over the effects of the action and the recommendations. 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 request that in your statutorily required reply to us regarding the EFH portion of this consultation, you clearly identify the number of conservation recommendations accepted.

Please direct questions and comments regarding this opinion to Scott E. Anderson, Fisheries Biologist in our Oregon Washington Coastal Area Office, at 360.753.5828.

Sincerely,

for William W. Stelle, Jr.
Regional Administrator

cc: Pamela Sanguinetti, COE

Endangered Species Act (ESA) Section 7(a)(2) Biological Programmatic Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation

Washington State Commercial Shellfish Aquaculture and Restoration Programmatic

NMFS Consultation Number: WCR-2014-1502

Action Agency: U.S. Army Corps of Engineers, Seattle District

Affected Species and NMFS' Determinations:

Species	Status	Is Action Likely to Adversely Affect Species or Critical Habitat?	Is Action Likely To Destroy or Adversely Modify Critical Habitat?
Canary rockfish (*Sebastes pinniger*) (Puget Sound/Georgia Basin)	Threatened	Yes	No
Bocaccio rockfish (*S. paucispinis*) (Puget Sound/Georgia Basin)	Endangered	No*	No
Hood Canal summer-run chum salmon (*Oncorhynchus keta*)	Threatened	Yes	No
Puget Sound Chinook salmon (*O. tshawytscha*)	Threatened	Yes	No
Puget Sound steelhead (*O. mykiss*)	Threatened	No*	No
Southern DPS green sturgeon (*Asipenser medirostris*)	Threatened	Yes	No
Columbia River chum salmon	Threatened	No*	No
Lower Columbia River Chinook salmon	Threatened	No*	No
Southern Resident Killer Whale (*Orcinus orca*)	Endangered	No*	No
SDPS eualchon	Threatened	No*	No

*Please refer to section 2.11 for the analysis of species or critical habitat that are not likely to be adversely affected.

Fishery Management Plan That Describes 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:

William W. Stelle, Jr.
Regional Administrator

Date: September 2, 2016

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ACRONYM GLOSSARY

PBA	Programmatic Biological Assessment
BMP	Best Management Practices
BRT	Biological Review Team
CFR	Code of Federal Regulations
CH	Critical Habitat
CHART	Critical Habitat Review Team
COE	U.S. Army COE of Engineers
CR	Columbia River
CRMC	Coastal Resources Management Council
DO	Dissolved Oxygen
DPS	Distinct Population Segment
DQA	Data Quality Act
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
ESA	Endangered Species Act
ESU	Evolutionarily Significant Units
FLUPSY	Floating Upwelling System
FR	Federal Register
GHSAA	Grays Harbor sub-action area
HAPC	Habitat Areas of Particular Concern
HUC	Hydrologic Unit Code
IPM	Integrated Pest Management
ITS	Incidental Take Statement
LCR	Lower Columbia River
LAA	Likely to Adversely Affect
Mg/L	milligrams per liter
MHHW	Mean Higher High Water
MM	Millimeter
MSA	Magnuson-Stevens Fishery Conservation and Management Act
NLAA	Not Likely To Adversely Affect
NMFS	National Marine Fisheries Service
NPDES	National Pollutant Discharge Elimination System
NTU	National Turbidity Units
NWP	Nationwide Permit
NWP 48	Nationwide Permit 48
Opinion	Biological Opinion
PAH	Polycyclic aromatic hydrocarbons
PBDE	Polybrominated dephenyl ethers
PBO	Programmatic Biological Opinion
PCBs	PolyChlorinated Biphenyls
PBF	Primary Constituent Element
PCN	Pre-Construction Notification
PDO	Pacific Decadal Oscillation
PFMC	Pacific Fishery Management Council
PPB	Parts per billion

PS	Puget Sound
PSP	Paralytic Shellfish Poisoning
PVC	Polyvinyl Chloride
SAV	Submerged Aquatic Vegetation
SPSAA	South Puget Sound Action area
TSS	Total Suspended Solids
U.S.C.	United States Code
USFWS	U.S. Fish and Wildlife Service
VSP	Viable Salmonid Populations
WDF	Washington Department of Fisheries
WDFW	Washington Department of Fish and Wildlife
WDNR	Washington Department of Natural Resources
WDOE	Washington State Department of Ecology
WRIA	Water Resource Inventory

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

The NMFS also completed an Essential Fish Habitat (EFH) consultation. It was prepared 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 600.

The PBO and EFH conservation recommendations are both in compliance with the Data Quality Act (44 U.S.C. 3504(d)(1) et seq.) and they underwent pre-dissemination review.

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 (section 515 of the Treasury and General Government Appropriations Act for Fiscal Year 2001, Public Law 106-554). A complete record of this consultation is on file at the Oregon Washington Coastal Area Office.

1.2 Consultation History

The U.S. Army Corps of Engineers (COE) authorizes and regulates shellfish activities under Section 404 of the Clean Water Act and Section 10 of the River and Harbor Act of 1899. This can take the form of individual project-specific permits or general permits. Project specific permits are typically referred to as standard or individual permits. Activities requiring COE authorization that are similar in nature and have minimal individual and cumulative environmental impacts may qualify for authorization by a general permit, such as a nationwide permit (NWP). The COE issues letters of verification for activities that qualify for an NWP. The complete set of NWPs is re-issued every five years. National and regional conditions are developed in concert with the NWPs.

In 2007, the COE issued Nationwide Permit (NWP) 48 to regulate existing commercial shellfish aquaculture activities. The COE submitted a programmatic biological assessment to NMFS for ESA consultation in 2007 to evaluate effects of this Federal action on listed species and critical habitat. The COE completed addendums to the PBA in 2008 for analysis of the insecticide carbaryl (which is not within the COEs jurisdiction). Separate biological opinions were issued to the COE by NMFS (NWR-2008-4151) and U.S. Fish and Wildlife Service (FWS) in 2009 (13410-F-2008-0461). In 2010, the COE provided an addendum to address new species listings.

NMFS issued a new biological opinion concluding this reinitiated consultation with the COE in 2011 (NWR-2010-4010).

In March of 2012, the COE issued a new NWP 48, which superseded the 2007 version of the NWP. Since the previous ESA consultation was based on and covered activities conducted under the 2007 version of the NWP 48, the ESA coverage it provides is limited to activities conducted under the 2007 NWP and does not extend to the activities conducted under the 2012 NWP 48. Consultation is therefore required to address activities conducted under the 2012 NWP 48. ESA consultation on all of the COE's 2012 NWPs was conducted on a national level, which resulted in a final Biological Opinion in November 2014. That opinion required NWP-specific consultations before the COE could issue an individual NWP. The Services are addressing that requirement for the 2012 NWP 48 with this PBO.

To avoid some of the limitations of conducting consultation solely on NWP 48 – including the limited scope of activities covered in the permit, and the short duration of the permit (5 years), the COE, in coordination with the Services, has developed a broader programmatic proposed action for this consultation. In contrast to the previous consultations on NWP 48, this consultation covers a number of additional shellfish related permitting actions the COE may take; it is not limited to activities covered by NWP 48. Shellfish related activities could potentially be conducted under other NWPs for purposes other than aquaculture or they could be conducted under standard individual permits. In most cases, the shellfish activities conducted for aquaculture are very similar or identical to the activities conducted for other shellfish related purposes (e.g., restoration). For reasons of consistency and efficiency, the proposed action for this consultation addresses all these potential shellfish related permitting actions.

The COE developed the proposed action in coordination with NMFS and FWS, with the objective of achieving ESA and MSA compliance in an efficient manner for shellfish activities authorized by the COE Seattle District's regulatory program. The agencies met numerous times between 2013 and 2016 to develop the proposed action including the covered activities and applicable conservation measures. This coordination process is termed Standard Local Operating Procedures for Endangered Species (SLOPES).

The agencies held at least fifteen meetings or phone conferences between April 2013 and September 5, 2014 to coordinate on the scope of activities and conservation measures to be included in the proposed action. Further meetings were held in 2015 and 2016 to discuss various concerns presented by tribes and other stakeholders. In their October 2015 programmatic biological assessment (PBA), the COE determined the proposed action was likely to adversely affect canary rockfish (*Sebastes pinniger*), Hood Canal summer-run chum (*Oncorhynchus keta*), southern DPS green sturgeon (*Acipenser medirostris*), Georgia Basin DPS of boccacio, and PS Chinook salmon, but was not likely to adversely affect Lower Columbia River (LCR) Chinook Salmon (*O. tshawytscha*), Columbia River chum, Puget Sound (PS) steelhead (*O. mykiss*), (*Sebastes paucispinis*), Georgia Basin DPS yelloweye rockfish (*S. ruberrimus*), Southern Resident Killer Whale (*Orcinus orca*), Pacific eulachon (*Thaleichthys pacificus*), and Humpback Whale (*Megaptera novaeangliae*) or their designated or proposed critical habitats.

On June 10, 2016, we shared a draft of this opinion with the COE. The COE submitted comments on the draft on June 27, 2016. We made edits and revisions to this opinion in response to the COE's comments. On July 15, 2016, a conference call was held with the COE and FWS to discuss revisions made to this opinion.

Initially, NMFS did not concur with the COE determination of effects for green sturgeon. However, upon analysis of more information, NMFS concluded that the action would was likely to adversely affect green sturgeon. In addition, NMFS concluded this action will have "no effect" on yelloweye rockfish and Humpback Whale because they do not occupy areas where shellfish aquaculture or its effects occur, and they are not addressed in this document. NMFS did not concur with COEs determination of likely to adversely affect Georgia Basin DPS boccacio and their critical habitat. Rather, we determined the proposed action was not likely to adversely affect boccacio and their critical habitat and our rationale is described in section 2.11 of this document. The NMFS concurred with all other effects determinations.

Table 1. Listed species, species effect determination, and critical habitat effect determination for this consultation (LAA- likely to adversely affect, NLAA- not likely to adversely affect)

Listed Species	**Species Effect Determination**	**Critical Habitat Determination**
Canary Rockfish	LAA	NLAA
Bocaccio	NLAA	NLAA
Hood Canal summer-run Chum	LAA	LAA
PS Chinook salmon	LAA	LAA
LCR Chinook salmon	NLAA	No effect
PS steelhead	NLAA	NLAA
CR Chum salmon	NLAA	No effect
SDPS green sturgeon	LAA	LAA
Yelloweye Rockfish	No effect	No effect
SDPS eulachon	NLAA	No effect
SR Killer Whale	NLAA	No effect
Humpback Whale	No effect	No effect

1.3 Proposed Action

"Action" means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by Federal agencies (50 CFR 402.02).

Under the proposed action, the COE will authorize new shellfish aquaculture operations, ongoing operations, and expansion of existing commercial shellfish operations, including operations moving into fallow areas. The proposed action also includes permitting for subtidal wild geoduck harvest, as well as for restoration activities for the purpose of habitat enhancement, ecological restoration, and re-population of native species. The action also includes recreation based culture activities, such as for personal use. The proposed action does not include the expansion of operations to include the cultivation of new species (i.e., species not previously cultivated in the relevant water body). The proposed action does not include construction of new attendant features such as docks, piers, boat ramps, stockpiles, staging areas, or depositing waste shell material back into waters of the United States. A complete list of activities not included in the proposed action or analyzed in this PBO can be found in Table 4, below. Rafts, floats, and FLUPSYs that were in place and operating for a shellfish related purpose prior to 18 March 2007 and meet the definition of a 'continuing' activity are included in the proposed action (Table 6). Installation and operation of 'new' structures (i.e., rafts, floats, and FLUPSYs) is not part of the proposed action. The proposed action includes a set of conservation measures developed jointly with the Services as part of a multi-agency Standard Local Operating Procedures for Endangered Species (SLOPES) process. These conservation measures must be adhered to in order for an activity to be authorized by the COE under this consultation.

As a result of the regulatory history of NWP 48 in Washington State there is an important distinction made by the COE Regulatory Program and carried forward in the PBA between 'continuing' and 'new' shellfish activities. 'Continuing' shellfish activities are those activities that had been granted a permit, license, or lease from a state or local agency specifically authorizing commercial shellfish aquaculture activities and that were occurring within a defined footprint prior to 18 March 2007. The emphasis is on the specific footprint on which the activity was occurring. Based on permit applications previously submitted to the COE, the continuing activities have been identified and recorded in a database that is maintained by the COE. 'New' activities are those activities that were undertaken after 18 March 2007 and essentially include all activities that do not qualify as continuing. The expansion of a continuing footprint into a new footprint that had not previously been in shellfish culture is treated as a new footprint or new activity for the purpose of the COE Regulatory Program. For purposes of the proposed action, a new activity would not be reclassified as a continuing activity in the future, but would remain classified as new.

Continuing activity footprints are further divided between areas in active cultivation/harvest and 'areas that are periodically allowed to lie fallow as part of normal operations' (reference from the COE's Final Notice for Reissuance of Nationwide Permits 72 FR 11092, March 12, 2007).

Shellfish operations are not always spatially contiguous and can include areas in which there has been no recent aquaculture activity and/or areas that periodically are allowed to lie fallow as part of normal operations. For the COE's purposes, the determination of continuing cultivated and continuing fallow acres is as of 18 March 2007. In other words, if a commercial shellfish area has not been under cultivation since 2007, it is deemed as fallow. The nature and extent of historical shellfish activity conducted on fallow acreage is unknown except for the fact that it was fallow in 2007 and have remained in a fallow state based on the most recently available information, which in most cases would be 2012 or 2013 when most of the continuing activities were authorized by the COE. There are no fallow lands associated with new activities. The geographic footprint and acreages for both continuing cultivated and continuing fallow areas have been previously identified on permit applications submitted to the COE, and are described in Table 2.

As discussed above, for management purposes shellfish activities within an area footprint are separated into 3 categories: continuing active, continuing fallow,, and new. How each of these categories is managed is reflected in certain Conservation Measures and in elements of the proposed action related to structures. Continuing activities that include the use of certain currently serviceable structures (i.e., rafts, floats, and Floating Upwelling Systems (FLUPSYS)) that were in place and authorized to be operating for a commercial shellfish aquaculture activity prior to 18 March 2007 are included among the list of covered activities for this consultation. The CMs for continuing active cultivation will apply to activities in areas identified as fallow. While it is uncertain how much activity may occur in fallow during the term of this Opinion, the COE assumed for purposes of analysis and NMFS also assumes that activity will occur in all fallow land.

In order for an applicant's proposed shellfish activities to be covered by this consultation, the activities must: 1) fall within the scope of activities described below, 2) incorporate the relevant Conservation Measures (below), 3) occur within the geographic area considered by the consultation (below), and 4) comply with any applicable terms and conditions (Section 2.8.4). For permit applicants seeking ESA coverage for shellfish activities that do not meet these conditions, an individual ESA consultation with the COE may be necessary prior to the issuance of a COE permit or verification letter.

The areas covered by the proposed action include waters of the United States within Washington State occupied by continuing shellfish activities, as well as areas suitable for new and expanded shellfish activities. For this consultation, these areas are divided into five sub-regions including Willapa Bay, Grays Harbor, North Puget Sound (aka Eastern Straits), Hood Canal, and South Puget Sound (table 2). Typically, continuing shellfish aquaculture operations consist of several sites covered by state or local aquaculture permit, license, or lease. Estimates of anticipated growth in the shellfish aquaculture industry were provided by the Pacific Coast Shellfish Growers Association (PCSGA). These estimates (below) were combined with existing acreage to inform the analysis in this PBO.

- An estimated 300 acres of commercial geoduck culture have been planted within Puget Sound to date. The COE estimates that this acreage could double over the next 20 years (COE, 2015). Much less acreage of geoduck aquaculture is anticipated to occur in Willapa Bay and Grays Harbor than in Puget Sound.

- An estimated 36,999 acres of tidal and subtidal lands (including fallow and continuing floating acres) are currently in aquaculture for clams and oysters within the geographic area of the proposed action. The COE estimates that 1,401 acres of new aquatic lands could be put into aquaculture production for mussels, clams, geoduck and oysters over the next 20 years (this does not include new cultivation on continuing fallow land). Along with predicted acreages of 160 for recreation and 155 for new shellfish restoration activities, estimated total acreage for new intertidal harvest and culture statewide is 1,716 acres, which, on average, represents an increase of commercial culture of about 10%, covering an additional 3.8% of intertidal area over the next 20 years.

- Across all growing areas of Washington State, an estimated 14,803 acres are currently recognized as fallow. Of these acres, 9,468 are in Willapa Bay and 1,820 are in Grays Harbor, 2,333 are in the NPSAA, 780 are in SPSAA, and 402 are in Hood Canal. In designated critical habitat for PS Chinook salmon and HCSR chum salmon, which does not include Willapa Bay or Grays Harbor, estimated acreage of fallow potentially co-located with eelgrass ranges in each sub-region from 14% (SPSAA) to 96% (NPSAA), (Table 3).

- The COE anticipates authorizing activities described and carried out under the WDNR HCP for subtidal geoduck harvest. Since the HCP provides ESA coverage, the COE would use the HCP consultation to address ESA compliance for these activities. The HCP activities are therefore not considered part of the proposed action in this PBA. Currently, 48,133 acres of potentially naturally occurring geoduck occurs within the action area. Harvest under the HCP would occur within this potentially harvestable acreage. Harvest under the proposed action would also occur in areas not covered by the HCP. The annually harvested acreage would typically be about 250 to 300 acres under the proposed action. This is in addition to the 250-300 acres that would be annually harvested under the HCP (WDNR 2008).

- Shellfish restoration activities within the scope of this PBO include activities to seed and re-populate tidal or subtidal waters for purposes of habitat enhancement, ecological restoration, water quality improvement, or to increase the population size of native shellfish species. Acreage of restoration activities potentially covered by this PBO include 24 in Hood Canal, 126 in SPS, and 5 in NPSAA, for a total of 155 acres (Table 2).

- Recreational shellfish activities could include various seeding, maintenance, and harvesting activities for all the PBA shellfish species (mussel, oyster, clam, and geoduck). The objective is to enhance populations sufficient to support regular recreational harvest (i.e., for personal use). In some cases the activities may resemble an aquaculture operation. Harvest could potentially occur on seeded or wild shellfish populations. Seeding and growing for purposes of shellfish related recreation would be limited to intertidal lands between +7 ft and - 4.5 ft MLLW. Acres proposed for recreational shellfish activities include 74 acres in Hood Canal, 41 in SPSAA, and 45 in NPSAA. The acreages are based on information provided by WDFW (Brady 2014), historical Corps permitting, and the judgment of Corps professional staff regarding future permitting expectations.

The proposed action includes issuance of permits for at least 20 years, beyond the typical 3 to 10 year COE authorization period for a COE permit. Applicants wishing to continue regulated shellfish activities must obtain reauthorization from the COE every five to ten years, Over the expected 20-year timeframe of the programmatic, activities located within the same footprint could be reauthorized by the Corps as many as three or four times. As discussed above, the geographic area for the proposed action has been divided into five regions to better analyze and manage local effects on aquatic resources. Acreage limits for authorized shellfish activities have been developed for each of the regions. If and when these acreage limits are reached, the COE may submit to NMFS an addendum to the proposed action to increase the acreage. Acreage limits were developed based on a 20-year horizon. Specific acreage limits for each sub-action area apply to "new" activities, as shown in Table 2.

The Corps has compiled information from permit applications, and has obtained estimates from the DNR, WDFW, and shellfish industry representatives, to project or estimate future growth of the industry over the next 20 years (COE 2015, pp. 40-49, 77-82). Over the estimated 20 years of the proposed action, the COE estimates growth in new shellfish culture of approximately 1,716 acres of new intertidal harvest and culture acreage statewide (1,401 for commercial purposes, 160 for recreation, and 155 for restoration). The precise geographic locations of new shellfish activities are not known since most of these are anticipated future activities. These estimates suggest future increases in aquaculture of approximately 32 percent in Hood Canal, 14 percent in south Puget Sound, and 9 percent in north Puget Sound; they also suggest future growth of 3 percent and less than 1 percent in Grays Harbor and Willapa Bay, respectively. The amount of anticipated new acreage in Willapa Bay comprises approximately 0.2 percent of the total intertidal acreage in Willapa Bay. The relative contribution of estimated new shellfish activity ranges up to 3.8 percent of total intertidal acreage in Hood Canal, with other areas between 0 and 1.5 percent (Table 2). The new acreage will contribute relatively little to the total existing shellfish activity acreage in each of the geographic regions. For purposes of this analysis, it is assumed that shellfish activities will occur in all areas currently identified as continuing fallow. When continuing fallow lands are combined with acreages of potential new culture areas, the estimate of acreage that could be brought into shellfish production during the next 20 years is increased significantly (Table 2).

Table 2. Continuing, new, and continuing fallow ground-based shellfish activity acreage relative to total tideland acreage in each sub-region of the action area (COE 2015)

	Grays Harbor		**Willapa Bay**		**Hood Canal**		**South Puget Sound**		**North Puget Sound**		**Total**	
	acres	% of total tidelands	acres	% of total tidelands	acres	% of total tidelands	acres	% of total tidelands	acres	% of total tidelands	acres	% of total tidelands
Total marine tideland acres	41,115		49,194		11,378		30,075		84,283		216,045	
continuing fallow aquaculture	1,820	4.4%	9,468	19.2%	402	3.5%	780	2.6%	2,333	2.8%	14,803	6.9%
new - aquaculture	100	0.2%	100	0.2%	438	3.8%	448	1.5%	315	0.4%	1,401	0.6%
new - recreation	0	0.0%	0	0.0%	74	0.7%	41	0.1%	45	0.1%	160	0.1%
new - restoration	0	0.0%	0	0.0%	24	0.2%	126	0.4%	5	0.0%	155	0.1%
total cont. fallow & new	1,920	4.7%	9,568	19.4%	938	8.2%	1,395	4.6%	2,698	3.2%	16,519	7.6%
continuing active aquaculture	1,145	2.8%	16,397	33.3%	949	8.3%	2,351	7.8%	1,354	1.6%	22,196	10.3%
cumulative total (cont. fallow/new + cont. active)	3,065	7%	25,965	53%	1,887	17%	3,746	12%	4,052	5%	38,715	18%

Table 3. Summary of shellfish acres in tidelands for sub-regions potentially co-located with *Z. marina* (COE, 2015)

	Grays Harbor*	Willapa Bay*	Hood Canal	S. Puget Sound	N. Puget Sound	Total
# Continuing cultivated footprints	17	161	34	21	21	235
Continuing cultivated acres	766	12,170	402	180	1,131	14,649
# continuing fallow footprints	13	81	42	1	13	150
Continuing fallow acres	1,152	7,448	294	95	2,333	11,322
Total Acres (active and Fallow)	1,918	19,618	685	275	3,370	25,866
% continuing active acreage potentially co-located with eelgrass	67%	74%	41%	8%	84%	55%
% continuing fallow potentially co-located with eelgrass	63%	79%	73%	12%	96%	65%
% eelgrass in region potentially co-located with aquaculture (active &fallow)	5%	49%	21%	9%	7%	18%

*No Critical Habitat for Salmonids

As described above, under the proposed action, the COE will authorize new shellfish aquaculture operations, ongoing operations, and expansion of existing commercial shellfish operations, including operations moving into fallow areas. The proposed action also includes subtidal wild geoduck harvest, as well as recreation and restoration activities for the purpose of habitat enhancement, ecological restoration, and re-population of native species. The proposed action does not include the expansion of operation for the cultivation of new species (i.e., species not previously cultivated in the relevant water body). The proposed action does not include construction of new attendant features such as docks, floating upwelling systems (FLUPSYs), piers, boat ramps, stockpiles, staging areas, or depositing waste shell material back into waters of the United States. A complete list of activities not included in the proposed action or analyzed in this PBO can be found in Table 4, below. Rafts, floats, and FLUPSYs that were in place and operating for a shellfish related purpose prior to 18 March 2007 and meet the definition of a 'continuing' activity are included in the proposed action. Installation and operation of 'new' structures is not part of the proposed action. The proposed action includes the installation of racks, trays, nets, lines, tubes, containers, and other structures necessary for existing commercial shellfish aquaculture operations. The action also includes discharges of dredged or fill material necessary for shellfish seeding, rearing, cultivating, transplanting, and harvesting activities.

Finally, the COE did not propose to include activities involving the application of any pesticides or herbicides for any purpose regardless of when the activity commenced under this programmatic consultation. Certain growers use imazamox which is permitted specifically for treatment of Japanese eelgrass on clam culture beds. Given the uncertainty over whether the

Corps might use this programmatic consultation to cover permitting for shellfish operations that use imazomox, we considered the use of imazomox as an interrelated activity in this Opinion. Activities involving the use of herbicides or pesticides other than imazamox for treatment of Japanese eelgrass on clam culture beds is not covered by this programmatic and will require individual consultation.

Table 4. Shellfish Activities Not Covered by the proposed action.

Excluded Activities and Structures
Vertical fencing/vertical nets or drift fences (includes oyster corrals)
New berms or dikes or the expansion or maintenance of existing, authorized berms or dikes
Use of a hopper-type barge or other method that results in material (i.e. gravel or shell) placed during graveling or frosting activities that is thicker than 1 inch in depth even for short periods of time.
Pile driving
Mooring Buoys
Upland Hatcheries
Cultivation of shellfish species not previously cultivated in the action area
Attendant features, such as docks, piers, boat ramps, stockpiles, or staging areas
Deposition of shell material back into waters of the United States as waste
Dredging or creating channels so as to redirect fresh water flow
Installation of new rafts, floats, or new FLUPSYS or the relocation or expansion of continuing rafts, floats, or FLUPSYS.
The use of materials that lack structural integrity in the marine environment (e.g. plastic children's wading pools, unencapsulated Styrofoam®).
Any form of chemical application to control undesired species (e.g., burrowing shrimp); however, use of imazamox to treat Zostera japonica on clam culture beds is considered interrelated and interdependent for purposes of this opinion. All other activities involving use of chemicals to treat undesired species are not covered by this programmatic.

Applicants for COE permits for the activities included in the proposed action must submit a permit application in order for the COE to evaluate regulatory compliance. In Washington State, the Joint Aquatic Resources Permit Application (JARPA) serves as the application. This application is required in all cases for individual permits. For verification under NWPs, the need for an application is determined by specific conditions associated with the NWPs. For an NWP, the application is also called a 'pre-construction notification' or PCN. NWP General Condition 18 (from the 2012 version of the NWPs) requires an application (or PCN) to be submitted when

there is potential to affect threatened or endangered species and/or critical habitat. Since there are a number of such species throughout Washington State waters, the application requirement is triggered in all cases. A permit application would therefore be required for all activities conducted under this consultation whether they could be authorized by an individual permit or a NWP or any similar regional permit offered by the COE's Seattle District. This means that written approval from the COE is required before work commences in all cases.
The COE will submit an annual report to the NMFS documenting all shellfish activities authorized under the proposed action by February 15 each year. Further, the COE will host annual or bi-annual coordination meetings with NMFS by March 31 of each year to discuss the annual report, new issues, and any actions that could make this programmatic consultation more efficient or accountable.

1.3.1 Conservation Measures

Shellfish activities that qualify for coverage under this PBO and subsequent COE permits will include the following conservation measures. Some of these measures are intended to avoid and minimize potential effects on ESA-listed species and their habitats. Other measures are intended to reduce water quality impacts as part of the Corp's authority under the Clean Water Act. Shellfish activities that do not employ these measures where applicable will not are not within the scope of this proposed action and are potentially liable under provisions of the Endangered Species Act unless they are covered under a separate ESA consultation and COE permit. For a definition of eelgrass to which applicable conservation measures would apply, as well as methods to identify such areas, NMFS refers to the Washington State Department of Natural Resources Eelgrass Tech memo, "Operational Definition of an Eelgrass (*Zostera marina*) Bed, 2011" (Appendix). These conservation measures are part of the COE's proposed action and stated in their October 2015 BA.

1. Gravel and shell shall be washed prior to use for substrate enhancement (e.g., frosting, shellfish bed restoration) and applied in minimal amounts using methods which result in less than 1 inch depth on the substrate annually. Shell material shall be procured from clean sources that do not deplete the exiting supply of shell bottom. Shells shall be cleaned or left on dry land for a minimum of one month, or both, before placement in the marine environment. Shells from the local area shall be used whenever possible. Shell or gravel material shall not be placed so that it creates piles on the substrate. Use of a split-hull (e.g., hopper-type) barge to place material is prohibited.

2. The placement of gravel or shell directly into the water column (i.e., graveling or frosting) shall not be conducted between February 1 and March 15 in designated critical habitat for Hood Canal summer chum salmon.

3. For 'new' activities only, gravel or shell material shall not be applied to enhance substrate for shellfish activities where native eelgrass (*Zostera marina*) or kelp (rooted/attached brown algae in the order *Laminariales*) is present.

4. Turbidity resulting from oyster dredge harvest shall be minimized by adjusting dredge bags to skim" the surface of the substrate during harvest.

5. Unsuitable material (e.g., trash, debris, car bodies, asphalt, tires) shall not be discharged or used as fill (e.g., used to secure nets, create nurseries, etc.).

6. For 'new' activities only, shellfish activities (e.g., racks, stakes, tubes, nets, bags, long-lines, on- bottom cultivation) shall not occur within 16 horizontal feet of native eelgrass (*Zostera marina*) or kelp (rooted/attached brown algae in the order *Laminariales*). If eelgrass is present in the vicinity of an area new to shellfish activities, the eelgrass shall be delineated and a map or sketch prepared and submitted to the Corps. Surveys to determine presence and location of eelgrass shall be done during times of peak above-ground biomass: June 1 – September 30. The following information must be included to scale: parcel boundaries, eelgrass locations and on-site dimensions, shellfish activity locations and dimensions.
7. For 'new' activities only, activities shall not occur above the tidal elevation of +7 feet (MLLW) if the area is listed as documented surf smelt (*Hypomesus pretiosus*) spawning habitat by WDFW. A map showing the location of documented surf smelt spawning habitat is available at the WDFW website.

8. For 'new' activities only, activities shall not occur above the tidal elevation of +5 feet (MLLW) if the area is documented as Pacific sand lance (*Ammodytes hexapterus*) spawning habitat by the WDFW. A map showing the location of documented Pacific sand lance spawning habitat is available at the WDFW website.

9. If conducting 1) mechanical dredge harvesting, 2) raking, 3) harrowing, 4) tilling, leveling or other bed preparation activities, 5) frosting or applying gravel or shell on beds, or 6) removing equipment or material (nets, tubes, bags) within a documented or potential spawning area for Pacific herring (*Clupea pallasi*) outside the approved work window (see Seattle District Corps website), the work area shall be surveyed for the presence of herring spawn prior to the activity occurring. Vegetation, substrate, and materials (nets, tubes, etc.) shall be inspected. If herring spawn is present, these activities are prohibited in the areas where spawning has occurred until such time as the eggs have hatched and herring spawn is no longer present. A record shall be maintained of spawn surveys including the date and time of surveys; the area, materials, and equipment surveyed; results of the survey, etc. The Corps and the Services shall be notified if spawn is detected during a survey. The record of spawn surveys shall be made available upon request to the Corps and the Services.

10. For 'new' activities only, activities occurring in or adjacent to potential spawning habitat for sand lance, or surf smelt shall have a spawn survey completed in the work area by an approved biologist[3] prior to undertaking bed preparation, maintenance, and harvest activities if work will occur outside approved work windows for these species. If eggs are present, these activities are prohibited in the areas where spawning has occurred until such time as the eggs have hatched and spawn is no longer present. A record shall be maintained of spawn surveys including the date and time of surveys; the area, materials, and equipment surveyed; results of the survey, etc. The Corps and the Services shall be

notified if spawn is detected during a survey. The record of spawn surveys shall be made available upon request to the Corps and the Services.

11. All shellfish gear (e.g., socks, bags, racks, marker stakes, rebar, nets, and tubes) that is not immediately needed or is not firmly secured to the substrate will be moved to a storage

12. area landward of MHHW prior to the next high tide. Gear that is firmly secured to the substrate may remain on the tidelands for a consecutive period of time up to 7 days. Note: This is not meant to apply to the wet storage of harvested shellfish.[1]

13. All pump intakes (e.g., for washing down gear) that use seawater shall be screened in accordance with NMFS and WDFW criteria. Note: This does not apply to work boat motor intakes (jet pumps) or through-hull intakes.

14. Land vehicles (e.g., all-terrain, trucks) shall be washed in an upland area such that wash water is not allowed to enter any stream, waterbody, or wetland. Wash water shall be disposed of upland in a location where all water is infiltrated into the ground (i.e., no flow into a waterbody or wetland).

15. Land vehicles shall be stored, fueled, and maintained in a vehicle staging area located 150 feet or more from any stream, waterbody, or wetland. Where this is not possible, documentation must be provided to the Corps as to why compliance is not possible, written approval from the Corps must be obtained, and the operators shall have a spill prevention plan and maintain a readily-available spill prevention and clean-up kit.

16. For boats and other gas-powered vehicles or power equipment that cannot be fueled in a staging area 150 feet away from a waterbody or at a fuel dock, fuels shall be transferred in Environmental Protection Agency (EPA)-compliant portable fuel containers 5 gallons or smaller at a time during refilling. A polypropylene pad or other appropriate spill protection and a funnel or spill-proof spout shall be used when refueling to prevent possible contamination of waters. A spill kit shall be available and used in the event of a spill. All spills shall be reported to the Washington Emergency Management Office at (800) 258-5990. All waste oil or other clean-up materials contaminated with petroleum products will be properly disposed of off-site.

17. All vehicles operated within 150 feet of any stream, waterbody, or wetland shall be inspected daily for fluid leaks before leaving the vehicle staging area. Any leaks detected shall be repaired in the vehicle staging area before the vehicle resumes operation and the leak and repair documented in a record that is available for review on request by the Corps and Services.

18. The direct or indirect contact of toxic compounds including creosote, wood preservatives, paint, etc. within the marine environment shall be prevented. *[This does not apply to boats]*

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[3] For information on how to become an “approved biologist” for forage fish surveys contact WDFW.

19. All tubes, mesh bags and area nets shall be clearly, indelibly, and permanently marked to identify the permittee name and contact information (e.g., telephone number, email address, mailing address). On the nets, identification markers shall be placed with a minimum of one identification marker for each 50 feet of net.

20. All equipment and gear including anti-predator nets, stakes, and tubes shall be tightly secured to prevent them from breaking free.

21. All foam material (whether used for floatation of for any other purpose) must be encapsulated within a shell that prevents breakup or loss of foam material into the water and is not readily subject to damage by ultraviolet radiation or abrasion. Un-encapsulated foam material used for current on-going activities shall be removed or replaced with the encapsulated type.

22. Tires shall not be used as part of above and below structures or where tires could potentially come in contact with the water (e.g., floatation, fenders, hinges). Tires used for floatation currently shall be replaced with inert or encapsulated materials, such as plastic or encased foam, during maintenance or repair of the structure.

23. At least once every three months, beaches in the project vicinity will be patrolled by crews who will retrieve debris (e.g., anti-predator nets, bags, stakes, disks, tubes) that escape from the project area. Within the project vicinity, locations will be identified where debris tends to accumulate due to wave, current, or wind action, and after weather events these locations shall be patrolled by crews who will remove and dispose of shellfish related debris appropriately. A record shall be maintained with the following information and the record will be made available upon request to the Corps, NMFS, and USFWS: date of patrol, location of areas patrolled, description of the type and amount of retrieved debris, other pertinent information.

24. When performing other activities on-site, the grower shall routinely inspect for and document any fish or wildlife found entangled in nets or other shellfish equipment. In the event that fish, bird, or mammal is found entangled, the grower shall: 1) provide immediate notice (within 24 hours) to WDFW (all species), Services (ESA listed species) or Marine Mammal Stranding Network (marine mammals), 2) attempt to release the individual(s) without harm, and 3) provide a written and photographic record of the event, including dates, species identification, number of individuals, and final disposition, to the Corps and Services. Contact the U.S. Fish and Wildlife Service Law Enforcement Office at (425) 883-8122 with any questions about the preservation of specimens.

25. Vehicles (e.g., ATVs, tractors) shall not be used within native eelgrass (*Zostera marina*). If there is no other alternative for site access, a plan will be developed describing specific measures and/or best management practices that will be undertaken to minimize negative effects to eelgrass from vehicle operation. The access plan shall include the following components: (a) frequency of access at each location, (b) use of only the minimum vehicles needed to conduct the work and a description of the minimum number of vehicles

needed at each visit, and (c) consistency in anchoring/grounding in the same location and/or traveling on the same path to restrict eelgrass

26. Vessels shall not ground or anchor in native eelgrass (*Zostera marina*) or kelp (rooted/attached brown algae in the order *Laminariales*) and paths through native eelgrass or kelp shall not be established. If there is no other access to the site or the special condition cannot be met due to human safety considerations, a site-specific plan shall be developed describing specific measures and/or best management practices that will be undertaken to minimize negative effects to eelgrass and kelp from vessel operation and accessing the shellfish areas. The access plan shall include the following components: (a) frequency of access at each location, (b) use of only the minimum number of boats and/or crew members needed to conduct the work and a description of the minimum number of boats and crewmembers needed at each visit, and (c) consistency in anchoring/grounding in the same location and/or walking on the same path to restrict eelgrass disturbance to a very small footprint.

27. Unless prohibited by substrate or other specific site conditions, floats and rafts shall use embedded anchors and midline floats to prevent dragging of anchors or lines. Floats and rafts that are not in compliance with this standard shall be updated to meet this standard during scheduled maintenance, repair, or replacement or before the end of the term of the next renewed authorization. [*Any alternative to using an embedded anchor must be approved by the NMFS*.

28. Activities that are directly associated with shellfish activities (e.g., access roads, wet storage) shall not result in removal of native riparian vegetation extending landward 150 ft horizontally from MHHW (includes both wetland and upland vegetation) and disturbance shall be limited to the minimum necessary to access or engage in shellfish activities.

29. Native salt marsh vegetation shall not be removed and disturbance shall be limited to the minimum necessary to access or engage in shellfish activities.

<u>Shellfish Activities in Washington State</u>

Shellfish aquaculture includes some activities that may affect ESA-listed salmon, rockfish, green sturgeon, and their designated or proposed critical habitat, as well as EFH as designated by the Magnuson Stevens Fisheries Management Act. Many aspects of shellfish aquaculture do not have such effects. A complete discussion of shellfish aquaculture is described below under sections titled “Activities Common to Shellfish Aquaculture”. The proposed action includes the 28 specific conservation measures (listed above) that are designed to avoid or reduce a variety of impacts to fish and habitat.

<u>Activities Common to All Shellfish Culture--Hatchery and Nursery Operations</u>

The FLUPSY (Figure 1), an integral part of many companies’ seed production systems, is a highly efficient method for growing seed out to a larger size. It translates the technique of the tank-enclosed upweller to a much larger scale by moving the upwellers into a floating structure that continuously draws natural seawater through the system. Juvenile clams and oysters, one to two millimeters in length, are transported to the FLUPSY from shellfish primary hatcheries and nursery settings. The seed is placed in bins with screened bottoms that are lowered into openings in a floating frame and suspended in the seawater. Several bins are placed in a row on either side of a central enclosed channel that ends at a paddlewheel or pump. The wheel or pump draws water out of the central channel, creating an inflow of seawater through the bottom of the seed bins, continuously feeding the juvenile shellfish with natural plankton from surrounding waters. The outflow from the bins is through a dropped section on one side of the bin facing the central channel. Typically, the FLUPSY platform is equipped with overhead hoists so the bins can be cleaned and moved. Once seed have reached a suitable size, they are removed from the FLUPSY and transplanted to a grow-out site.

Geoducks are not normally raised in a FLUPSY, but are grown to seed size in small screened containers that are filled with native-bed sand. The containers are placed on the bed, or suspended from rafts, to allow the seed to continue growing in a protected environment during a summer period where seawater can flow through naturally. These containers vary in size and shape depending on site conditions. Not all geoduck farms contain such nursery systems. Maintenance of and use of existing FLUPSYs are activities eligible for permitting in this proposed action. New FLUPSYs are not part of the proposed action.

Figure 1. A FLUPSY (Fisher Island Oysters 2007)

Activities Common to All Shellfish Aquaculture—Supporting Activities

Vessel Operations

Shellfish culture generally employs small vessels to access the beds used in intertidal culture or the rafts used in suspended oyster and mussel culture. Almost all of these vessels are a size considered “small craft,” or less than about 66 feet overall length. Typical vessels are small, open work boats powered by two- or four-stroke outboard motors. Vessels ferry crews and material to and from the culture beds and rafts. Larger work boats and occasionally barges are used for activities like spreading oyster shell or graveling, transporting rafts or mechanical equipment such as harvesters, and transporting harvested shellfish. The work boats serving shellfish beds are normally grounded on mudflats or vacant culture beds to load and offload personnel and equipment.

Work on Beach

At low tides crews must walk over the culture beds and immediately adjacent areas to perform almost all activities that occur on the beds. These include bed preparation, inspection and maintenance during grow-out, and harvest. At some sites, the beach is accessed directly from the land, and in these cases the crews also traverse (by foot or All-Terrain Vehicle) the beach to work sites.

Activities Specific to Mussel Raft and Longline Culture

Two species of mussels are farmed on the United States west coast: *Mytilus trossulus*, commonly known as the Blue Mussel and *Mytilus galloprovincialis*, commonly known as the Mediterranean or Gallo Mussel. The mussel culture activities described below may be performed at any time of the day and at any time of the year. They are not dependent on season or tides.

Mussels are grown suspended from rafts or surface longlines anchored in subtidal waters. Raft platforms are constructed of lumber, aluminum, galvanized steel, and plywood. Typically, two to three rafts are moored together to form a unit.

Flotation is made from reclaimed polyurethane food-grade barrels, or coated or vinyl-wrapped polystyrene foam. Raft cultures may be enclosed by nets to exclude predators. Surface longlines are made of heavy polypropylene or nylon rope suspended by floats or buoys attached at intervals along the lines and anchored in place at each end.

Seeding

Naturally spawned mussel seed sets on lines or metal screen frames in net cages that are suspended in the water during the late spring spawning season. Hatchery seed, when used, is set on lines or screen frames at the nursery, and then transported to the mussel farm for planting. Once the seed reaches six to twelve millimeters long, which can take several months in winter or several weeks in summer, it is scraped from the frames or stripped from the lines and sluiced into polyethylene net sausage-like tubes, called “socks,” each with a strand of line threaded down the length of the sock for strength. Concrete weights with stainless steel wire hooks are hung on the bottom end of each mussel sock for tension. The socks are then lashed to the raft, longlines or stakes, and suspended under the water.

Grow-out

When the mussels reach about one inch in length, the weights are often removed from the socks and saved for reuse. If the predator exclusion nets become fouled, blocking the flow of microalgae to the mussels, they may be cleaned in place by hand or by mechanical methods. The nets may also be removed from the water, shell or other debris removed and returned to the raft waters.

Harvesting

When the mussels reach market size, socks or lines of mussels are freed from the longline, stake or raft structure for cleaning and grading. The mussels are stripped from the socks and bulk-bagged and tagged for transport to shore and the processing plant. Weights are reclaimed for re-use, and used socking and lines are recycled or disposed of at an appropriate waste facility.

Activities Specific to Oyster Culture

Several species of oysters are cultured on the West Coast including the Pacific oyster (*Crassostrea gigas*), Olympia oyster (*Ostrea lurida*), Kumamoto oyster (*Crassostrea sikamea*), Eastern oyster (also known as American oyster) (*Crassostrea virginica*), and the European flat oyster (*Ostrea edulis*).

Productive oyster ground is dependent on a number of variables including salinity, temperature, substrate quality, water quality, and types of predators present. Oyster ground is often classified or referred to by its use, such as seed ground, grow-out ground or fattening beds.

Many oyster culture activities and also clam culture activities are performed during extra low tides that expose the culture bed, so that operations can be performed by workers on foot. Other activities, such as oyster mechanical harvest, occur at high tides. Lower tides occur for a period of several days each lunar month (29 days). These tides occur near midnight in December, near noon in June, and at corresponding intermediate times in the other months. During these lower tides, the workers may typically be on the bed for three to six hours, depending on tidal elevations. In this document, work performed during these monthly low tides is described as occurring “during low tide.” Except as noted below, such work can occur at any time of the year.

Oyster Longline Culture

Seed is prepared as described above under “oyster cultch preparation and setting.” Stakes of metal or polyvinyl chloride (PVC) plastic pipe are stuck in the ground in rows by hand during low tides. Long polypropylene or nylon lines with a piece of seeded oyster cultch attached approximately every foot are suspended above the ground by the stakes.

The oysters grow in clusters supported by the longlines, which keep them from sinking into soft substrate and protect them from certain pests and predators. Oysters are allowed to grow over two to three years. Longlines are checked periodically during low tides to ensure that they remain secured to the PVC pipe and that the PVC pipe remains in place.

Longlined oysters may be harvested by hand or by machine. Hand harvest entails cutting oyster clusters off lines by hand at low tide and placing the clusters in harvest tubs equipped with buoys for retrieval by a vessel equipped with a boom crane or hydraulic hoist at a higher tide. The oysters are then barged to shore. Some smaller operations carry the tubs off the beach by hand.

With mechanical harvesting, buoys are attached at intervals along the lines at low tide. On a high tide, the buoys are hooked to a special reel mounted on a vessel that pulls the lines off the stakes and reels them onto the boat. The oyster clusters are cut from the lines, then barged to shore and transported to processing plants or market.

In some areas, silt may build up as a result of wave and wind action on the substrate and need to be leveled at the end of a growing cycle. The substrate may be leveled either manually or by mechanical means to address accumulations of sediment that have occurred since the previous planting cycle. Most residual oysters ("drop offs") dislodged from the lines during the previous growing cycle are removed from the ground prior to replanting. These actions are performed during low tides. If the PVC or metal stakes were removed after the previous harvest they are replaced by hand. When bed preparation is complete, long polypropylene or nylon lines with a piece of seeded oyster cultch attached approximately every foot are suspended above the ground between the stakes.

After a harvest, some practitioners pull all the pipe stakes from the bed, harvest residual drop-off oysters using bottom culture methods, and drag the ground to level it and remove debris before putting the stakes back for the next cycle. Other practitioners leave the stakes in place from cycle to cycle, depending on the conditions in their growing area.

Oyster Rack-and-Bag Culture

Beds are prepared during low tides by removing debris such as small driftwood, and natural pests such as marine snails. In some cases, the substrate is hardened with crushed oyster shells and/or gravel. The ground may be marked with stakes for working purposes. During low tides, some operations install lines and PVC pipe or metal stakes on the bed to secure the bags. Wood or metal racks may be used to support the bags off the ground. Racks with legs may be placed directly on the bottom, or supports may be driven into the bottom. Bags are typically attached to racks with reusable plastic or wire ties.

Single-set seed is placed in reusable plastic net bags closed with plastic ties or galvanized metal rings. Oysters are allowed to grow in the bags on the metal or wooden racks. The operation is checked periodically during low tides to ensure that the bags remain secured to the racks. During harvest, bags are released from supports, if any, loaded into a boat or (during low tides) a wheelbarrow for transport to shore, and then transported to processing plants or market.

An emerging technique for growing oysters is the flip-bag technique to achieve symmetrically-formed shell and a higher value product. This technique uses a series of lines oriented parallel with the beach. The tops of the oyster bags are attached to the suspended lines, with floats attached to the bottom of the bags. When the tide rises, the bag also rises, tumbling the oysters. Floatation is typically done with a small, crab-pot type bullet float.

Oyster Stake Culture

Beds are prepared during low tides in the intertidal zone by removing debris such as small driftwood, and pests such as marine snails and starfish. In some areas, the substrate may occasionally be hardened with crushed oyster shells, but usually soft mud or sand bottoms require little or no enhancement. During low tide, stakes made of hard-surfaced non-toxic materials, such as PVC pipe, are driven into the ground approximately two feet apart to allow good water circulation and easy access at harvest. Stakes are typically limited to two feet in height to minimize obstruction to boaters.

Stakes can be seeded in hatchery setting tanks before being planted in the beds or bare stakes might be planted in areas where there is a reliable natural seed set. Bare stakes might be planted during the prior winter to allow barnacles and other organisms to attach to the stakes, increasing the surface area available for setting oyster spat. An alternative method of seeding is to attach from one to several pieces of seeded cultch to each stake.

Stakes are left in place through a two to four year growing cycle. Each piece of seeded cultch attached to stakes grows into a cluster of market-size oysters suspended above the mud and most pests. In areas where natural spawning occurs, multiple year classes of oysters grow on the stakes, with smaller, younger oysters growing on top of older oysters.

Oysters are selectively hand harvested during low tide by prying clusters of market-sized oysters from the stakes, or removing the clusters and the stakes, and placing them in baskets or buckets. The containers are tagged and either hand carried off the beach or loaded into a boat at a higher tide for transport to shore.

The clusters are separated into singles, sorted, culled and rinsed if destined for the single oyster market, or left as clusters if intended for the shucked oyster market, and transported to processing plants. Undersized single oysters from the clusters are transplanted to a special bed to continue growing until harvest, since they cannot reattach to the stakes, and are harvested using bottom culture methods when they reach market size.

Oysters that fall from or are knocked off the stakes are harvested periodically using bottom culture methods. Market-sized drop-offs that have not settled into the mud are harvested along with those pried from the stakes, and those that have settled into the mud are periodically picked and transplanted to firmer ground to improve their condition for harvest at a later time. Bed maintenance takes place during harvest when stakes are repositioned, straightened, or replaced, and the oysters are thinned to relieve overcrowding.

Oyster Bottom Culture

Prior to planting a new crop of oysters, oyster beds may be cleaned of debris such as small driftwood and pests such as marine snails by hand or by dragging a chain or net bag during a low tide. The bag removes any oysters remaining on the bed after a harvest as well as pests, debris and mud build-up. If the substrate is too soft or muddy and not naturally suitable for planting oysters, it may be hardened, typically by spraying crushed shell, often mixed with washed gravel, from the deck of a barge using a pump and hose. Several runs are made over marked ground to ensure the material is spread evenly. The ground may be marked with stakes.

Seed oysters attached to cultch shell may be sprayed from the deck of barges or cast by hand onto marked beds at an even rate to achieve optimum densities. In some cases, farms rely solely on natural set of oyster seed on existing beds. If bottom culture is done with bags, single-set seed is placed in reusable plastic net bags closed with plastic ties or galvanized metal rings. The bags are placed in the intertidal zone directly on the ground during a low tide.

Oysters may be transplanted from one site to another at some point during grow-out. For example, oysters may be moved from an initial growing area to “fattening” grounds where higher levels of nutrients are found, allowing the oysters to grow more rapidly for market. Practitioners must abide by all transfer permits, regulations, and requirements when transplanting oysters from one area to another to assure pests (such as marine snails) are not accidentally introduced into growing areas.

In areas where the substrate is soft, the oysters may sink into the mud. Unlike clams that live in the substrate, oysters must stay on the surface to survive. When shells become buried, the oysters must be dug with a harrow to periodically pull them up out of the mud. The harrow is a skidder with rake-like tines, towed along the bottom by a boat. The harrow penetrates the substrate by a few inches and moves the oysters back to the surface.

During hand harvest, workers hand-pick oysters into bushel-sized containers at low tide. These may be emptied into large (10 to 30 bushel) containers equipped with ropes and buoys so they can be lifted with a boom crane onto the deck of a barge at high tide. Smaller containers are sometimes placed or dumped on decks of scows for retrieval at high tide or are carried off the beach at low tide.

Mechanical or dredge harvest occurs by use of a harvest bag that is lowered from a barge or boat by boom crane or hydraulic winch at high tide and pulled along the bottom to scoop up or 'dredge' the oysters. The dredge bags have a leading edge (blade) consisting of a steel frame with teeth and a steel mesh collection bag attached to the frame. As the dredge bags are towed across the substrate, the oysters are loosened and guided into the bags. The bag is then hoisted onto the boat deck, emptied, and then redeployed. Two dredge bags may be towed simultaneously off each side of the boat. The boats can haul large volumes that can weigh over twenty tons. Dredge equipment can typically be adjusted so that the correct depth is dredged as tide levels change. A given area may be dredged twice in succession to ensure recovery of the maximum number of oysters (Corps 2014a). Harrowing may occur between the two successive dredge events in order to increase recovery of oysters. Alternatively, the area may be hand harvested at low tide after initial dredging to obtain any remaining oysters.

Single oysters cultured loose on the bottom are often hand harvested into mesh bags or baskets to minimize handling and damage to shells. When single oyster culture on the bottom is done in hard plastic mesh bags, the bags are simply loaded into a boat or (during low tide) a wheelbarrow for transport to shore, then transported to processing plants or market.

Oyster Suspended Culture

Oysters are farmed in the subtidal zone using lantern nets, bags, trays, cages, or vertical ropes or wires suspended from surface longlines, or to a lesser extent, rafts. Surface longlines are heavy lines suspended by floats or buoys attached at intervals along the lines, anchored in place at each end. Lantern nets, adopted from Japanese shellfish culture, are stacks of round mesh-covered wire trays enclosed in tough plastic netting. The nets, bags, trays, cages, or vertical ropes or wires are hung from the surface longlines under the floats or buoys, or from rafts.

Single oysters are regularly sorted and graded throughout the growth cycle. Every three or four months the trays are pulled up, the stacks taken apart, oysters put through a hand or mechanical grading process, the trays restocked, stacks rebuilt and de-fouled and returned to the water. Oysters grown on vertical lines are in clusters and receive little attention between seeding and harvesting.

A vessel equipped with davits and winches works along the lines, and the trays, nets or bags are detached from the line one by one and lifted into the boat. The gear is washed as it is pulled aboard. Oysters are emptied from the gear and placed into tubs, then cleaned and sorted on board the harvest vessel, on an on-site work raft, or at an offsite processing facility.

Oysters grown using suspended culture may be transplanted to an intertidal bed for two to four weeks to “harden.” Hardening extends the shelf-life of suspended culture oysters by conditioning them to close their shells tightly when out of the water and retaining body fluids. Abrasion on the beach substrate literally hardens the shell making it less prone to chipping, breakage, and mortality during transport. If hardened, the oysters are re-harvested using bottom culture harvest methods. Alternatively oysters grown by suspended culture may be hung from docks when tidal cycles expose and harden them. This improves their shelf life as they are trained to close up tightly to survive between tidal cycles.

<u>Littleneck, Manila, and Butter Clam</u>

Clams are grown according to two methods considered during this consultation, ground culture and bag culture.

Ground Culture

Prior to planting clam seed on the tidelands, beds are prepared in a number of ways depending on the location. Bed preparation activities are similar to those described above for oyster bottom culture. The substrate may be prepared by removing aquatic vegetation, mussels, and other undesired species. Any shellfish present on site may be harvested to reduce competition. These activities could be conducted by hand or by mechanical means (e.g., water jet, harrowing).

Graveling (also called frosting) is a common activity employed for clam culture. This consists of adding gravel and/or shell when the tide is high enough to float a barge. Graveling by vessel often occurs during about a two hour window at slack tide. Applying at the slack tide allows for a more accurate placement of the graveling material. In a 1-2 hour period, about 1 acre can be graveled to a depth of up to 1 inch
(Corps 2014a). Several thin layers of material may be placed over a period of days (Figure 3-13). To place a single 0.5-inch layer requires about 70 cubic yards of washed gravel or shell per acre. An individual site would not be graveled more frequently than once per year. Many sites are graveled annually whereas other may be graveled at a lesser frequency.

Clam seed is typically acquired from hatcheries and planted in the spring and early summer. Intertidal trays or bags may be used as nursery systems until seed is of sufficient size to plant. The trays are typically two-foot by two-foot with ¼ inch diameter openings that permit water to flow through. They are employed in stacks of six or seven, and placed in the lower intertidal areas secured with rebar or anchored with sand bags. Clam bags as described in the section on bag culture can also be used to hold clams in a nursery system. Natural spawning and setting of clams also occurs. Clam seed sizes and methods of seeding vary, depending on site-specific factors such as predation and weather conditions. Planting methods include hand-spreading seed at low tide upon bare, exposed substrate; hand-spreading seed on an incoming tide when the water is approximately four inches deep; hand-spreading seed on an outgoing tide when the water is approximately two to three feet deep; or spreading seed at high tide from a boat.

Immediately after seeding, cover nets (Figure 2) may be placed over the seeded areas to protect clams from predators such as crabs and ducks. Cover nets are typically made from plastic such as polypropylene. The net edges are typically buried in a trench or weighed with a lead line and secured with rebar stakes. Predator cover netting typically remains on site until harvest.

Figure 2. Clam Cover Nets (COE 2015)

Maintenance and Grow-out
After each growing season, surveys may be conducted during low tide to assess seed survival and distribution, and to estimate potential yield. Based on survey results, additional seeding activity may occur. Netting used to protect clams from predation can become fouled with barnacles, mussels, aquatic vegetation (e.g., algae, eelgrass) or other organisms. The nets usually remain on site throughout the growing period. Fouling organisms may be removed by hand or by mechanical means while the nets are in place. Depending on local conditions, net cleaning may occur as often as monthly or not at all.
Biofouling occurs most frequently during the late spring and summer months.

Harvest
Before harvest begins, bed boundaries may be staked and any predator netting folded back during a low tide. Hand harvesters dig clams during low tides using a clam rake Shovels or other hand operated tools may also be used. Market-size clams (typically about 3 years of age) are selectively harvested, placed in buckets, bagged, tagged, and removed. Undersized clams are returned to beds for future harvests. Since a given clam bed may contain multiple year classes of clams, it may be harvested on a regular schedule (such as annually) to harvest individual year classes of clams. Clams harvested for sale are generally left in net bags in wet storage. Clams are typically maintained in wet storage either directly in marine waters or in upland tanks filled with seawater for at least 24 hours in order to purges and. Upland tanks are connected to the marine waters through intake and outfall structures (pipes) that are compliant with the NPDES.

Technology has been developed to harvest clams mechanically, although this is utilized by only a handful of practitioners at present. The equipment is driven on the substrate when the tide is out and excavates the substrate to a depth of 4-6 inches in order to extract clams. Clams are harvested after about 3 years. Approximately 0.8 acres per day of clams can be mechanically harvested. This technology may become more widely practiced due to labor and industry workforce concerns. Multiple crops may be in the ground at any time, depending upon the level of productivity of the ground. Beds may be dug annually, or as infrequently as once every four years. The use of a 'hydraulic escalator harvester' equipment is not included among the covered activities.

Bag Culture

Prior to setting bags on the tidelands, debris is removed from the area to be planted and shallow (typically two to four inches) trenches may be dug during low tide with rakes or hoes to provide a more secure foundation for setting down the clam bags.

Clam seed (typically five to eight millimeters) is placed in reusable plastic net bags closed with plastic ties or galvanized metal rings. Substrate, consisting of gravel and shell fragments, may be added to the bags. Bags may be placed in shallow trenches during low tide and allowed to “silt-in,” i.e., burrow into the substrate. In high current or wind areas, bags may be held in place with four- to-six inch metal stakes, placed by hand. Bags are monitored during low tides throughout the grow-out cycle to make sure they are properly secured, and turned occasionally to optimize growth.

When the clams reach market size, the bags are removed from the growing area. Harvesting occurs when there is one to two feet of water, so that sand and mud that accumulated in the bags can be sieved from the bags in place. Bags are brought to the processing site, and any added substrate is separated for later reuse.

Geoduck Culture

Native geoduck (*Panopea abrupta*), the largest known burrowing clam, is a relatively new species for culture, and culture techniques are rapidly evolving and changing. Currently, Washington is the principal U.S. state farming geoducks, though there are pilot operations in Alaska and extensive farms in British Columbia. Farms are located in the intertidal zone, although subtidal farming of geoducks is currently in an initial experimental phase.

Prior to planting geoduck, bed preparation may include raking debris aquatic vegetation and cleaning clearing the beds of algae, mussel mats, and other growth, predator species. A pre-harvest of existing shellfish may also occur. This work is done during low tide.

The most common method of culture currently in use consists of placing 10- to 12-inch long sections of four to six inch-diameter PVC pipe by hand into the substrate during low tide, usually leaving two to three inches of pipe exposed. Sizes vary among growers. Tubes are typically installed into the substrate at a density of about 1 tube per square ft or about 42,000 tubes per acre. Two to four seed clams are placed in each tube where they burrow into the substrate. The top of each pipe is may be covered with a plastic mesh net and secured with a rubber band to exclude predators. Additional netting may be placed over the tube field in addition to or in lieu of individual nets to prevent the tubes from being dislodged due to storm or wind and wave action. Some growers use flexible net tubes (Vexar®) instead of the PVC pipe, which eliminates the need for the additional cover netting. Intertidal geoduck culture typically ranges between the +5.0 and the -4.5 feet tidal elevation (MLLW). Geoduck seed can also be directly set into the substrate without the use of any structure.

Another method being used to exclude predators is net tunnels. The tunnels are made from 4-foot wide rolls of polyethylene net placed over a rebar frame to hold the net a couple of inches above the substrate with the net edges buried by the substrate. They are currently being used in the intertidal area. The mesh opening of the net is either 1/4-inch or 3/8-inch. A 24-inch wide net without a rebar frame may also be used.

Tubes and netting are removed after one or two growing seasons 18 months to 2 years, once the young clams have buried themselves to a depth adequate to evade predators, normally about 14 inches. The tubes are saved to reuse at another planting.. After tube removal, large area nets may be redeployed over the bed for several months. The tubes and nets are often taken to upland locations and allowed to dry in order to easily remove fouling organisms. They are then typically reused. As the clams grow, they may gradually dislodge the tubes from the substrate before they can be
removed. The dislodged tubes could potentially be swept away from the site by the tides.

Cultivated geoducks are typically harvested 4 to 7 years after planting or when they reach about 2 pounds A site seeded at 160,000 per acre might be expected to produce 32,000 to 40,000 marketable geoduck per acre. The geoducks are harvested in the intertidal zone at low tide or by divers at high tide in the intertidal or subtidal zone. In either case, the geoducks are typically harvested using hand-operated water jet probes. For water jet harvest, the probe is a pipe about 18 to 24 inches long with a nozzle on the end that releases surface-supplied seawater from a 1-inch internal diameter hose at a pressure of about 40 pounds per square inch (about the same pressure as that from a standard garden hose) and a flow of up to 20 gallons per minute.

This harvest method allows the hand extraction of geoducks, which burrow as deep as 3 feet. The harvester inserts the probe in the substrate next to an exposed geoduck siphon or the hole left when the siphon is retracted. By discharging pressurized water around the geoduck, the sediment is loosened and the clam is removed by hand. For the dive harvester, this entire process takes 5 to 10 seconds. Each diver carries a mesh bag to collect the harvested geoducks. Divers periodically surface to unload their bags. One diver can harvest 500 to 1,000 geoducks per day. Multiple divers may work in an area at one time. Dive harvesters work no more than 3 to 4 hours per day.

Geoduck harvesting occurs year-round and is not limited by tidal height. However, dive harvesting tends to be the dominant method during winter months (November through February) due to the prevalence of high daytime tides, the absence of suitable low tides for daytime beach harvest, and generally favorable market conditions during that period. Both low-tide and dive harvests may occur on the same sites. It is estimated that the dive harvest is used about 75% of the time compared to the non-dive harvest method (Cheney 2007 referenced in Anchor 2010). Harvest occurs until all harvestable-sized geoduck are removed from the harvest area. Harvesters make several sweeps of a tract to ensure all harvestable-sized geoduck are removed. Because of differences in geoduck growth rates with a mix of harvest-sized and under-sized clams, only a portion of a project area may be harvested, with the remainder set aside for later dive or beach harvest. Additionally, a dive harvest is typically supplemented with beach harvest when clam densities are reduced in the project area. Harvest may also be constrained by tide and current conditions with slow or slack water conditions reducing or restricting the ability to effectively harvest with divers.

Dive harvest is the typical method used for harvesting subtidal geoducks. Dive harvesters work within an approximate 100-foot range from the harvest vessel, or to the maximum lengths of their air and water lines. Intakes for supplying water to the onboard pumps are positioned several feet below the water surface. Intakes will be screened per Conservation Measure.

As stipulated in CM 12, pump intake screens are sized below NMFS' criteria for juvenile fish, meaning that they provide assurance that juvenile fish will not be entrained in water uptake.

Wild Subtidal Geoduck Harvest

In 2008, a low-effect Habitat Conservation Plan (HCP) was signed by NMFS and USFWS for the geoduck harvest program conducted by Washington State Department of Natural Resources (WDNR) on WDNR lands. This geoduck harvest is for naturally occurring (not cultivated) geoduck. We note that 'take' of listed fishes was determined by NMFS to occur as a result of geoduck harvest. As noted above, activities covered by the HCP are not included in the proposed action for this programmatic opinion.

Under this proposed action, the Corps could authorize subtidal geoduck harvest activities conducted outside the framework of the HCP. Acreage for these activities is included in the proposed action and discussed in the effects section of the PBA. The vast majority of this harvest is expected to occur on state owned subtidal lands within identified geoduck management tracts. However it could also occur on non-state owned subtidal lands. WDNR indicates there is a total of 1,085 acres of non-state-owned subtidal land in Washington State (WDNR 2013a). It is uncertain to what degree these lands contain geoduck at high enough densities for harvest. For the purpose of the PBA, it is assumed geoduck harvest would occur on these acres in the Hood Canal, North and South Puget Sound regions of the PBA where native geoduck occur. The non-state-owned land acres for each region are estimates made by the Corps based on the WDNR aquatic parcel database (WDNR 2014a).

The majority of harvest of subtidal geoduck uses the same dive harvest techniques discussed above. Most of the subtidal geoduck harvest would occur at depths between -18 ft to -70 ft. An unknown acreage may be in shallower subtidal areas on the non-state owned lands. The only activity that would occur on this acreage is geoduck dive harvest as described in the PBA and in the HCP (WDNR 2008). Harvest could occur at multiple locations simultaneously. For a given location, harvest could occur daily over a period of months at a time. The same location could also be harvested intermittently for several years in a row depending on the status of the remaining geoduck population. The conservation measures would be applied to subtidal geoduck harvest just as they would be applied to other activities covered by the PBA.

Recreation

The Corps proposes to issue permits for recreational shellfish activities. These activities could include various seeding, maintenance, and harvest activities for all species covered in the proposed action (mussel, oyster, clam, and geoduck). The objective is to enhance local populations sufficient to support regular recreational harvest for personal use. In some cases the activities may resemble an aquaculture operation. Harvest could potentially occur on seeded or wild shellfish populations. Seeding and growing for purposes of recreational shellfish would be limited to intertidal lands between +7 ft and -4.5 ft MLLW. Expected acreages are based on information provided by WDFW from historical COE permitting and the judgement of COE professional staff regarding future permitting actions. Acreages for recreation are found in Table 2.

Restoration Activities

Restoration activities included within the scope of the proposed action include activities to seed and re-populate tidal or subtidal waters for purposes of habitat enhancement, ecological restoration, water quality improvement, or to increase the population size of native shellfish species. These activities could include seeding, planting, maintenance, and grow-out activities. Harvesting would generally not be considered a restoration activity except for purposes of scientific monitoring. Restoration activities are expected to occur only once as opposed to occurring on a regular (e.g., annually) basis like commercial aquaculture and recreation activities. The acreage estimates (Table 2) are based on the historical rate of Corps permitting for these types of activities.

Interdependent and Interrelated Actions

The joint consultation regulations (50 CFR 402 et. seq.) require consideration of the effects of interrelated and interdependent actions during consultation. Interrelated actions are those that are part of a larger action and depend on the larger action for their justification. Interdependent actions are those that have no independent utility apart from the action under consideration (50 CFR 402.02).

Interrelated and interdependent activities identified as part of the proposed action include vessel and vehicle traffic and upland storage sites. Another interrelated action is the application of imazamox (trade name Clearcast™) to non-native Japanese eelgrass (Zostera japonica) (japonica) on clam culture beds only (not authorized for geoduck or oysters) in Willapa Bay.

Vessel traffic contributes noise and vehicle traffic causes sediment compaction in where all-terrain vehicles or other are used to access the beach. The additional vessel traffic contributed by shellfish activities to the total traffic in the various geographic regions is negligible in most areas. In more remote locations, such as Willapa Bay, the shellfish activity traffic may constitute a high percentage of the total traffic. Conservation Measures would help to minimize any effects from vehicle and vessel traffic.

Upland storage sites would be used to store shellfish equipment such as nets, bags, racks, and tubes. Shell could also be stored at these sites. Effects to the environment from the use of these sites would be minor in part due to the Conservation Measures (p. 11) which would minimize effects to vegetation and require certain best management practices.

1.4 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 is all areas directly or indirectly affected by the Federal action and not merely the immediate area involved in the action (50 CFR 402.02). The action area for this consultation consists of five sub-regions of the waters of Washington State in which shellfish activities affect the local environment. These areas include locations in South Puget Sound, North Puget Sound, Hood Canal, Willapa Bay, and Grays Harbor. The larger geographic area containing the action area is depicted in Figures 2 and 3 below, but the action area itself is but a fraction of the geography depicted in those figures.

The action area includes all of the tidelands and nearshore marine waters associated with continuing and "new" shellfish activities (including projected future activities), encompassing an area of approximately 38,716 acres (Corps 2015), in addition, the action area includes 48,133 potentially harvestable acres where subtidal geoduck harvest could occur.

The action area specifically includes the total area within the footprint of sites currently under cultivation, and also includes areas that have been previously managed but are currently categorized as fallow. The action area also includes those areas where new shellfish activities could occur. While it is impossible to predict where they will occur with precision, estimates of acreage in each water body were provided by the COE based on feedback from PCSGA. The totals of predicted new acreages are included in the action area description. In addition, the action area includes additional area surrounding each individual managed site to account for the drift of turbid water beyond the footprint of each managed site. We note our estimate of 'take' during subtidal dive harvest in the HCP stated, "harm from increased turbidity will occur within a zone of 450 feet down current of the specific harvest sites, and will persist for a period of hours at each site." We also note that tidal currents flowing across subtidal harvest sites have potential to move sands and silts onto nearby sites at unknown concentrations. Other activities that can increase turbidity include bottom and long-line mechanical harvest, and regular maintenance activities. In summary, activities that generate sediment may cause turbid water to drift outside of the footprint of the active plot, expanding the affected area by as much as a few hundred linear feet, depending on grain size, fetch, and current velocities. Thus for purposes of this analysis, we include a 450 foot buffer around all sites to account for potential turbidity. The amount of acreage within existing farms is summarized in Table 8.

Based on information provided by applicants on the type of equipment that could be used, the COE has estimated noise buffers extending about 4,000 feet upland from MHHW. Due to the interrelated activity of vessel traffic, which could occur throughout the action area from the shoreline to navigation channels which are roughly in the center of each of the subregions, and the potential geographic locations for new activities including subtidal geoduck harvest, the entire inland marine area identified in Figure 3 is included within the action area.

All activities affecting listed species considered in this consultation will occur on: (1) area that is currently being used for shellfish aquaculture; (2) land that is currently termed fallow; and (3) area that is cultivated and harvested recreationally, and (4) shellfish restoration areas, (5)areas of wild geoduck harvest (6) new locations within the range of ESA-listed species, designated CH, and/or EFH designated under the MSA.

The following portions of the action area are designated as critical habitat for or occupied by ESA-listed species as follows:

<u>LAA Species</u>

- Canary rockfish- North Puget Sound,
- PS Chinook salmon- South Puget Sound, North Puget Sound, Hood Canal
- PS Chinook salmon critical habitat- South Puget Sound, North Puget Sound, and Hood Canal
- HCSR Chum salmon- Hood Canal
- HCSR Chum salmon critical habitat- Hood Canal
- Southern DPS green sturgeon
- Southern DPS green sturgeon critical habitat-Grays Harbor and Willapa Bay

<u>NLAA Species</u>

- PS steelhead (NLAA, see section 2.11)- South Puget Sound, North Puget Sound, Hood Canal
  Canary rockfish critical habitat (NLAA, see section 2.11)- South Puget Sound, North Puget Sound, Hood Canal.
- Southern Resident Killer Whale (NLAA, see section 2.11) South Puget Sound, North Puget Sound, Hood Canal
- LCR Chinook Salmon- Willapa Bay
- Columbia River Chum salmon-Willapa Bay

Each sub-action area involved in this consultation is also designated as EFH for Pacific Coast groundfish (PFMC 2006), coastal pelagic species (PFMC 1998), and/or Pacific Coast salmon (PFMC 1999), or are in areas where environmental effects of the proposed project may adversely affect designated EFH for those species.

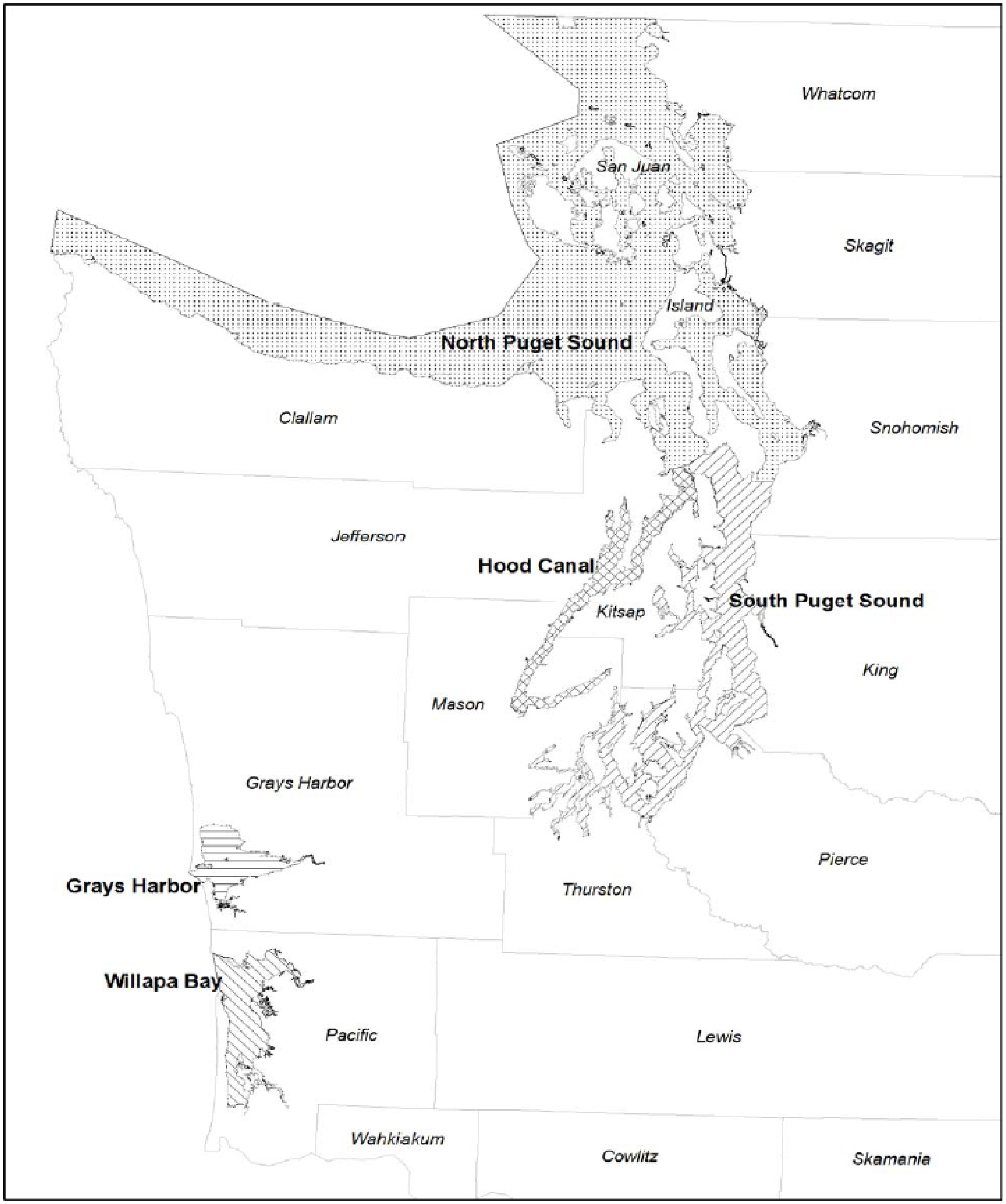

Figure 3. Washington State Shellfish Action Area (COE 2015)

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, Federal agencies must ensure that their actions are not likely to jeopardize the continued existence of endangered or threatened species, or adversely modify or destroy their designated critical habitat. Per the requirements of the ESA, Federal action agencies consult with NMFS and section 7(b)(3) requires that, at the conclusion of consultation, NMFS provides an opinion stating how the agency's actions would affect listed species and their critical habitat. If incidental take is expected, section 7(b)(4) requires NMFS to provide an incidental take statement (ITS) that specifies the impact of any incidental taking and includes non-discretionary reasonable and prudent measures and terms and conditions to minimize such impacts.

The proposed action is not likely to adversely affect species in Table 1 or their critical habitat. The analysis is found in the "Not Likely to Adversely Affect" Determinations (Section 2.11).

2.1 Analytical Approach

This PBO includes both a jeopardy analysis and an adverse modification analysis.
The jeopardy analysis relies upon the regulatory definition of "to jeopardize the continued existence of a listed species," which is "to engage in an action that 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 PBO relies on the definition of "destruction or adverse modification", which "means a direct or indirect alteration that appreciably diminishes the value of critical habitat for the conservation of a listed species. Such alterations may include, but are not limited to, those that alter the physical or biological features essential to the conservation of a species or that preclude or significantly delay development of such features" (81 FR 7214).

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

- Identify the rangewide status of the species and critical habitat likely to be adversely affected by the proposed action.
- Describe the environmental baseline in the action area.
- Analyze the effects of the proposed action on both species and their habitat using an "exposure-response-risk" approach.
- Describe any cumulative effects in the action area.
- Integrate and synthesize the above factors to assess the risk that the proposed action poses to species and critical habitat.
- Reach jeopardy and adverse modification conclusions.
- If necessary, define a reasonable and prudent alternative to the proposed action.

2.2 Rangewide Status of the Species and Critical Habitat

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

One factor affecting the rangewide status of canary rockfish and PS Chinook salmon and salmonid critical habitat and aquatic habitat at large is climate change. As described in ISAB (2007), effects of climate change that have influenced the habitat and species affected by the proposed action, and that are expected to continue to do so in the future include: increased ocean temperature, increased stratification of the water column, and changes in intensity and timing of coastal upwelling. These continuing changes have potential at some time to alter primary and secondary productivity, the structure of marine communities, and in turn, the growth, productivity, survival, and migrations of salmonids. A mismatch between earlier salmon smolt migrations (due to earlier peak spring freshwater flows and decreased incubation period) and altered upwelling may reduce marine survival rates. Decades of ocean observations now show that CO_2 absorbed by the ocean is changing the chemistry of the seawater, in a process called ocean acidification. Increased concentration of CO2 reduces the availability of carbonate for shell-forming invertebrates, including some that are prey items for juvenile salmonids. In addition, increased acidity of marine waters has been linked to altered development of shellfish larvae, thereby triggering different management of water-sources for hatcheries in some places (Feely et al. 2012).

In some large estuaries, effects of climate change that have influenced the habitat and species in the action area, and that are expected to continue to do so in the future include: higher winter freshwater flows and higher sea level elevation may lead to altered sediment routing and wave damage; lower freshwater flows in late spring and summer may lead to upstream extension of the salt wedge, possibly influencing the distribution of salmonid prey and predators; and increased temperature of freshwater inflows may extend the range of warm-adapted non-indigenous species that are normally found only in freshwater. In all of these cases, the specific effects on salmon abundance, productivity, spatial distribution and diversity are poorly understood (ISAB, 2007).

Climate change also has negative implications for designated freshwater critical habitats in the Pacific Northwest (CIG 2004; Scheuerell and Williams 2005; Zabel et al. 2006; ISAB 2007). The distribution and productivity of salmonid populations in the region are likely to be affected (Beechie et al. 2006). Average annual Northwest air temperatures have increased by approximately 1ºC since 1900, or about 50% more than the global average over the same period (ISAB 2007). The latest climate models project a warming of 0.1 ºC to 0.6 ºC per decade over the next century. According to the Independent Scientific Advisory Board (ISAB), these effects pose the following impacts over the next 40 years:

- Warmer air temperatures will result in diminished snowpacks and a shift to more winter/spring rain and runoff, rather than snow that is stored until the spring/summer melt season.

- With a smaller snowpack, these watersheds will see their runoff diminished earlier in the season, resulting in lower stream-flows in the June through September period. River flows in general and peak river flows are likely to increase during the winter due to more precipitation falling as rain rather than snow.

- Water temperatures are expected to rise, especially during the summer months when lower stream-flows co-occur with warmer air temperatures. As climate change progresses and stream temperatures warm, thermal refugia will be essential to persistence of many salmonid populations. Thermal refugia are important for providing salmon and steelhead with patches of suitable habitat while allowing them to undertake migrations through, or to make foraging forays into, areas with greater than optimal temperatures. To avoid waters above summer maximum temperatures, juvenile rearing may be increasingly found only in the confluence of colder tributaries or other areas of cold water refugia (Mantua et al. 2009).

These changes will not be spatially homogeneous across the entire Pacific Northwest. Low-lying areas are likely to be more affected. Climate change may have long-term effects that include, but are not limited to, depletion of cold water habitat, variation in quality and quantity of tributary rearing habitat, alterations to migration patterns, accelerated embryo development, premature emergence of fry, and increased competition among species (ISAB 2007).

Habitat preservation and restoration actions can help mitigate the adverse impacts of climate change on salmonids. Examples include restoring connections to historical floodplains and freshwater and estuarine habitats to provide fish refugia and areas to store excess floodwaters, protecting and restoring riparian vegetation to ameliorate stream temperature increases, and purchasing or applying easements to lands that provide important cold water or refuge habitat (Battin et al. 2007; ISAB 2007). Harvest and hatchery actions can respond to changing conditions associated with climate change by incorporating greater uncertainty in assumptions about environmental conditions and conservative assumptions about salmon survival in setting management and program objectives and in determining rearing and release strategies (Beer and Anderson 2013)

2.2.1 Status of Listed Species

Puget Sound Chinook Salmon

We adopted the recovery plan for Puget Sound Chinook in January 2007. The recovery plan consists of two documents: the Puget Sound salmon recovery plan (Shared Strategy for Puget Sound 2007) and a supplement by NMFS (2006). The recovery plan adopts ESU and population level viability criteria recommended by the Puget Sound Technical Recovery Team (PSTRT) (Ruckelshaus *et al.* 2002). The PSTRT's biological recovery criteria will be met when the following conditions are achieved:

- All watersheds improve from current conditions, resulting in improved status for the species;
- At least two to four Chinook salmon populations in each of the five biogeographical regions of Puget Sound attain a "low" risk status over the long-term;
- At least one or more populations from major diversity groups historically present in each of the five Puget Sound regions attain a "low" risk status;
- Tributaries to Puget Sound not identified as primary freshwater habitat for any of the 22 identified populations are functioning in a manner that is sufficient to support an ESU-wide recovery scenario; and
- Production of Chinook salmon from tributaries to Puget Sound not identified as primary freshwater habitat for any of the 22 identified populations occurs in a manner consistent with ESU recovery.

Spatial Structure and Diversity. This species includes all naturally spawned populations of Chinook salmon from rivers and streams flowing into Puget Sound including the Straits of Juan De Fuca from the Elwha River, eastward, including rivers and streams flowing into Hood Canal, South Sound, North Sound and the Strait of Georgia in Washington, and progeny of 26 artificial propagation programs (USDC 2014). The PS-TRT identified 22 independent populations, grouped into five major geographic regions, based on consideration of historical distribution, geographic isolation, dispersal rates, genetic data, life history information, population dynamics, and environmental and ecological diversity (Table 5).

Indices of spatial distribution and diversity have not been developed at the population level. Based on a Shannon Diversity Index at the ESU level, diversity is declining (due primarily to the increased abundance of returns to the Whidbey Basin region) for both distribution among populations and among regions (Ford 2011). Overall, the new information on abundance, productivity, spatial structure and diversity since the 2005 status review does not indicate a change in the biological risk category (Ford 2011).

Table 5. Extant PS Chinook salmon populations in each geographic region (Ford 2011).

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

Abundance and Productivity.
Total abundance in the ESU over the entire time series shows that individual populations have varied in increasing or decreasing abundance, with some being dominated by hatchery returns. Generally, many populations experienced an increase in abundance from during the years 2000-2008 and then declining in the last 5 years. Abundance across the Puget Sound ESU has generally decreased since the last status review, with only 6 of 22 populations (Cascade, Cedar, Mid-Hood Canal, Nisqually, Suiattle and Upper Sauk) show a positive % change in the 5-year geometric mean natural-origin spawner abundances since the prior status review. However, all 6 of these populations have relatively low natural spawning abundances of < 1000 fish, so these increases represent small changes in total abundance. Given lack of high confidence in survey techniques, particularly with small populations, there remains substantial uncertainty in detecting trends in small populations.

Fifteen-year trends in log wild spawner abundance were computed over two time periods (1990-2005 and 1999-2014) for each Puget Sound Chinook population. Trends were negative in the latter period for 17 of the 22 populations but only 2 of the 22 populations (Elwha and Puyallup) in the earlier period. Thus there is a general decline in wild spawner abundance across all MPGs in the recent fifteen years. North Fork Nooksack (Strait of Georgia MPG), Cascade and Upper Sauk (Whidby Basin MPG), Cedar (Central/South MPG) and Dungeness (Strait of Juan de Fuca MPG), are the only populations with positive trends. The Cedar and the Upper Sauk populations are the only two populations that show increasing trends between the earlier and later 15-year time periods. The average productivity trend across the ESU for the 1990-2005 15-year time period was 0.05. The average trends for the Regions/MPGs are Strait of Georgia (0.05), Whidby Basin (0.04), Central/South Puget Sound (0.06), Hood Canal (0.02), and Strait of Juan de Fuca (0.06). The average trend across the ESU for the later 15-year time period (1999-2014) was -0.02. The average trends for the Regions/MPGs are Strait of Georgia (-0.01), Whidby Basin (-0.02), Central/South Puget Sound (-0.03), Hood Canal (-0.07), and Strait of Juan de Fuca (0.01). While the previous status review in 2010 (Ford *et al*. 2011) concluded there was no obvious trend for the total ESU escapements and trends for individual populations were variable, addition of the data to 2014 now does show widespread negative trends in natural-origin Chinook salmon spawner population abundances.

Limiting Factors. Limiting factors for this species include:

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

Hood Canal Summer-run Chum Salmon

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

- Spatial Structure: 1) Spawning aggregations are distributed across the historical range of the population. 2) Most spawning aggregations are within 20 km of adjacent aggregations. 3) Major spawning aggregations are distributed across the historical range of the population and are not more than approximately 40 km apart. Further, a viable population has spawning, rearing, and migratory habitats that function in a manner that is consistent with population persistence
- Diversity: Depending on the geographic extent and ecological context of the population, a viable population includes one or more persistent spawning aggregations from each of the two to four major ecological diversity groups historically present within the two populations (see also McElhany et al. 2000).
- Abundance and Productivity: Achievement of minimum abundance levels associated with persistence of Hood Canal Summer Chum ESU populations that are based on two assumptions about productivity and environmental response (Table 6).

Table 6. Hood Canal summer-run chum ESU abundance and productivity recovery goals (Sands *et al.* 2007).

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

Spatial Structure and Diversity. This species includes all naturally spawned populations of summer-run chum salmon in Hood Canal and its tributaries; populations in Olympic Peninsula rivers between Hood Canal and Dungeness Bay, Washington; and progeny of four artificial propagation programs (USDC 2014). The Strait of Juan de Fuca population spawns in rivers and streams entering the eastern Strait and Admiralty Inlet. The Hood Canal population includes all spawning aggregations within the Hood Canal area (Hood Canal Coordinating Council 2005; NMFS 2007). The PS-TRT identified two independent populations of Hood Canal summer chum salmon (Sands *et al.* 2009), which include 16 historical stocks or spawning aggregations (including eight that are extant), based on consideration of historical distribution, geographic isolation, dispersal rates, genetic data, life history information, population dynamics, and environmental and ecological diversity (Table 7). The historical populations included at least those 16 spawning aggregation units and likely some additional undocumented and less-persistent aggregations (Sands *et al.* 2007). Programs are underway to reintroduce summer-run chum salmon to several of the watersheds where stocks were lost.

Table 7. HC summer chum salmon populations (geographic regions), population aggregations, and their status (Ford 2011).

Geographic Region (Population)	Stock (Watershed)	Status
Strait of Juan de Fuca	Dungeness River	Unknown <5 adult returns annually recently
	Jimmycomelately Creek	Extant
	Salmon River	Extant
	Snow River	Extant
	Chimacum Creek	Extinct but reintroduced with natural spawning reported starting in 1999
Hood Canal	Big Quilcene River	Extant
	Little Quilcene River	Extant
	Dosewallips River	Extant
	Duckabush River	Extant
	Hamma Hamma River	Extant
	Lilliwaup Creek	Extant
	Big Beef Creek	Extinct but reintroduced with adult returns reported starting in 2001
	Anderson Creek	Extinct
	Dewatto Creek	Extinct, no returns mid 1990's, some natural recolonization apparent but numbers remain low (<70 annually)
	Tahuya River	Extinct but reintroduced with increased adult returns reported starting 2006
	Union River	Extant
	Skokomish River	Extinct; no spawning reported prior to 2001; very low numbers of adult returns (<40 annually) reported in recent years
	Finch Creek	Extinct

Diversity is increasing from the low values seen in the 1990s, due both to the reintroduction of spawning aggregates and the more uniform relative abundance between populations; this is a good sign for viability in terms of spatial structure and diversity. Spawning survey data shows that the spawning distribution within most streams has been extended farther upstream as abundance has increased (WDFW and Point No Point Treaty Tribes 2007). Estimates of population viability from three time periods (brood years 1971-2006, 1985-2006, and 1990-2006) all indicate that Hood Canal and Strait of Juan de Fuca populations of summer-run chum salmon are not currently viable (Ford 2011).

Abundance and Productivity. Overall, the new information considered does not indicate a change in the biological risk category since the last status review in 2005 (Ford 2011). The spawning abundance of this species has clearly increased since the time of listing, although the recent abundance is down from the previous 5 years. However, productivity in the last 5-year period (2002-2006) has been very low, especially compared to the relatively high productivity in the 5-10 previous years (WDFW and Point No Point Treaty Tribes 2007). This is a concern for viability. Since abundance is increasing and productivity is decreasing, improvements in habitat and ecosystem function likely are needed. A recovery plan was finalized for this species on January 19, 2007.

Limiting factors. Limiting factors for this species include (Hood Canal Coordinating Council 2005; NOAA Fisheries 2011):

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

Puget Sound Canary Rockfish

Puget Sound/Georgia Basin Distinct Population Segments of yelloweye rockfish and canary rockfish were listed as threatened and bocaccio as endangered under the ESA on April 27, 2010 (75 FR 22276). We determined that Puget Sound/Georgia Basin DPS of bocaccio is at high risk of extinction throughout all of its range and that the Puget Sound/Georgia Basin DPSs of yelloweye rockfish and canary rockfish are at moderate risk of extinction throughout all of their range (Drake et al., 2010). In this section we limit our discussion to canary rockfish; because we concluded the action is not likely to adversely affect yelloweye or bocaccio, or their critical habitat, discussion of those species is found in Section 2.11. In this section, we describe canary rockfish abundance and productivity, spatial structure/connectivity, and diversity (collectively termed viability criteria).

Puget Sound/Georgia Basin DPSs include all canary rockfish found in waters of the Puget Sound, the Strait of Georgia, and the Strait of Juan de Fuca east of the Victoria Sill, which crosses the Strait west of Dungeness Spit. Puget Sound can be subdivided into five interconnected basins separated by shallow sills: (1) The San Juan/Strait of Juan de Fuca basin, (2) Main Basin, (3) Whidbey Basin, (4) South Puget Sound, and (5) Hood Canal. We use the term "Puget Sound Proper" to refer to all of these basins except the San Juan/Strait of Juan de Fuca basin.

The life-histories of canary rockfish are made up of a larval and pelagic juvenile stage, a juvenile stage, sub-adult stage, and an adult stage. Because canary rockfish are uncommon in the Eastern Straits (including the San Juan Islands), and extremely rare in the four sub-basins of Puget Sound proper, the following ecological information comes from several sources concerning the coasts of California, Oregon, Washington, British Columbia, and Southeast Alaska.

Larval and Pelagic Juvenile Stage. All rockfish fertilize their eggs internally and the young are extruded as larvae at sizes of 0.1 to 0.2 inches. In Puget Sound, canary larvae are released during November to January and become free-swimming in the water column at sizes of about 0.5 to 0.8 inches. (Greene and Godersky, 2012). Larvae can make small local movements to pursue food immediately after birth (Tagal et al., 2002) and are passively distributed with prevailing currents (NMFS 2003). Larvae are often observed under free floating algae, seagrass, and detached kelp (Love et al. 2002) but they also occupy the full water column (Moser and Boehert 1991, Weis

2004). Limited advection of marine waters across the sills that separate the five basins in Puget Sound likely keep most larvae near where they are born rather than dispersing to adjacent basins (Drake et al., 2010). Large differences in timing and numbers of rockfish larvae among the 5 basins was measured by Greene and Godersky (2012), with none in Hood Canal, very low densities in the south basin, and relatively more larval fishes in basins closer to the ocean. None of the samples identified to species (n= 495) included canary, which suggests very low recruitment and few spawners, and emphasizes the natural barriers to movement of larvae and juveniles between the Eastern Straits and four Puget Sound sub-basins (Mofjeld and Larsen 1984)

Though there is a dearth of studies that have sampled for any species of rockfish larvae presence in Puget Sound outside of the spring time, larval rockfish occur throughout the year along the Pacific Coast and very likely occupy part of the action area throughout the year (Waldron 1972, Westerheim and Harling 1975, Moser and Boehert 1991, Love et al., 2002, Weis 2004). Each species produces from several thousand to over a million eggs within one birth event (Love et al., 2002).

All species of larval rockfish are extremely fragile and mortality rates range from approximately 21 % to 50% per day immediately after birth (Weis 2004) and rise to 70% seven to 12 days after their birth (Canino and Francis 1989). Their small size, relative inability to store food within their gut, and slow swimming speeds likely contribute to this high mortality rate by making them vulnerable to predators and starvation. Predators of larval rockfish include herring, surf smelt, salmon, and many other fish.

Nearshore Juvenile Stage. According to Love et al. 2002, “larvae and pelagic juvenile canaries occur in the upper 100 m (330 ft.) of the water column for up to 3-4 months, after which they descend to benthic habitats. They start to appear in tide pools and kelp beds in April. Off Oregon, at least some pelagic juveniles remain in the water column through July. At about 4 cm (1.6 in.), canaries commonly occur in groups at depths of 15 to 20 m (50-75 ft.) at the interface between sand and rock outcrop, mostly during the day, and disperse onto adjacent sandflats at night. Off southeast Alaska, large juveniles and subadults have been seen in water as shallow as 11 m (36 ft.). Juveniles gradually move from shallow habitat to deeper adult habitat toward the end of summer.”

According to Drake et al. (2010), “Estimates of larval duration range 1–2 months (Moser 1996a) to 3–4 months (Love et al. 2002) after which they settle to tide pools, rocky reefs, kelp beds, low rock, and cobble areas (Love et al. 1991, Cailliet et al. 2000, Love et al. 2002).” Love et al (1991) reported that juvenile canaries were noted for moving into sub-tidal bottoms at the rock-sand interface. Typical of rockfish species that inhabit both pelagic and demersal habitats in the mid-range of depths (100 to 500 ft), canary juveniles are reported to move onto shallow reefs along with juveniles of shallow-dwelling species.

A study of juvenile rockfish diets in California found that canaries had the most diverse of the seven species studied, feeding on both open water (pelagic) prey and bottom-associated (demersal) prey (Singer 1985). While some rockfish species feed on either open-water or bottom –associated invertebrates, juvenile canaries feed on prey in both types of habitats. Juvenile canaries were first found in next to sub-tidal kelp forests in April at about one inch long. “Sebastes pinniger- was the only species which showed different foraging patterns between juveniles and adults. Juvenile S. pinniger- were generally found close to the bottom over sand or in association with the rock/sand interface at the edge of the reef (Carr 1983; pers. obs.) while adults occur higher in the water column in deep water offshore. Juveniles fed demersally on copepods over sand and drift algae very near the kelp forest. Adults feed in the water column on euphausiids and small fish (Phillips 1964). Recently, adults have been found to be more demersal feeders than other offshore rockfish (Brodeur 1982).”

Day and night shifts in habitat features are summarized by Love et al. (2002). “Young-of-the-year S. pinniger aggregate during the day in areas of low-relief rock and mixed rock and sand, characteristic of sand channels and the reef-sand interface. During the evening crepuscular period, they accumulate along the outer edge of the reef and move out over open sand bottom, where they remain through the night. The process is reversed at dawn (Carr 1983).”

Intertidal and shallow subtidal habitat features offer a beneficial mix of warmer temperatures, food, and refuge from predators for the species of juvenile rockfish that inhabit shallow areas (Love et al., 2002). In general, areas with floating and submerged kelp species support the highest densities of most species of juvenile rockfish (Carr 1983, Halderson and Richards 1987, Matthews, 1989, Hayden-Spear 2006). Of the four species of rockfish in the action area whose juveniles inhabit intertidal areas (Love et al. 2002), canary are the least abundant and therefore the least likely to overlap with shellfish culture activities. Few adult canary rockfish have been found recently in each of the four Puget Sound sub-basins, and the paucity of spawners, combined with natural barriers between sub-basins and Puget Sound, means that larvae and juveniles are quite rare in Puget Sound, i.e., south of Port Townsend (Green and Godersky 2012). None of the other three species are ESA-listed and one is quite common, the black rockfish (*S. melanops*).

Sub-Adult and Adult. Subadult and adult canary rockfish typically use deep habitats with moderate to extreme steepness, complex bathymetry, and rock and boulder-cobble complexes (Love et al., 2002). A measure of this habitat complexity is "rugosity", which is a measurement of small-scale variations or amplitude in the height of a surface-in this case, the ocean bottom. Within Puget Sound, deep benthic habitats with higher rugosity values are more likely to be used by adult rockfish of many species, including canary. A synthesis of canary rockfish in British Columbia mapped adult habitats in the Strait of Juan de Fuca extending about 10 to 12 miles offshore (COSEWIC 2007). That study summarized the species’ habitat: California studies indicate that larvae and pelagic juvenile canary rockfish are found in the top 100 m of the water column for up to 3-4 months after parturition, and then settle to benthic habitats (Love et al. 2002). They have been reported in depths of 15-20 m at the interfaces between sand and rock outcrops (Love et al. 2002). Research on the west coast of Vancouver Island (WCVI) indicated that juveniles tended to move from depths of 10 m to deeper waters as they grew and aged, although adults were found at shallow depths (Gillespie et al. 1993; data source: GFBio). While the observed depth range for adults indicated by the bottom trawl fishery is about 70-270 m (95% percentile), most trawl catches came from bottom trawl tows in bottom depths of 135- 190 m (source database: PacHarvTrawl).

In Puget Sound, adult canary rockfish have been documented historically both in areas of high relief (rocky) and in non-rocky substrates such as sand, mud, and other unconsolidated sediments (Miller and Borton 1980, WDFW unpublished data). Canary rockfish have large home ranges, move long distances, and inhabit the water column (Love et al., 2002). Adults are most commonly found in waters deeper than 120 feet and over hard bottom (36 meters) (Love et al., 2002, Orr et al., 2000).

Maximum age of canary rockfish is at least 84 years (Love et al., 2002), although 60 to 75 years is more common (Caillet et al, 2000). They reach 50 percent maturity at around 16 inches in length (40 cm) and ages of 7 to 13 (Love et al. 2002). Because larger, older females release many more larvae than young mature fish, and canary rockfish are easily caught in offshore trawls or nearshore lines, fishing is the major limiting factor (Drake et al. 2010). Years of lightly-regulated catching of mature canary rockfish in Puget Sound resulted in that species' severe decline in abundance and continued very low recruitment with juveniles (Drake et al., 2010).

Food Sources. Canary rockfish feed on many kinds of invertebrates and fish in both pelagic and demersal environments. Larvae feed on very small pelagic organisms such as zooplankton, copepods and phytoplankton. Juvenile rockfish feed on a mix of pelagic and demersal invertebrates and fishes. Sub adult and adult canary rockfish eat mostly pelagic prey, e.g., crab larvae, shrimp euphasids *(Crustacea spp)*, jellyfish *(Scyphozoans spp)*, and many other fish species that inhabit their preferred depths and bottom-features (Lea et al., 1999, Love et al, 2002, Palsson et al., 2009

Fish eaten by adult rockfish include flatfish *(Family Pleuronectidae)*, Pollock *(Theragra chalcogramma)*, Pacific hake *(Merluccius productus)*, Pacific cod *(Gadus macrocephalus)* perch *(Rhacochilus spp)* and forage fish that include Pacific herring *(Clupea harengus pallasi)*, surf smelt *(Hypomesus pretiosus)*, and Pacific sand lance *(Ammodytes hexapterus).*

There is no single reliable population estimate for any of the DPSs (Drake et al. 2010). Despite this limitation, catch data provides evidence that each species' abundance has dramatically declined (Drake et al. 2010). Catches of canary rockfish have declined as a proportion of the overall rockfish catch (Palsson et al. 2009; Drake et al. 2010). The total rockfish population in the Puget Sound region is estimated to have declined by 3 percent per year for the past several decades, which corresponds to an approximate 70 percent decline from 1965 to 2007 (Drake et al. 2010).

The legacy of past overfishing and current by-catch mortality in recreational fisheries were determined to be by far the most serious threats to the canary rockfish populations, because no larger, older fish have been observed since the early 2000s, meaning there is very little recruitment of juveniles. Loss of nearshore habitat, low dissolved oxygen levels, chemical contamination, and high nutrient loading were also ranked as likely threats (Drake et al. 2010).

Southern DPS Green Sturgeon

We have released a recovery outline for this species (NMFS 2010). This preliminary document identifies important threats to abate, including exposure to contaminants, loss of estuarine and delta function, and other activities that impact spawning, rearing and feeding habitats. Key recovery needs are restoring access to suitable habitat, improving potential habitat, and establishing additional spawning populations.

Spatial Structure and Diversity. Two DPSs have been defined for green sturgeon (*Acipenser medirostris*), a northern DPS (spawning populations in the Klamath and Rogue rivers) and a southern DPS (spawners in the Sacramento River). Southern green sturgeon includes all naturally-spawned populations of green sturgeon that occur south of the Eel River in Humboldt County, California. When not spawning, this anadromous species is broadly distributed in nearshore marine areas from Mexico to the Bering Sea. Although it is commonly observed in bays, estuaries, and sometimes the deep riverine mainstem in lower elevation reaches of non-natal rivers along the west coast of North America, the distribution and timing of estuarine use are poorly understood.

In addition to the PS recovery domain, southern green sturgeon occur in the WLC, OC, and SONCC recovery domains. We are in the process of developing a recovery plan for this species.

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

2.2.2 Status of Critical Habitat

Puget Sound Recovery Domain. Critical habitat has been designated throughout Puget Sound and in the action area for PS Chinook salmon, HC summer-run chum salmon, and PSGB canary rockfish. Notable tributary river basins in and near the Puget Sound basin include the Nooksack, Skagit, Stillaguamish, Snohomish, Lake Washington, Green, Puyallup, White, Nisqually, Skokomish, Duckabush, Dosewallips, Big Quilcene, Elwha, and Dungeness rivers.

The designation(s) of critical habitat for Chinook salmon uses the term primary constituent element or essential features. The new critical habitat regulations (81 FR 74PBF14) replace 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 primary constituent elements, physical or biological features, or essential features. In this biological opinion, we use the term PBF to mean PBF or essential feature, as appropriate for the specific critical habitat. The physical or biological features (PBFs) for PS Chinook salmon are the sites and the physical characteristics’ of such sites, which are essential to support one or more life stages of the ESU.

Freshwater PBFs for salmon. Water quality is a PBF of spawning, rearing, and migration habitats. In many areas, water quality is affected by sediment load. Landslides can occur naturally in steep, forested lands, and inappropriate land use practices combined with severe storms in some places have accelerated their frequency and the amount of sediment delivered to streams. Fine sediment from unsurfaced roads has also contributed to stream sedimentation. Historical logging removed most of the riparian trees near many stream channels. Water quality in many locations of CH is also impaired by warm temperature. Agricultural and urban conversion has permanently altered riparian vegetation in the river valleys, leaving either no trees, or a thin band of trees. The riparian zones along many agricultural areas are now dominated by alder, invasive canary grass and blackberries, and provide substantially reduced stream shade. Impervious surface in urban and urbanizing watersheds has interrupted hyphoreic processes that would otherwise allow cool water recharge, thus stormwater returns to streams are warmer, and also carry a variety of chemical pollutants. Lack of riparian trees has also decreased, and in many areas precluded, large wood recruitment (NMFS 2007).

Habitat complexity and floodplain connectivity are PBFs of spawning and rearing habitat areas. These PBFs have been modified or eliminated by diking, agriculture, revetments, railroads and roads, especially in lower river reaches. Significant loss of secondary channels in major valley floodplains occurs throughout this region. Confined main channels create high-energy peak flows that remove smaller substrate particles and large wood. The loss of side-channels, oxbow lakes, and backwater habitats has resulted in a significant loss of juvenile salmonid rearing and refuge habitat. When the water level of Lake Washington was lowered 9 feet in the 1910s, thousands of acres of wetlands along the shoreline of Lake Washington, Lake Sammamish and the Sammamish River corridor were drained and converted to agricultural and urban uses. Wetlands play an important role in hydrologic processes, as they store water which ameliorates high and low flows. The interchange of surface and groundwater in complex stream and wetland systems helps to moderate stream temperatures. Forest wetlands are estimated to have diminished by one-third in Washington State (FEMAT 1993, Spence 1996, NMFS 2007).

Severe alteration of riparian habitat, elevated water temperatures, elevated levels of nutrients, increased nitrogen and phosphorus, and higher levels of turbidity, presumably from urban and highway runoff, wastewater treatment, failing septic systems, and agriculture or livestock impacts, have been documented in many Puget Sound tributaries (NMFS 2007).
In some rivers, peak stream flows are believed to have increased over time due to paving (roads and parking areas), reduced percolation through surface soils on residential and agricultural lands, simplified and extended drainage networks, loss of wetlands, and rain-on-snow events in (NMFS 2007). In urbanized Puget Sound, there is a strong association between land use and land cover attributes and mortality rates of coho salmon spawners likely due to runoff containing contaminants emitted from motor vehicles (Feist 1996).

The amount of accessible spawning habitat has been reduced in some areas as dams constructed for hydropower generation, irrigation, or flood control have substantially affected PS Chinook salmon populations in a number of river systems. The construction and operation of dams have blocked access to spawning and rearing habitat, changed flow patterns, resulted in elevated temperatures and stranding of juvenile migrants, and degraded downstream spawning and rearing habitat by reducing recruitment of spawning gravel and large wood to downstream areas (NMFS 2007). These actions tend to promote downstream channel incision and simplification (Kondolf 1997), limiting fish habitat. Water withdrawals reduce available fish habitat and alter sediment transport. Hydropower projects sometimes changed flow rates, stranding and killing fish, and reducing aquatic invertebrate (food source) productivity (Hunter 1992).

Marine and Estuarine PBFs for salmon. The nearshore marine habitats which are a PBF for juvenile outmigrant salmonids have been extensively altered and armored by industrial and residential development near the mouths of many of Puget Sound's tributaries. A railroad runs along large portions of the eastern shoreline of Puget Sound, eliminating natural cover along the shore and natural recruitment of beach sand and gravels (NMFS 2007).
Adverse water quality of the near-shore environment occurs some years in the southeastern areas of Hood Canal, when natural circulation is altered and marine oxygen is depleted in late summer, causing significant fish kills. Circulation of marine waters is naturally limited, and partially driven by freshwater runoff, which is often low in the late summer. In addition to higher loading of nitrogen from alders growing along many streams, human development has increased nutrient loads from failing septic systems along the shoreline, and from use of nitrate and phosphate fertilizers on lawns and farms. Shoreline residential development is widespread and dense in many places. The combination of highways and dense residential development has degraded certain physical and chemical characteristics of the near-shore environment (NMFS 2007) (Hood Canal Coordinating Council 2005).

In summary, salmon critical habitat throughout the Puget Sound basin has been degraded by numerous management activities, including hydropower development, loss of mature riparian forests, increased sediment inputs, removal of large wood, intense urbanization, agriculture, alteration of floodplain and stream morphology (i.e., channel modifications and diking), altered riparian vegetation, wetland draining and conversion, dredging of spawning and rearing habitats, armoring of shorelines, marina and port development, road and railroad construction and maintenance, logging, and mining. Changes in habitat quantity, availability, diversity, as well as altered flow, temperature, sediment load and channel stability are common limiting factors in areas of salmon critical habitat. While PBFs are degraded throughout much of the designated CH of the domain, many areas are still ranked as providing high conservation value due to the important role that those locations serve in meeting salmonid life history needs, or due to the relative importance of the populations that rely on those locations.

The PS recovery domain CHART (NOAA Fisheries 2005) determined that only a few watersheds with PBFs for Chinook salmon in the Whidbey Basin (Skagit River/Gorge Lake, Cascade River, Upper Sauk River, and the Tye and Beckler rivers) were in good-to-excellent condition with no potential for improvement. Most HUC5 watersheds are in fair-to-poor or fair-to-good condition, with some or a high potential for improvement (Table 4).

Table 8. Puget Sound Recovery Domain: Current and potential quality of HUC5 watersheds identified as supporting historically independent populations of ESA-listed Chinook salmon (CK) and chum salmon (CM) (NOAA Fisheries 2005).[2] Watersheds are ranked primarily by "current quality" and secondly by their "potential for restoration."

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

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

[2] On January 14, 2013, NMFS published a proposed rule for the designation of critical habitat for LCR coho salmon and PS steelhead USDC (2013). "Endangered and threatened species; Designation of critical habitat for Lower Columbia River coho salmon and Puget Sound steelhead; Proposed rule." U.S Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. Federal Register **78**(9): 2726-2796.. A draft biological report, which includes a CHART assessment for PS salmon, was also completed NMFS (2012). Designation of critical habitat for Lower Columbia River coho salmon and Puget Sound steelhead, Draft biological report. National Marine Fisheries Service, Protected Resources Division. Portland, Oregon.. Habitat quality assessments for PS steelhead are out for review; therefore, they are not included on this table.

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

Watershed Name(s) and HUC_5 Code(s)	Listed Species	Current Quality	Restoration Potential
Puyallup River (405)	CK	0	2
Hood Canal #1711001xxx			
Dosewallips River (805)	CK/CM	2	1/2
Kitsap – Kennedy/Goldsborough (900)	CK	2	1
Hamma Hamma River (803)	CK/CM	1/2	1/2
Lower West Hood Canal Frontal (802)	CK/CM	0/2	0/1
Skokomish River (701)	CK/CM	1/0	2/1
Duckabush River (804)	CK/CM	1	2
Upper West Hood Canal Frontal (807)	CM	1	2
Big Quilcene River (806)	CM	1	1/2
West Kitsap (808)	CM	1	1
Kitsap – Prairie-3 (902)	CK	1	1
Port Ludlow/Chimacum Creek (908)	CM	1	1
Strait of Juan de Fuca Olympic #1711002xxx			
Dungeness River (003)	CK/CM	2/1	1/2
Discovery Bay (001) & Sequim Bay (002)	CM	1	2
Elwha River (007)	CK	1	2

Critical Habitat for Canary Rockfish Critical habitat for canary rockfish 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 canary rockfish 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.

Critical Habitat in Willapa Bay and Grays Harbor

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

For freshwater rivers north of and including the Eel River, the areas upstream of the head of the tide were not considered part of the geographical area occupied by the southern DPS. However, the critical habitat designation recognizes not only the importance of natal habitats, but of habitats throughout their range. Critical habitat has been designated in coastal U.S. marine waters within 60 fathoms depth from Monterey Bay, California (including Monterey Bay), north to Cape Flattery, Washington, including the Strait of Juan de Fuca, Washington, to its United States boundary; the Sacramento River, lower Feather River, and lower Yuba River in California; the Sacramento-San Joaquin Delta and Suisun, San Pablo, and San Francisco bays in California; the lower Columbia River estuary; and certain coastal bays and estuaries in California (Humboldt Bay), Oregon (Coos Bay, Winchester Bay, Yaquina Bay, and Nehalem Bay), and Washington (Willapa Bay and Grays Harbor) and freshwater (USDC 2009b). Table 26 below delineates physical and biological features for southern green sturgeon.

Table 9. Physical or biological features of critical habitat designated for southern green sturgeon and corresponding species life history events.

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

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

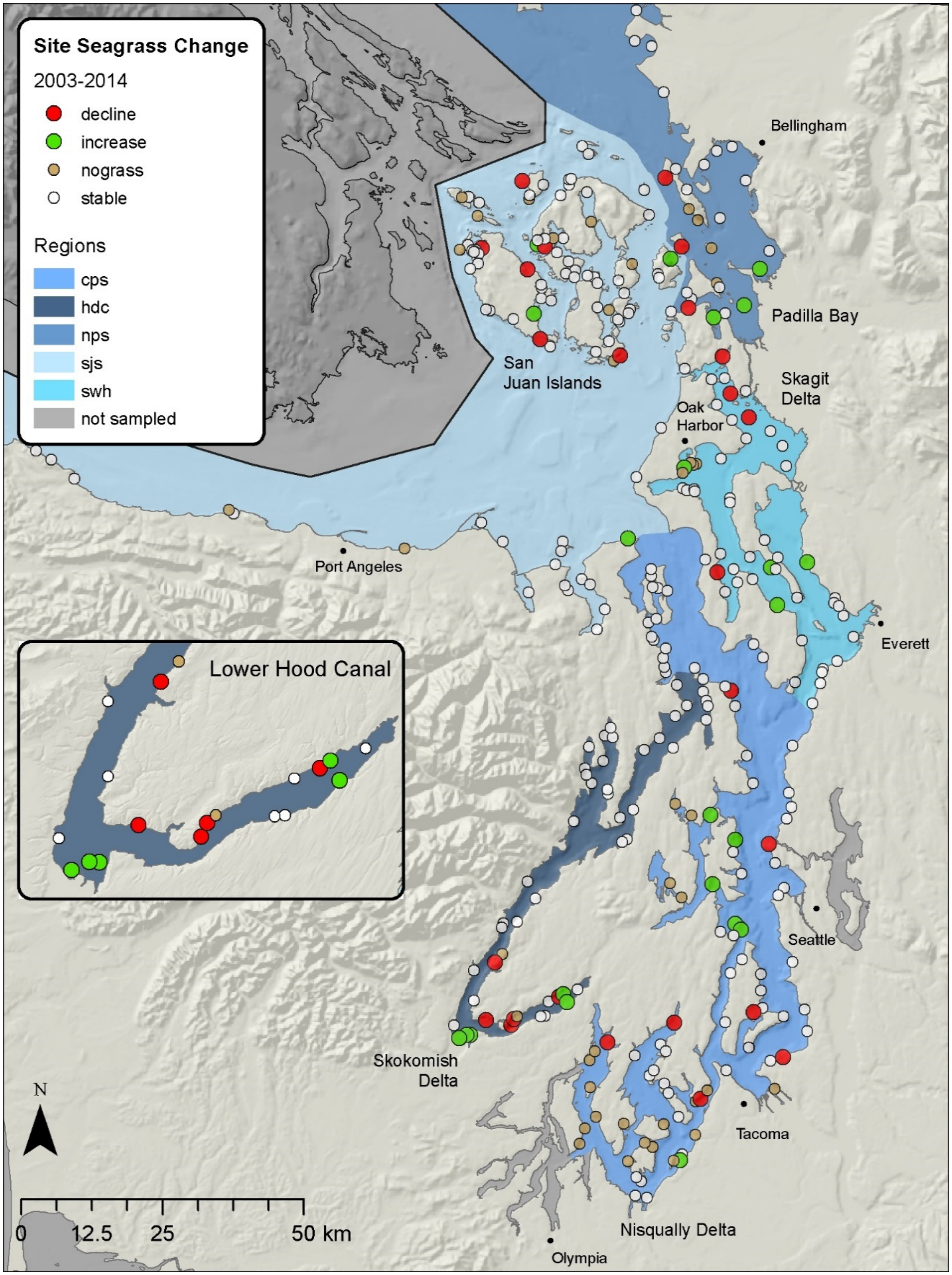

Figure 4. Sites with significant trends in seagrass area between 2003 and 2014 (Fig 12 from WADNR 2016).

2.3 Environmental Baseline

The "environmental baseline" includes the past and present impacts of all Federal, state, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of state or private actions which are contemporaneous with the consultation in process (50 CFR 402.02).

The action area consists of five sub-areas (Table 10) of nearshore, each with many shellfish farms. Within each farm, there are one or more managed sites or plots. The aquatic lands within the farms are either privately owned or leased from another private individual or the Washington Department of Natural Resources (WDNR). Shellfish aquaculture activities have been ongoing in these various sub-areas for many years. In some areas, such as Willapa Bay, shellfish aquaculture has been occurring for as long as 150 years. The existence of shellfish management, in addition to other factors in managed areas, has influenced prevailing conditions in these places. For example, the introduction of invasive species such as spartina and marine snails, among other things attributed to past aquaculture activities, have likely affected eelgrass presence and the habitat function of SAV generally.

The spatial extent of aquaculture acreage covered by the proposed action drives the size of the action area for this consultation. The amount of acreage within existing farms is summarized in Table 8. With the exception of turbidity, effects are confined to the immediate farm. Activities that generate sediment may cause turbid water to drift outside of the footprint of the active plot, expanding the affected area by as much as a few hundred linear feet, depending on grain size, fetch, and current velocities. The site factors that influence effects of the action are the hydrodynamics of the farm site, and the proximity between, and density of, farms within sensitive aquatic habitats and CH. Table 8 presents the number of shellfish aquaculture parcels and acreage farmed in each sub-action area.

Table 10. Summary of total acreage potentially authorized for shellfish activity during the anticipated 20 year period of the proposed action (COE 2015)

	Grays Harbor	Willapa Bay	Hood Canal	South Puget Sound	North Puget Sound	Total
Commercial Aquaculture	3,065	25,965	1,789	3,578	4,002	38,400
Subtidal geoduck harvest	0	0	6,703	22,676	18,754	48,133
Recreation	0	0	74	41	45	160
Restoration	0	0	24	126	5	155

Willapa Bay Sub-Action Area

Approximately two-thirds of the Willapa Bay sub-Action Area (WBSAA) upland in the watershed is composed of commercial forest lands. Cranberry farms comprise an additional seven percent, including 1400 acres of bogs. The Willapa watershed supports fall Chinook salmon, coho salmon, fall chum salmon and winter steelhead trout. However, none of these species is listed under the ESA. Out of basin ESA-listed fish that are known to use Willapa Bay for juvenile rearing include LCR Chinook salmon and CR chum salmon, however, Willapa Bay is not designated critical habitat for these species. There are no ESA-listed rockfish populations in the Willapa or Grays Harbor Watershed. Critical habitat for green sturgeon is designated in the Willapa sub-area.

The relatively shallow bay has more than 50 percent of its 79,000 acres exposed at low tide with much of the remaining surface area, except for channels, covered by one to six feet of water. Tidal levels in the bay vary each day from 14 to 16 feet and during a complete tidal cycle about 45 percent of the water in the bay is exchanged into the Pacific Ocean. Willapa Bay opens to the Pacific Ocean at its northwestern corner through a broad shallow pass about six miles wide between Cape Shoalwater and Leadbetter Point. Continuing ground-based shellfish activities cover 25,836 acres in Willapa Bay, with approximately 16,395 acres in continuing ground-based culture. The primary aquaculture species cultivated in Willapa Bay are oysters and clams. Notably, eelgrass beds cover about 24% of the water surface, or 14,400 acres (Thom et al, 2003). Clam cover nets and mechanical harvest are used extensively in Willapa Bay.

Grays Harbor Sub-Action Area

The Grays Harbor sub-Action Area (GHSAA) is a shallow, bar-built estuary located on the central Washington coast north of Willapa Bay. Depths average less than 20 feet, with depths at the entrance reaching a maximum of 80 feet. The navigation channel is dredged annually to a depth of 30 feet. Freshwater inputs are attributed to the Chehalis, Hoquiam, Wishkah, Humptulips, Johns, and Elk River sub-watersheds which have a combined drainage basin of approximately 2,550 square miles. The Chehalis River provides approximately 80 percent of the freshwater input into Grays Harbor. The primary aquaculture species cultivated in Grays Harbor are oysters and clams. Listed species in Grays Harbor include green sturgeon. Critical habitat has been designated for green sturgeon in Grays Harbor. In 1981, eelgrass covered an estimated 1,160 acres, or 2% of the total area of about 59,300 acres (Thom 1984). Clam cover nets and mechanical harvest are used extensively in Grays Harbor.

Within the GHSAA, shellfish aquaculture occurs in the estuary. The estimated total continuing active and fallow acreage in the GHSAA is 2,965 acres with 95 acres proposed as new.

South Puget Sound Sub-Action Area

This area is occupied by PS Chinook salmon, PS steelhead (NLAA, see section 2.11), canary rockfish, and their designated CH. There are no major river systems in this basin. Inlets and mudflats laid down at stream confluences provide a variety of nearshore habitats. Slow and thorough tidal mixing consistent with the long, finger-like water bodies of Oyster Bay, Oakland Bay, Mud Bay, North Bay, Eld Inlet, Hammersley Inlet, Totten Inlet, Skookum Inlet, and upper Case Inlet provides nutrient rich waters at stream outlets. These sheltered, nutrient rich waterways are highly conducive to shellfish aquaculture. As with most accessible shorelines, residential development is generally found at the lower portions of streams near salt water bays in this basin. In more developed areas in the SPSAA such as the cities of Olympia, Shelton, and Tacoma, nearshore areas with suitable habitat for native species is shrinking as shoreline development proceeds. Bulkheads, stormwater pollution, riparian removal, dredging, overwater structures, and other anthropogenic features have fragmented or removed habitat and altered natural sediment and organic nutrient regimes (Simenstad et al. 2011). The distribution of eelgrass is limited to areas east of Case Inlet, with eelgrass essentially absent from the protected bays and inlets termed South Puget Sound West (Short 2014). The SPSSA has approximately 3,111 acres of continuing ground-based shellfish activities.

Hood Canal Sub-Action Area

The Hood Canal sub-Action Area (HCSAA) consists of three WRIAs (14, 15, and 16). This area is occupied by Hood Canal summer-run chum salmon, PS Chinook salmon, PS steelhead, and canary rockfish, as well as designated critical habitat for salmon and rockfish, and critical habitat for PS steelhead. The WRIAs 14 and 15 include the east and south shores of Hood Canal. The WRIAs 14 and 15 extend from Foulweather Bluff in the north to the town of Union in the south. The WRIA 16 is located along the eastern slope of the Olympic Mountains and extends from the Turner Creek watershed in southeast Jefferson County southward to, and including, the Skokomish watershed in northwest Mason County. The four principal watersheds that feed into Hood Canal are the Dosewallips, the Duckabush, the Hamma Hamma and the Skokomish. These originate in the Olympic Mountains and flow into the western shore of Hood Canal.

Shellfish aquaculture is conducted in Hood Canal comprising approximately 1,323 acres. The small coves and bays have minimum activity although Port Gamble has a substantial farm growing geoduck and other clam species and oysters.

The southern portion of Hood Canal experienced depleted oxygen events dating from the 1930s, with 2002, 2003, and 2006 events that resulted in notable fish die-offs. The stratified and slow overturning circulation of Hood Canal is known to be a natural factor conducive to seasonal hypoxia. Several factors are involved, including both natural factors such as climate and inputs of ocean and freshwater that affect the flushing of Hood Canal, as well as human loadings of nutrients and carbon that affect the amount algal growth and the organic load that ultimately deteriorate and cause a drawdown in oxygen concentrations (Newton et al. (Newton, et al 2011). In 2013, the City of Belfair, WA completed a new zero-discharge sewage treatment and reclamation facility. This is hoped to be a significant step towards reducing nutrient inputs in southern Hood Canal. Nevertheless, southern Hood Canal nearshore habitat is a mix of functional and degraded condition from residential and commercial development.

Shallow areas of Hood Canal shoreline are a diverse network of mudflats, dendritic tidal channels, lagoons, salt marshes, eelgrass beds, and sandy beaches that provide estuarine habitat for both juvenile and adult salmonids and their prey (Kuttel, 2003). The most recent monitoring reports show more eelgrass monitoring sites in Hood Canal, particularly southern Hood Canal, showing expansion of eelgrass rather than reduction (WDNR, 2016).

North Puget Sound Sub-Action Area
The North Puget Sound sub-Action Area (NPSSAA) contains Whidbey Basin, Admiralty Inlet, Strait of Juan de Fuca, and the San Juan Archipelago. The largest fresh water inputs come from the Skagit, Stillaguamish, Snohomish, Nooksack, and Elwha Rivers. As with other sub-basins discussed above, commercial and residential near-shore areas have altered habitat functions, with bulkheads, overwater structures, stormwater inputs, and other anthropogenic features degrading baseline conditions. However, other areas within the NPSAA contain large tracts of functioning nearshore or shallow water habitat. At nearly 8,000 acres, Padilla Bay is recognized to contain the largest native eelgrass meadow in Puget Sound, and the second largest on the west coast. Skagit and Samish Bay, also in the NPSAA, also contain large eelgrass meadows at 7,033 acres and 5,350 acres, respectively. Between the years 2010 and 2014, WDNR recorded increases of eelgrass at most monitoring sites in the NPSAA, with Padilla Bay and Samish Bay showing small, but statistically significant increases over time (WDNR, 2016).

The relative shallowness of the Whidbey Basin is complemented by a much larger percentage of tidelands than any of the other Puget Sound basins. There are a reported 56 parcels in shellfish production in the North Puget Sound sub-area comprising approximately 3,623 acres. The Samish Bay portion of the North Puget Sound sub-area includes WRIA 6 and WRIA 3, the Lower Skagit/Samish basins. While Samish Bay is the largest culture area in the NPSSAA, other ongoing shellfish culture areas include Discovery Bay, Padilla Bay, and other areas along the Strait of Juan de Fuca. Estimates for number of parcels were not available for areas outside of Samish Bay. The NPSAA contains PS Chinook salmon, canary rockfish and their designated CH, as well as PS steelhead and their critical habitat.

Factors Affecting the Condition of the Environmental Baseline

Below, NMFS summarizes the factors affecting the condition and quantity of habitat features and processes necessary to support the listed species in the action area. These factors are climate change, contaminants, habitat modification, nutrients and pathogens, the condition of estuarine submerged vegetation (especially eelgrass). Canary rockfish are present in the Puget Sound portion of the action area and express all life history stages there. Puget Sound Chinook salmon are also present in the Puget Sound (including Sound Hood Canal) portion of the action area. Critical habitat for PS Chinook salmon is designated throughout Puget Sound and Hood Canal from -98 ft to extreme high water.

Climate Change. As described in ISAB (2007), effects of climate change that have influenced the habitat and species in the action area, and that are expected to continue to do so in the future include: increased ocean temperature, increased stratification of the water column, and changes in intensity and timing of coastal upwelling. These continuing changes will alter primary and secondary productivity, the structure of marine communities, and in turn, the growth, productivity, survival, and migrations of salmonids. A mismatch between earlier smolt migrations (due to earlier peak spring freshwater flows and decreased incubation period) and altered upwelling may reduce marine survival rates. Decades of ocean observations now show that CO_2 absorbed by the ocean is changing the chemistry of the seawater, in a process called ocean acidification. Increased concentration of CO2 reduces the availability of carbonate for shell-forming invertebrates including some that are prey items for juvenile salmonids (Feely et al. 2012). Also, increased levels of CO_2 combined with warmer seawater are expected to favor growth of eelgrass (Palacios and Zimmerman 2015)

***Environmental Contaminants*.** Contaminants from upland and port development enter marine and fresh waters and sediments from numerous sources, but are typically concentrated near populated areas of high human activity and industrialization (Ecology and King County 2011). In the past 150 years, people have released a wide variety of chemicals into various water bodies affecting conditions in the action area, many of which are toxic to humans, animals, and plants. While contamination by a number of toxics, such as lead, polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), and dioxins, has been reduced by use restrictions, other chemicals continue to be used and many enter into Puget Sound through stormwater runoff, wastewater discharges, and nonpoint sources, adding to a legacy of contamination (Ecology, 2011). These factors are also likely present for Grays Harbor, which is surrounded (albeit to a lesser extent than is Puget Sound) by suburban, urban, and industrial land uses. Willapa Bay is surrounded by rural and undeveloped land uses such that contaminants from these sources are likely much less influential on existing conditions than in Grays Harbor or Puget Sound.

Toxic chemicals in the sediments of the action area can expose salmon and other organisms to unhealthy concentrations of contaminants, typically through the food chain as rearing juveniles ingest invertebrates living in contaminated sediments (Ecology and King County 2011). Toxic contamination of nearshore and marine ecosystems in Puget Sound and the coastal estuaries can reduce the ability of the nearshore and marine ecosystems to provide high quality prey items for listed fish.

Oil spills have occurred in the action area, and there is potential for spills in the future. Oil can be discharged into the marine environment in any number of ways, including shipping accidents, refineries and associated production facilities, and pipelines. Despite many improvements in spill prevention since the late 1980s, much of the action area remains at risk from serious spills because of the heavy volume of shipping traffic and proximity to petroleum refining centers in inland waters. Numerous oil tankers transit through the action area throughout the year. The magnitude of the risks posed by oil discharges in this area is difficult to precisely quantify or estimate, but may be decreasing because of new oil spill prevention procedures in the state of Washington (WDOE 2007).

The combination of hydrologic isolation with the persistent (resisting degradation) and bioaccumulative (increasing within in organisms over time) nature of many chemical contaminants creates additional risk for the Puget Sound and coastal estuary ecosystems. Chinook salmon that remain as residents in Puget Sound (both as a result of natural tendencies and hatchery practices), rather than migrate to the ocean, are several times more contaminated than other Chinook salmon populations along the West Coast (West et al.2011). Another indication of this is found in Pacific herring, one of Puget Sound's keystone forage fish species. Scientists have shown high body burdens of PCBs in this species from the central and Southern basins of Puget Sound—comparable to herring from northern Europe's severely contaminated Baltic Sea (PSP 2007). The most recent synthesis of Puget Sound water quality highlights the priority for monitoring toxics in Puget Sound fishes (PSEMP 2013).

The toxic contaminants that harm or threaten the health of the action area include chemicals designed and synthesized to meet industrial needs, agricultural products such as pesticides, byproducts of manufacturing or the combustion of fuel, fossil fuels, and naturally occurring toxic elements that may become unusually highly concentrated in the environment because of human uses or other activities. Release of these chemicals to the environment can occur through designed and controlled human actions (e.g., application of pesticides or the discharge of wastes through outfall pipes, smokestacks, and exhaust pipes) or as unintended consequences of human activities (e.g., oil and chemical spills, leaching from landfills, and runoff of chemicals from the deterioration or wear of roofs, pavement, and tires) (Ecology, 2011).

Hood Canal is less developed and as yet does not show the same indications of contaminants as does the greater Puget Sound region. Likewise, Willapa Bay and Grays Harbor are sparsely developed and have not identified contaminant issues when investigated by state resource agencies. Willapa Bay has been listed for fecal coliform bacteria on Ecology's 303(d) list but overall toxins have not been reported as a problem in the region. Grays Harbor's inner harbor is industrialized with mills, landfills, and log storage. Chemicals from pulp mills have historically damaged water quality. But no areas of the harbor are currently listed for 303(d) impairment.

Nutrients and Pathogens. Water quality is a primary factor affecting the health of marine and freshwater species in Western Washington (PSEMP 2013, PSEMP 2014). As Washington's population grows and urbanization of the action area continues, freshwater and marine ecosystems are under rising pressure from human activities that increase nutrient and pathogen pollution. Inputs of nutrients and pathogens affect ecosystem functions, the health and habitat of aquatic species, including economically important species (such as salmon and shellfish), and human health.

Nutrients consist of a variety of natural and synthetic substances that stimulate plant growth and enrich aquatic ecosystems. As a general rule, phosphorus tends to be the limiting nutrient in freshwater systems, and nitrogen tends to be the limiting nutrient in marine systems. This means that increased loadings of these nutrients can have significant effects on the character and condition of these respective systems.

Human activities have had a profound effect on the cycling of nutrients worldwide and nutrient pollution in the action area. Nutrient availability in the action area involves inputs from natural and human sources, such as upwelling and inflow of oceanic waters, flows from rivers and streams, stormwater runoff carrying fertilizers and other materials, discharges from sewage treatment plants, atmospheric deposition, and numerous other sources. It also involves uptake by phytoplankton and other aquatic vegetation and export to oceanic waters.

Increased nutrient loading can dramatically change the structure and function of freshwater and marine ecosystems by altering biogeochemical cycles and producing cascading effects throughout the ecosystem and food web, such as prolonged algae blooms, depressed oxygen levels, fish kills and losses of aquatic vegetation. Biomass of cultured and native shellfish has the potential to substantially reduce nutrient loading by providing a pathway for nitrogen to be sequestered and removed from sheltered coastal waters (Bricker et al. 2007, Saurel et al 2014).

Also, elevated levels of nitrogen have been studied as a stressor on eelgrass in certain places in Puget Sound (Short 2014).

Pathogen pollution is an equally significant water quality problem in the action area. Pathogens are disease-causing microorganisms that include a variety of protozoa, bacteria, and viruses. Some pathogens occur naturally in the marine environment (e.g., *Vibrio parahaemolyticus*). Most, however, are carried by host organisms and are associated with human and animals feces from such sources as onsite sewage systems and municipal sewage treatment plants, stormwater runoff, and boat waste. Pathogen pollution causes a range of environmental, human health, and economic impacts that include the contamination of shellfish beds, recreational waters and beaches, drinking water supplies, and other water-related resources.

Primary Productivity. Phytoplankton are microscopic plants and unicellular plant/animals (protists) that form an important part of the foundation of the marine water-column food web. Species composition at any given time, and abundance of each species, depends on a complex interaction between environmental (e.g., light, temperature, inorganic nutrient availability) determinants of productivity, biological influences (e.g., intensity of grazing) and rates of settlement. These processes contribute, determine the rate and amount of energy available to pelagic and benthic ecosystems, and result in a seasonal pattern of abundance and distribution of the invertebrate predators and the food chain that they support.

Phytoplankton has not been recognized as a limiting factor for Puget Sound food webs (Strickland 1983, Greene et al. 2012). Available monitoring reports and research were reviewed to understand phytoplankton trends throughout Puget Sound. In general, elevated levels of anthropogenic derived nutrients in south Puget Sound are believed to cause more abundant phytoplankton, which in turn are consumed by a variety of aquatic organisms, including commercially raised shellfish (PSEMP 2014). In the following section, we focus on Totten Inlet in South Puget Sound to analyze dynamics of phytoplankton trends and consumption in an area with a high density of shellfish culture.

Because Totten Inlet in the SPSAA contains the highest densities of shellfish culture in Puget Sound, any potential impacts to phytoplankton abundance and subsequent trophic levels would likely bear out here. We reviewed studies on primary productivity in Totten Inlet as a surrogate to ascertain a conservative estimate of phytoplankton conditions in areas with shellfish culture. Phytoplankton abundance in Totten Inlet in 2002 and 2003 was characterized by relatively low numbers of cells per unit volume in late fall and winter (<100,000 cells/L) (378,500 cells/gal) (Newfields, 2009). In early spring, there was a short, large diatom bloom (3,156,000 to 4,123,000 cells/L) (11,945,460 to 15,605,555 cells/gal) of primarily *Chaetoceros* spp., followed by more modest abundance in late May through July. Then a second bloom (220,000 to nearly 1 million cells/L) (832,700 to nearly 3,785,000 cells/gal) of diatoms and dinoflagellates was typical in late summer early fall. These abundances are believed to be similar to other embayments in south Puget Sound, which has overall high productivity of phyto- and zooplankton. Another way to measure primary production by phytoplankton in Totten Inlet is rates of organic carbon per time, ie, 44,777 tons of carbon per year (t C/yr) during the spring/summer period, plus another 3,380 t C/yr during the fall/winter (Newfields 2009). As such, it was noted that even if the consumption by shellfish increased by 10 fold and with the addition of the estimated North Totten Inlet mussel farm consumption of 107,348 kg C/yr (118.35 t C/yr), the consumption by cultivated shellfish would only be 1.5 percent of the calculated spring/summer phytoplankton production within Totten Inlet. The area of most extensive aquaculture (Totten Inlet) maintains higher bivalve growth than elsewhere in Puget Sound (Ruesink et al. in prep.), and only local phytoplankton depletion around raft structures has been documented. Overall, existing evidence from the West Coast confirms that cultured bivalves affect water properties, but the effect is largely evident at small spatial scales (Dumbauld et al. 2009). This topic is also the subject of ongoing research by the Pacific Shellfish Institute and others in south Puget Sound.

Habitat Modification. Human activities have combined to overall mostly degrade and slightly restore areas of habitat in the action area. Polluted water bodies, dredged and filled estuarine rearing areas (Bishop and Morgan 1996), nearshore overwater structures, and shoreline armoring (Penttila, 2007) have adversely affected nearshore and marine functions and processes (Johannessen et al 2104).

Condition of Submerged Aquatic Vegetation. Eelgrass (*Zostera marina*) habitat is known for the ecological functions it provides to the nearshore estuarine community (Blackmon et al. 2006). Eelgrass supports a complex food web. In addition to providing the surface area for growth of epiphytic algae, eelgrass beds reduce wave energy, which causes the deposition of fine sediments and detrital material and is the base of a complex food web (Simenstad et al. 1979). Summer-run chum juvenile salmon particularly feed on benthic copepods that are in the food chain based on organic plant material from inter- and sub-tidal plants, including eelgrass, as well as marsh plants and algae (NMFS 2007a). Micro-invertebrates associated with eelgrass beds and shellfish beds (e.g., harpacticoid copepods, gammarid amphipods, and cumaceans), are commonly reported to be important components in the diets of juvenile Pacific salmonids, herring, smelts and flatfishes (Blackmon et al. 2006).

Eelgrass beds are divided into two habitat types. A significant amount of eelgrass occurs in large "flats", which can be large shallow embayments or small pocket beaches. Close to one-fifth of all the eelgrass in Puget Sound grows in one large flat, Padilla Bay. Eelgrass also occurs in narrow fringing beds along steeper shorelines. These fringing beds can be corridors for migrating salmon and other wildlife. About one-half of all eelgrass in Puget Sound occurs in these fringing beds. In Puget Sound, the optimal growth range for eelgrass are tidal elevations at plus 1 foot to minus 8 feet, as reported in the PBA. However, the extreme ranges of eelgrass growth from plus 1.5 m (5 feet), to minus 6.9 m (23 feet), meaning much of the Puget Sound eelgrass exists subtidally (COE, 2015).

Eelgrass is found in sediments ranging from mud to clean sand; its upper limit is set by desiccation (in the intertidal zone) and its lower limit by light limitation (in the shallow subtidal zone). *Z. marina* grows in several bed configurations or patterns. In areas where conditions are thought to be most suitable, beds are solid or continuous. In other areas there may be persistent patchy beds, often at the ends or edges of solid beds. Continuous beds are often found in extensive tideflats, and discontinuous beds in areas fringing linear shorelines. Little is known about interannual variation in bed area, but it appears to be less than 10 percent, or several feet from the edge of a bed (Mumford 2007).

Z. marina shows several interesting landscape distribution attributes. First, the lack of beds in southern Puget Sound is attributed to a combination of high tidal amplitudes and timing of low tides during the summer. During extreme low tide events, especially during hot summer middays, desiccation/heat stress limits the upper distribution, while at high tides, enough water covers the plants to limit net photosynthesis at depth. At the point where tidal amplitude is enough to cause the lower limit to be the same as the upper limit, eelgrass will not grow. The heat stress is exacerbated by the fact that the timing of extreme low tides in southern Puget Sound is in midday, when temperatures are the highest. In contrast, on the outer coast and straits, lowest tides are early in the morning, before the heat of the day (WDNR, 2015).

A variety of human impacts affects eelgrass growth. These include docks, which shade the bottom; increased nutrient inputs to the nearshore, which can cause plankton blooms or excess growth of eelgrass epiphytes (both of which can reduce the ability of eelgrass to get enough light) (Short 2014); and numerous aquaculture activities, which compete for space. Toxics, such as metals and crude oil, directly impact eelgrass and kelp. Low oxygen and the related high sulfide levels in sediments impact eelgrass. Bioturbation, grazing, and disease are additional possible causes for eelgrass decline. Compared to an eelgrass meadow without any human disturbance, eelgrass is typically sparse in areas where active shellfish culture directly overlaps with eelgrass beds.

An estimated 24,300 ± 2,200 hectares (about 60,000 acres, ± 5,400) of eelgrass were present in Puget Sound in 2014 (WADNR 2016). No comprehensive records describe of the extent of eelgrass meadows from before the major influx of humans in the late 1800s (Thom and Hallum, 1990). Areas of eelgrass are believed to have changed overall in Puget Sound, with some areas shrinking due to physical changes in shorelines, periodic physical disturbances, and degradation in water quality as the region has grown in population (Thom and Hallum 1990; Thom et al. 1995; Dowty et al. 2010; Thom et al. 2011). Near the historic mouth of the Skagit River, moving the river away from Padilla Bay before about 1900 is believed to have triggered favorable conditions for eelgrass over several thousand acres: today this bay has the single largest eelgrass meadows in Puget Sound (Dowty et al 2010). The WDNR (2016) reports that there have not been significant trends over the past 11 years of eelgrass monitoring, although there is some evidence that suggests minor increases in eelgrass area between 2010 and 2013 (WDNR, 2016).

Human-induced disturbances, assumed to have caused most of the loss and threats to critical nearshore habitats, are expected to increase with population growth and coastal and watershed development.

Puget Sound Forage Fish. Rice, in Shipman et al (2010,) states the clearest impacts of shoreline modifications on biota in Puget Sound are reduced survival of embryos of forage fish on upper beaches, as well as loss of high-shore invertebrates.

Surf smelt and Pacific sand lance are key parts of the Puget Sound food web, providing food for many sea birds, marine mammals and fishes (Krueger et al in Shipman, 2010). Shoreline armoring is the greatest threat to surf smelt and sand lance spawning habitat, as armoring affects beach morphology and results in the direct loss of spawning habitat (Krueger et al *in* Shipman 2010). In addition to shoreline armoring, sea level rise is likely to cause widespread loss of spawning habitat for these two species. Indirectly, the decline of forage fish habitat has likely led to a decline in forage for adult and sub-adult salmonids, as well other fish and wildlife species.

Relevance of Baseline Conditions on Canary Rockfish, PS Chinook salmon, HCSR chum salmon, green sturgeon, and their Critical Habitat

While historical overfishing is largely blamed for declining numbers of canary and other rockfish species, factors that drive baseline conditions are believed to have also affected canary rockfish (Drake et al 2010). Rockfish in urban areas are exposed to high levels of chemical contamination, which may be affecting their reproductive success. Poor water quality in Hood Canal, where low dissolved oxygen conditions are exacerbated by natural and anthropogenic factors (Bricker et al 2007), has resulted in periodic kills of many species of rockfish as well as other species. Lost or abandoned fishing nets trap and kill s some rockfish in the Straits Habitat modification of shallow nearshore areas that preclude the growth of kelp such as overwater structures are presumed to have generally decreased juvenile rearing and foraging areas for the fish species and lifestages that use those habitats (Drake et al 2010).

Puget Sound Chinook salmon and their designated critical habitat have also suffered cumulative impacts as a result of the previously described elements including overwater structures, bulkheads, pollution, and other habitat modifications, in both their marine and freshwater habitats. Shorelines and watersheds in Puget Sound are densely developed with urban housing and industry. Stormwater runoff, septic effluent, timber harvest, and agricultural practices contribute to water quality degradation for listed aquatic species, particularly Chinook salmon and their prey. The sharp underwater light contrasts from overwater structures cause delays in migration from disorientation, fish school (dispersal resulting in a loss of refugia), and altered migration routes around the structures (Simenstad 1999). The characteristics of an overwater structure, including height and width, orientation, and piling type and number, can affect the severity of the shade-related impacts (Southard et al. 2006). Bulkheads typically preclude development of riparian functions and remove sources of beach material, degrading nearshore habitat conditions for PS Chinook, as well as forage fish and other organisms.

2.4 Effects of the Action on Species and Critical Habitat

Under the ESA, "effects of the action" means the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action, that will be added to the environmental baseline (50 CFR 402.02). Indirect effects are those that are caused by the proposed action and are later in time, but still are reasonably certain to occur.

Effects of the action are the direct and indirect effects of an action on the listed species or CH, together with the effects of other activities that are interrelated or interdependent with that action, that will be added to the environmental baseline (50 CFR 402.02). The proposed action is issuance of a COE individual permits or verifications under general permits that will enable new, expanded, and ongoing shellfish activities whose past effects already inform, in part, the condition of the environmental baseline. Therefore, this section describes those effects, and examines whether and to what extent canary rockfish, and PS Chinook salmon will be exposed to the effects; how fish will each respond to exposure; and to what extent the proposed action will adversely affect the quality and function of critical habitat PBFs for PS Chinook salmon, HCSR chum salmon, and green sturgeon in the action area.

2.4.1 Effects on Species

Complete descriptions of the aquaculture methods for growing and harvesting shellfish were presented in the description of the proposed action. The activities fall within the general categories of bed preparation, seeding, grow out, and harvest. Some of these activities occur only once in a harvest cycle of a shellfish species at a particular site while other activities, e.g. harrowing, may occur more than once in the planting and harvesting cycle. As discussed in the consultation history section above, we concur with the COE determination of LAA for Canary rockfish, PS Chinook salmon, HCSR chum salmon, and Southern DPS green sturgeon. We did not concur with the COE's LAA determinations for boccacio, for which we determined the proposed action is NLAA. We concurred with COE determinations of NLAA for LCR Chinook salmon, Columbia River chum salmon, PS steelhead, eulachon, and Southern Resident Killer Whale. Rationale for the NLAA determinations is discussed in Section 2.11.

The section concludes with a discussion of the extent and relevance of those impacts on the affected population. Table 11 (below) summarizes effects determinations for this consultation.

Table 11. Summary of Effects Determinations and Conclusions

ESA-Listed Species	Status	Is Action Likely to Adversely Affect Species or Critical Habitat?	Is Action Likely To Jeopardize the Species?	Is Action Likely To Destroy or Adversely Modify Critical Habitat?
Puget Sound steelhead (*Oncorhynchus mykiss*)	Threatened	No	No	No
Puget Sound Chinook salmon (*O. tshawytscha*)	Threatened	Yes	No	No
Lower Columbia River Chinook Salmon (*O. tshawytscha*)	Threatened	No	No	N/A
Columbia River Chum Salmon (*O. keta*)	Threatened	No	No	N/A
Hood Canal Summer-Run Chum Salmon (*O. keta*)	Threatened	Yes	No	No
Southern Green Sturgeon (*Acipenser medirostris*)	Threatened	Yes	No	No
Canary Rockfish (*Sebastes pinniger*)	Threatened	Yes-Species No-CH	No	No
Boccacio Rockfish (*Sebastes paucispinis*)	Endangered	No	No	No
Southern Resident Killer Whale (*Orincus orca*)	Endangered	No	No	No

Canary Rockfish
Direct Effects from Mechanical Oyster Harvest
As discussed in Section 1.3, mechanical harvest of bottom culture oysters occurs in several locations including north Puget Sound, Hood Canal, Willapa Bay, and Grays Harbor. Canary rockfish would only be affected by harvest activities in North Puget Sound. Listed canary rockfish are not present in Willapa Bay or Grays Harbor. To identify potential effects on canary rockfish associated with mechanical harvest, NMFS reviewed species habitat use, life stage, and habitat types associated with areas of mechanical harvest.

A few canary rockfish are presumed to inhabit areas of central Puget Sound, but are not currently confirmed to occur in Hood Canal. North Puget Sound is recognized to have the most abundant rockfish populations compared to the rest of Puget Sound (Palsson et al. 2009), due mainly to its rocky, diverse substrate and abundance of kelp. While at least four species of juvenile (young-of-year) rockfish are known to occupy shallows with eelgrass, kelp, and other structure for rearing in the action area (Love et al 2002), limited evidence appears to suggest that some juvenile rockfish, perhaps including canary, typically associated with eelgrass and kelp, may also seek out habitat created by oyster culture as habitat. In Discovery Bay in 2005, researchers from WDFW inadvertently collected unidentified juvenile rockfish using oyster bags set out at depths of 10, 16, and 23 feet placed on sand dominated substrate (Cheng and Hillier, 2011). Although bottom culture oysters wouldn't necessarily provide the type of layered, three-dimensional habitat that an oyster bag would provide, NMFS reviewed available literature to ascertain whether it was reasonable to assume some juvenile canary rockfish may use bottom culture oysters as rearing and/or cover habitat. Reviewed data included presence and timing associated with proposed critical habitat, species abundance, species biology, and proximity to mechanically harvested oyster cultivation areas (Drake et al 2010, Palsson et al 2009, Love et al 2002). Several species of juvenile rockfish may be present in ground-based oyster culture, particularly in areas near canary rockfish critical habitat. Because the rockfish caught in oyster bags, as described above, were not identified to species, a review of rockfish biology and abundance was used to estimate potential presence of ESA-listed boccaccio, yelloweye rockfish, and canary rockfish. Boccacio rockfish are extremely rare in Puget Sound, with canary and yelloweye rare (Palsson et al. 2009; Drake et al. 2010). For example, a study to estimate rockfish densities in various Puget Sound regions collected a total of 495 larval rockfish. Among the 495 collected, no fish were identified as boccacio or canary rockfish (Green and Godersky, 2012). Nevertheless, canary rockfish are known to use a variety of substrates in the shallows as juveniles (Love et al., 1991, Love et al., 2002). Generally, juvenile canary rockfish were observed along the Oregon coast in shallow areas including tidepools and kelp beds in April, and moved to deeper water through the spring and summer as they grew. Because juvenile Canary rockfish are strongly associated with rocky kelp habitats, exposure to effects from most shellfish aquaculture actions is likely to be infrequent. As discussed above, some canary rockfish may also use oyster shells for cover and rearing.

Mechanical harvest, although widely used in Willapa Bay and Grays Harbor, is used sparingly in Puget Sound compared to other harvest methods. The NPSAA currently contains approximately 200 acres of continuing ground-based active acres that are harvested mechanically. Given the extended time-frame of this proposed action, we believe that mechanical harvest is likely to affect larval canary rockfish upon occasion in the NPSAA and could occur on up to 200 acres during the period of the proposed action.

Given the potential acreage of mechanical harvest in NPSAA for this 20-year action and the proximity to functioning rockfish habitat, it is reasonably certain that some canary rockfish may be present in ground-based oyster habitat during mechanical oyster harvest. While juvenile canary rockfish may have the swimming speed to avoid mechanical harvest gear, NMFS assumes they may find cover in oyster shells to be harvested upon disturbance. Because of the infrequent use of mechanical harvest and because juvenile canary rockfish are sparsely dispersed among a very large area compared to the action area, only a few canary rockfish are likely to suffer injury or death from mechanical harvest each year, and only in the NPSAA, north of Point Wilson (Point Wilson demarcates the boundary between mid and north Puget Sound). Because canary rockfish are a fecund species which can produce 200,000 to 2 million eggs in a reproductive cycle, the loss of a few juvenile canary rockfish juveniles each year will have no bearing on population viability. Effects on canary rockfish critical habitat are described in Section 2.11.

Cultch Bag Collection and Transport.
As discussed above, juvenile rockfish of unknown species have been observed in utilized oyster (cultch) bags as habitat in Discovery Bay, Washington. The NMFS analyzed the potential for take of canary rockfish during cultch bag collection in oyster cultivation areas. Because cultch bags are typically placed at tidal elevations of +1 or higher, and because collection happens when the tide is out, it is extremely unlikely that juvenile canary rockfish would be occupying a cultch bag during removal and transport.

Figure 5. Oyster Cultch Bags Used to Collect Rockfish in Discovery Bay

Green Sturgeon
Mechanical Harvest

Mechanical harvest and associated harrowing are widely used in both Willapa Bay and Grays Harbor. According the COE, approximately 11,071 acres could be harvested mechanically in Willapa Bay, with another 7,236 acres of continuing fallow and 60 acres of new culture area that could be brought into production over the next 20 years, totaling 18,367 acres of mechanical harvest (COE, 2015). In Grays Harbor, approximately 996 acres are in continuing active ground-based culture with mechanical harvest, with another 1,767 acres of continuing fallow that could be brought into production and harvested mechanically over the next 20 years, totaling 2,763 acres. Green sturgeon that use these estuaries are sub-adults to adults, and as such are strong swimmers that can use a variety of habitats in the estuarine environment. However, given the 20 year time frame of the action coupled with the scale and frequency of mechanical harvest, we find likely that adverse effects on green sturgeon from contact with a mechanical harvester or harrow could occur during that activity. As such, take of green sturgeon reasonably certain to occur in these sub-regions.

Salmonids (PS Chinook and HCSR Chum)
Suspended Sediment

Many aquaculture activities produce minor levels of elevated suspended sediment. These activities, including harrowing, beach preparation, and maintenance activities are not expected to produce suspended sediment at levels that would be expected to adversely affect listed fish.

Geoduck dive harvest and mechanical harvest in particular, are also known to produce elevated suspended sediment and subsequent turbidity. Geoduck dive harvest is used throughout the Puget Sound for both intertidal and subtidal harvest. Because geoduck culture occurs in mostly sandy substrate, dive harvest produces small sediment plumes that generally settle out quickly (Short and Walton, et al 1992). Further, harvest of geoduck occurs one geoduck at a time, producing sporadic, dispersed plumes over the harvest area. While mechanical oyster harvest is widely used in Willapa Bay and Grays Harbor, it is rarely used in Puget Sound and the Eastern Straits. Nevertheless, in areas where mechanical harvest used, elevated suspended sediments and subsequent turbidity would be expected.

Effects on salmonids from elevated turbidity have been well documented. Newcombe and Jensen (1996) analyzed some 80 reports on documented fish responses to suspended sediment in streams and estuaries, and identified a 14-point scale of ill effects based on behavioral, physiological and pathological responses to suspended sediment concentration and duration of exposure. The logistic relationship between TSS concentration and exposure duration represents the effective 'dose' experienced by fish from which a range in responses can be predicted. In consultation practice, we have interpreted level 6 on the Newcombe and Jensen (1996) scale as the 'break point', where fish exposure to suspended sediment may lead to adverse effects. This level is reached, for example, at exposure to high levels of suspended sediment (1,097mg/L) for 1 to 3 hours.

Studies have also shown that salmonids have an ability to detect and distinguish turbidity and other water quality gradients (Bisson and Bilby 1982 Servize and Marins 1992), and that larger juvenile salmonids are more tolerant to suspended sediment than smaller juveniles (Servizi and Martens 1992). The highest levels of turbidity would be produced by mechanical harvest. Because mechanical harvest happens at depths sufficient to avoid grounding by a work boat with a crane, it is highly unlikely that young of the year juvenile salmonids would co-occur in the vicinity of the mechanical harvest because they prefer very shallow habitat (Fresh, 2006). As such, any salmonid in the area affected by mechanical harvest would likely be older and larger than young of the year, with stronger swimming abilities, and would have the ability to move away from high levels of suspended sediment; thus, we do not expect adverse effects to any listed fish. Increases in suspended sediments are very unlikely to reach a level that would rise to the levels of injury, death, or significant behavior modification.

Suppression of Eelgrass

The main mechanism through which the proposed action is likely to affect PS Chinook salmon is through effects to eelgrass. With the exception of new culture areas that require a 16 foot-buffer from eelgrass, the proposed action is reasonably certain to disturb eelgrass, and perhaps reduce plant densities within the footprint of management actions covered by the proposed action. A 16-foot buffer from native eelgrass will be required for all new shellfish culture areas to accommodate natural expansion and contraction of eelgrass, as documented in Puget Sound by DNR (Unpublished data). The proposed action is likely to maintain conditions limiting eelgrass beds within the continuing active footprints; and to disturb and suppress eelgrass where active management is initiated at previously fallow sites inhabited by mature eelgrass beds. As noted earlier, there is no information available regarding the amount of fallow acres inhabited by eelgrass that might be converted to active culture during the term of the proposed action, so to be conservative, we assume for purposes of analysis that all fallow acres may be converted to active culture during the term of the proposed action.

Eelgrass beds provide cover for juvenile salmonids, and structure for the spawning of species upon which juvenile salmonids prey. Eelgrass beds and eelgrass patches are a foundational element in the inter-tidal and sub-tidal environment, throughout the action area, supporting the base of the food web. Throughout most of the Puget Sound region, eelgrass is of primary importance as a herring spawning substrate (Mumford 2007; Blackmon et al. 2006). Eelgrass patches also provide cover and forage for herring (and other forage creatures) (Blackmon 2006) upon which juvenile salmon and steelhead feed (Groot and Margolis, 1991).

Juvenile salmonids utilize a variety of habitats during their migration through Puget Sound. Early emigrants, particularly Chinook salmon, which spend weeks to several months in nearshore areas, use eelgrass because it provides cover, refuge and a prey base for small fish at this vulnerable life stage. Juvenile HCSR chum salmon, which migrate quickly through estuarine habitat on their way to the ocean, will occur in eelgrass and other shallow nearshore areas within their emigration habitats, but do not rely on eelgrass directly. Their main prey feed on detritus from salt marsh and eelgrass, as well as other upland, intertidal, and sub-tidal plants. We note HC summer chum are emigrating mid-Feb through March, a time when eelgrass is senesced and at its lowest biomass. Also, we note the estuarine use model appended to the HCSR chum salmon recovery plan (2005) was mistakenly founded entirely on data from fall-run chum salmon, and the purported reliance on eelgrass described in that model is not supported by the best available science (WDFW, 2000). Juvenile HCSR chum salmon's dependence on a variety of habitats as opposed to a single habitat (eelgrass), is further supported by Simenstad et al 1998; "from variety of ecological standpoints, the functions of this beach landscape for migrating juvenile summer chum should be viewed as the net effect of the arrangement of habitat patches, rather than the independent effect of any one habitat". Further, we found no data to support the notion that impacts on eelgrass in Hood Canal are having negative effects on HCSR chum salmon. Therefore, we discount potential for adverse effects on HCSR chum salmon of altered eelgrass by shellfish culture. The following discussion is focused on effects of suppressed eelgrass on PS Chinook salmon.

Beds of eelgrass are dynamic in response to natural and human disturbance (Mumford 2007). Eelgrass spreads from both seed source and rhizome growth. Where sufficient rhizome nodes remain intact following disturbance, eelgrass can recover (Cabaco et al. 2005), although recovery may take an extended period of time and eelgrass density may be initially lower. Eelgrass regrowth can occur on a shellfish bed following aquaculture activities that have removed existing eelgrass, but cyclical management activities alter the density of eelgrass in managed sites for a season or more, with higher densities returning after season of no disturbance (Horwith 2013). The type of aquaculture practiced is significant when considering the degree and type of disturbance to eelgrass in a given aquaculture area. Several authors have documented reductions in the spatial cover and density of eelgrass plants in response to oyster cultivation directly on the bottom (Rumrill and Christy, 1996, Schreffler and Griffin, 1999, Tiranni, 1995). Lower density of eelgrass in shellfish beds is also probable for off-bottom culture as well, as it limits conditions favorable to eelgrass growth. Off-bottom, stake (see Griffin 1997), and rack culture is associated with sedimentation, which appears to be the primary cause of eelgrass depletion observed in some areas where this type of aquaculture is practiced (Everett et al 1995). According to Tallis et al (2009), eelgrass in closely-spaced longline growing areas was 32% smaller than reference sites, and had a production rate of about 70%. Bottom cultivation led to increased eelgrass growth rates, but also led to lower density of eelgrass. In particular, dredge harvested bottom cultivation resulted in 70 percent fewer eelgrass plants, while hand harvested bottom culture resulted in 30% fewer plants (Tallis, et al. 2009). However, the same study observed increased growth rate of eelgrass in recently dredge harvested areas compared to reference areas (Tallis, et al. 2009). In summary, management of a culture area and periodic harvest is expected to generally result in decreased eelgrass densities within the growing area. Further, direct ground placement of growing apparatus such as oyster bags and other gear, can preclude or reduce colonization of eelgrass. Various aspects of geoduck culture (presence of tubes and disturbance after harvest, for example), also results in a lower density of eelgrass for a season or more (Ruesink and Hacker 2005).

Other studies further discuss the dynamics and reactions of eelgrass given different shellfish techniques, and indicate that eelgrass can thrive at levels close to undisturbed levels at least temporarily with certain aquaculture methods. Horwith (2013) documented a large colonization of eelgrass during a geoduck grow cycle. In Humboldt Bay, California, Rumrill and Poulton (2003) found that at certain spacing of the longlines, eelgrass density as was nearly the equivalent of that in the reference plots. Specifically, longline spacing of 2.5 feet, 5 feet, and 10 feet were observed. Spatial cover and density of eelgrass plants within the10 foot spacing plot were within the range of variability observed in the reference (control) study plots (Rumrill and Poulton (2003). We note that longlines do limit some amount of eelgrass survival directly below the lines, and particularly if they are mechanically harvested, which can damage eelgrass that was directly beneath the line. As such, within the footprint of managed sites where aquaculture is occurring, complete recovery of eelgrass in one season following no disturbance is unlikely.

The regional nearshore section of the PS Chinook salmon recovery plan (2007) identifies potentially detrimental impacts from shellfish culture to nearshore habitats, including negative impacts to eelgrass meadows. However, as described above, more recent studies suggest that while some adverse effects are likely, the total effects are more nuanced than the regional nearshore section states. (Horwith 2013, Dumbauld et al 2009, WSG 2013). The impacts described in the regional nearshore section include decreased eelgrass abundance, decreased shoot density and cover, and poor natural recovery after the cessation of oyster culture in a given area (Williams, et al. 2001 in Recovery Plan 2005). The Recovery Plan cites “studies referenced by Williams 2001” that reported decreases in benthic surface area and direct physical disturbance as probable causes of eelgrass impacts at culture sites. Williams (2001) also looked at mechanical oyster harvest (oyster dredging), and noted a decrease of eelgrass not only within the harvest site, but in adjacent, non-dredged sites as well, suggesting effects on eelgrass from elevated sedimentation can occur outside of managed shellfish plots. The Plan also identifies off-bottom culture, particularly rack culture, results in shading and either erosion or sedimentation that appear to be the primary cause of eelgrass depletion in those areas. Both rack and stake culture cause a decrease in eelgrass, and stake culture additionally results in an increase in algae such as Ulva (sea lettuce) and *Enteromorpha.* Excessive growth of these algae on eelgrass are suspected of having a negative effect on eelgrass (Griffin, 1997). While there is undoubtedly some limited adverse impact to eelgrass from ground disturbances involved in shellfish culture, the more recent research suggests that eelgrass can recolonize disturbed areas quickly and can persist at lower levels in actively cultivated areas. A review of publically available aerial photography (e.g. Google Earth) shows apparently dense eelgrass sites immediately adjacent to managed aquaculture sites. Such review also shows that eelgrass is also present at low to medium densities at many aquaculture sites, at least during portions of the production cycle at these sites. This occurrence was recently documented at the Fisk Bar site in Samish Bay, where geoduck was planted in nearly bare mud in 2002 (Figure 6). Eelgrass that colonized the site, and was reduced upon harvest of the geoduck in 2008. In following years the area was replanted, and tubes were removed. In 2013, the area was a dense eelgrass meadow with geoducks nearing harvest stage (Figure 7) (Horwith, 2013). After harvest, eelgrass would be at a much lower density. It should also be noted that this site is near eelgrass meadows with a large seed source, which is not the case for all culture areas. Although shellfish aquaculture does not prevent eelgrass growth or its spread to sites next to or near managed sites, the historic and ongoing activities of shellfish aquaculture limit the formation of high density eelgrass beds within currently cultivated aquaculture sites, depending on the culture type (Tallis, 2009). In contrast, perhaps with the exception of turbidity produced by mechanical harvest, harrowing, and other ground-disturbing activities, there is nothing inherent in shellfish aquaculture that impairs or prevents the growth of eelgrass and formation of functional beds adjacent to or near active shellfish aquaculture sites (Cziesla, et al. 2015).

In summary, shellfish activities will result in varied levels of effects on eelgrass, although most activities, including most ongoing activities, will continue to suppress eelgrass to some degree. Mechanical harvest has the greatest effect on eelgrass, while longline culture appears to have minimal effect when spaced at certain intervals. As such, we conclude there is a reduced level of eelgrass that will continue into the future, and eelgrass will also be precluded from fully colonizing most but not all currently fallow areas that come into production over the next 20 years.

Figure 6. Fisk Bar Initial Geoduck Planting 2002.

Figure 7. *Z. marina* at Fisk Bar Geoduck Site, 2014.

As discussed earlier, juvenile salmonids use eelgrass for forage and cover. PS Chinook are particularly reliant on eelgrass for cover. Studies suggest that the forage-related impacts of disturbance to and suppression of eelgrass resulting from shellfish culture have very limited impacts on forage, because managed shellfish sites are themselves inhabited by forage species. For example, Dumbauld (1997) found that when comparing the function of habitat at oyster bottom culture sites to eelgrass beds and mud bottom habitat, both eelgrass beds and oyster culture sites provide similar species richness and habitat utilization by salmonids compared with adjacent mud flat habitats. Densities of epibenthic invertebrates, including harpacticoid copepods, gammarid amphipods, and cumaceans, were elevated at some oyster cultivation sites where they can serve as prey items for emigrating Chinook and coho salmon (Simenstad et al., 1991). A study of similar comparisons with rack and bag shell fish aquaculture found similar results in a tidal estuary in Southern Rhode Island (DeAlteris et al. 2004). Large expanses of living oysters and shell rubble have been shown to serve as important nursery and refuge habitat for juvenile fishes, shrimps, crabs, and other invertebrates (Ambrose and Anderson, 1990; Doty et al., 1990, Dumbauld et al., 1993, Eggleston and Armstrong, 1995, Simenstad and Fresh, 1995). We did not locate studies that discuss use of shellfish growing areas by juvenile salmonids, and as such, the use of these areas by juvenile salmonids as forage or cover has not been confirmed. Nevertheless, given that PS Chinook salmon are widely distributed in Puget Sound and Hood Canal, we find no reason to believe they don’t spend part of their life cycle foraging or rearing in aquaculture sites. In summary, the effects of the proposed action on salmonid forage attributable to effects on eelgrass are expected to be very minor.

Chinook salmon are preyed on by a wide variety of fish, birds and mammals during their nearshore residence (Fresh 1997). Simenstad et al. (1982) suggested that some features of nearshore ecosystems may help reduce predation on juvenile salmon. These include high levels of turbidity, presence of shallow water habitat (including eelgrass), and abundant and diverse prey resources that sustain high growth rates and allow juvenile salmon to rapidly outgrow many of their predators. When exposed to predators, juvenile Chinook salmon preferentially chose eelgrass habitat over oyster clusters in field experiments in an enclosure, as well as in mesocosm experiments involving exposure to a mock predator (Dumbauld et al. 2004). The proposed action will result in decreased cover through suppression of eelgrass throughout the nearshore range of Chinook salmon in Puget Sound. This effect will result increased predation and will negatively affect the survival of Puget Sound Chinook salmon

As described above, shellfish aquaculture activities are expected to disturb and suppress eelgrass growth, and thus would be expected to limit the amount of cover available to juvenile PS Chinook in areas where these activities overlap with eelgrass beds. To analyze the extent of this effect on PS Chinook salmon, we looked at spatial overlap between these species and aquaculture culture areas. More specifically, we looked at likely overlaps with eelgrass, aquaculture, and juvenile salmon. Because fallow areas are most likely to have mature eelgrass beds, we would expect impacts to be greatest in those areas, upon initiation of new culture activities. Without confirmed acreages of colonization by eelgrass in fallow areas, the COE in their PBA relied on WDNR monitoring data and potential overlap with existing fallow areas in designated critical habitat for PS Chinook salmon. Fallow acres in the SPSAA, NPSAA, and Hood Canal combined are approximately 3535 acres; with 402 in Hood Canal, 780 in SPSAA, and 2,333 in the NPSAA (Table 12). Based on overlap with existing WDNR eelgrass data, the COE estimated eelgrass may have colonized a total of 2,722 fallow acres, with 294 in Hood Canal, 2,333 acres in NPSAA, and 95 in the SPSAA.

Continuing culture activities are likely to result in ongoing suppressed levels or cyclical disturbance of eelgrass growth, as opposed to new disturbance. Acreages of continuing active aquaculture in total and located in eelgrass are summarized in Table 12. As with the overlap between fallow land and eelgrass, the largest amount of overlap between active aquaculture and eelgrass is in NPSAA (1131 of 1354 acres of active aquaculture in eelgrass), followed by Hood Canal (392 of 949 acres of active aquaculture are in eelgrass) and SPSAA (180 of 2351 acres of active aquaculture are in eelgrass).

Table 12. Summary of Continuing Activities Potentially co-located with Eelgrass (COE, 2015)

		Grays Harbor			Willapa Bay			Hood Canal			South Puget Sound			North Puget Sound			Total		
		active	fallow	total	active	fallow	total	active	fallow	total	active	fallow	total	active	fallow	total	active	fallow	total
Total continuing aquaculture	# footprints	26	17	28	239	114	251	111	117	209	362	99	375	70	26	71	808	373	934
	acres	1,145	1,820	2,965	16,397	9,468	25,865	949	402	1,351	2,351	780	3,131	1,354	2,333	3,687	22,196	14,803	36,999
Aquaculture potentially co-located with eelgrass	# footprints	17	13	--	161	81	--	34	42	--	2	1	--	21	13	--	235	150	--
	acres	766	1,152	1,918	12,170	7,448	19,618	392	294	685	180	95	275	1,131	2,239	3,370	14,639	11,227	25,866
% of aquaculture acres potentially co-located with eelgrass		67%	63%	65%	74%	79%	76%	41%	73%	51%	8%	12%	9%	84%	96%	91%	66%	76%	70%
Total eelgrass acres in region				36,415			39,861			3,265			2,950			47,725			130,216
% of total eelgrass in region potentially co-located with aquaculture				5%			49%			21%			9%			7%			20%

Notes:
1. Analysis is based on a single point coordinate for each aquaculture footprint provided in permit applications. If single coordinate is located within or upland of WDNR mapped eelgrass boundary, assume entire acreage associated with that coordinate is co-located with eelgrass. The analysis is therefore conservative and should be considered a course estimate appropriate for the broad action area.
2. Eelgrass data for Willapa Bay and Grays Harbor from WDNR (2001), and for other regions from WDNR (2013b).

Given the relatively low overlap between continuing shellfish footprints (including currently cultivated and fallow acres) and eelgrass beds in SPSAA, the two areas in which the greatest potential for impacts are Hood Canal and NPSAA. In Hood Canal, a total of 949 acres are in active cultivation, with a total of 392 of those acres in mapped eelgrass, and approximately 294 acres are currently fallow and potentially colonized by eelgrass (Table 3). As discussed in Section 2.3, the most recent information suggests a slightly positive trend in eelgrass abundance in Hood Canal from 2010 to 2014. In greater Puget Sound, including Hood Canal, a total of 438 new acres of intertidal area are anticipated to be brought into cultivation over the next 20 years, and will be required to follow the 16-foot buffer requirements from native eelgrass, this is not expected to diminish eelgrass density or function of existing eelgrass. Further, many sites of Hood Canal aquaculture are within 5 miles of Chinook salmon natal estuaries, and some lie directly in migratory routes used by juvenile salmonids in Hood Canal. We note the Regional Nearshore and Marine Aspects of Salmon Recovery, Shared Strategy (2005) highlights the greater value of Chinook salmon fry habitat within 5 miles of natal estuaries. As such, significant overlap of culture areas with nearshore migratory zones for young of the year salmonids will expose them to potential effects from periodic eelgrass disturbance from culture harvest and general aquaculture operations in Hood Canal.

In the NPSAA, where 2,333 acres are currently fallow and estimated eelgrass overlap with fallow is 96% (2,239 acres), the reinitiation of aquaculture activities on fallow land could affect a relatively large area. Approximately 50% of the intertidal area in Samish Bay is classified as continuing (10%) or fallow (40%). Thus, the overlap of eelgrass and potential future aquaculture areas throughout Puget Sound, and particularly Samish Bay and Hood Canal, will result in widespread, cumulative disturbance in eelgrass and some change in the functions it provides. As noted above, the most direct disturbance of eelgrass will come from expansion of aquaculture into current fallow areas where eelgrass has colonized. In total, fallow areas potentially colonized by eelgrass in Hood Canal and NPSAA total approximately 2,464 acres. We believe it is likely that an increase in area of disturbance to, and lower densities of native eelgrass in Puget Sound resulting from future commercial shellfish aquaculture (ongoing culture and expansion into fallow areas), will affect the ability of juvenile PS Chinook to find cover. This exposure is likely to result in a slight reduction in survival for juvenile PS Chinook salmon.

Cover Nets

Cover nets are used for clam culture and geoduck culture throughout the action area where shellfish culture occurs. As indicated by the acreage of geoduck and clam culture, and considering continuing fallow areas that could be brought into production of the 20-year time frame of the proposed action, cover nets are estimated to be used during the growing cycle, but not all simultaneously on 6,017 acres in Willapa Bay, 876 acres in Hood Canal, 2,735 acers in SPSAA, and 2,841 acres in NPSAA (COE, 2015) According to COE (2015), there are no cover nets used or proposed in Grays Harbor. On one occasion in Baynes Sound, British Columbia, a Manilla clam net was documented to have killed forage fish (Caseinlet.org). The proposed action includes a conservation measures to minimize this occurrence. We could not locate any reports that indicated any ESA-listed fish have been killed by cover nets. Nevertheless, given the prevalence of cover nets throughout the greater Puget Sound, Hood Canal and Willapa Bay and the 20-year time frame of the proposed action, it is reasonably certain that a few juvenile Chinook salmon, a few juvenile HCSR chum salmon, a few canary rockfish, and a few green sturgeon could become entangled in a cover net and be killed.

Nearshore Disturbance

When they first enter saltwater, juvenile chum are very small (typically less than 50 mm), not strong swimmers, and typically remain in very shallow water close to the shoreline (Simenstad 2000). They are thus more vulnerable to the activities conducted under the proposed action at this stage in their life history than other ESA-listed salmonids. There are a number of relatively small streams (e.g., Jimmycomelately Cr., Tahuya River) and even some larger streams (e.g., Hamma Hamma River) with spawning chum populations that have substantial aquaculture acreage located at the river mouth. For example, of the approximately 140 acres of tidelands at the mouth of Jimmycomelately Cr., 68 are classified as fallow aquaculture and 11 acres are classified as active aquaculture. The fallow acreage alone represents about 50% of the total tideland area. It is possible substantial new acreage could also be initiated in one or several of these estuaries to the point where most of the estuarine tidelands are engaged in some form of aquaculture. Aquaculture activities in these areas can include occasional vehicle traffic and vessel grounding, temporary placement of oyster apparatus (crates, etc), geoduck harvest, foot traffic, and other aquaculture-related activities.

If shellfish culture activities were conducted in the main flow of the channel, chum may be vulnerable to injury from striking equipment or being crushed. The action would result in temporary in-water disturbance and noise associated with human activity including foot traffic and movement of shellfish gear. These effects would occur broadly throughout the action area and occur on a near daily basis for the 20-year period of the proposed action including when juvenile chum salmon are present. These activities would displace juveniles. They may be unable to avoid areas with high levels of activity in some cases, for example, in tidal channels adjacent to work areas. Given the narrow band of shallow water habitat along the shoreline in Hood Canal, it is possible a shellfish activity and its immediate effects could occupy most of this shoreline habitat in a localized area and potentially interrupt migration, forcing juveniles into deeper waters and increasing their vulnerability to predators. As such, it is reasonably certain that a few HCSRC salmon could be injured or killed as a result of these activities during the 20-year time frame of the proposed action.

Other Effects

The following potential effects to listed species are expected to be minimal.

Potential for pollution from PVC Geoduck Tubes

As discussed above, geoduck culture uses PVC tubes as part of the growing process. We analyzed the degradation of rigid polyvinyl chloride (PVC) pipe tubes inserted in the beach, and possible leaching of contaminants from the plastic into marine waters. We reviewed applicable literature to better understand the fate of rigid PVC in marine water. From this literature, it appears that the material (PVC) is inert, and sediment near tubes on geoduck farms has not shown any evidence of microplastics or leaching of metals (Schenck, 2011). Laboratory analysis indicates PVC is sensitive to temperatures above about 122°F and high ultraviolet light exposure, and that these are the conditions where some leaching may occur (CEPA 2006, Younan et al, 1985). Neither of these conditions occur during shellfish culture. Further, if PVC pipe was exposed to enough ultra-violet sunlight that the PVC did depolymerize, the chlorine in the PVC might release as chloride ions. This is a relatively non-toxic form of chlorine and is a major constituent of seawater, composing over 1 percent of the weight of seawater. As such, any increase in chloride from PVC depolymerization would be undetectable (Schenck, 2011). Other constituents of concern in PVC are lead, silver, and chromium. Sediment testing around both new and used PVC tubes after 20 months in typical geoduck sediment revealed metals are not detectable in sediment regardless of what pipe was used (Schenck, 2011). Further, Pearce et al. (2007) detected no significant differences in percent organics, oxidation reduction potential, total organic carbon, and total nitrogen immediately before or up to 12 months after the geoduck clam seeding process. We also looked at the potential for leaching of phthalates, a plasticizer used in the production of PVC. However, rigid PVC, including the pipe material used in geoduck culture, does not contain phthalates. As discussed above in the conservation measures section, best management practices including securing cover nets and labeling of geoduck PVC tubes are intended to avoid and minimize the loss of tubes into Puget Sound. Because there is no indication that any detectable contaminants are released from geoduck tubes, we find it unlikely that this would result in any discernable effect on PS Chinook, canary rockfish, HCSR chum salmon, or green sturgeon.

Noise

Noise from equipment operation could temporarily disturb and displace aquatic species from the local area. To estimate noise produced by shellfish activities, an analysis was conducted using data from Wyatt (2008) for a commonly used vessel, a 21-foot Boston Whaler with a 250 horsepower Johnson 2-cycle outboard motor. Operating this vessel at full speed produced a sound measured at 147.2 decibels (dB) root mean square (RMS) re 1 microPascal at 1 meter4. Assuming a background underwater sound level of 120 dB RMS, which is the threshold established by NMFS for behavioral effects to marine mammals, and using the practical spreading loss model preferred by NMFS and USFWS, sound produced by this vessel would attenuate to 120 dB RMS within 65 meters (213 feet). Larger vessels could also be used on occasion which could potentially generate greater underwater sound levels.

The intermittent use of power equipment is likely to produce in air noise of up to 81 dBA for dive harvesting and 82 dBA for shoreline work. Over marine water, the 81 dBA value would attenuate to the background level (57 dBA) within 792 feet and over a terrestrial habitat the 82 dBA would attenuate to the background noise level of a rural environment (35 dBA) within 3793 feet (0.71 mile). Maximum surface noise levels from boat operations and dive support equipment for subtidal geoduck harvest was measured at 61 to 58 dBA at a distance of 100 feet where auxiliary equipment was housed on deck and 55 to 53 dBA where equipment was housed below deck (WDNR 2008).

While these sound levels may cause ESA listed fish to temporarily avoid the area from where sound is emitted, they do not reach levels that would cause any harm or result in take of any listed fish or marine mammal.

Benthic Disturbance.
Benthic disturbance for this analysis refers to the various activities that involve a physical interaction with the bottom. Activities that interact with the bottom under the proposed action include site and plot preparation, grow-out, and harvest. Benthic disturbance is also associated with restoration activities covered by this consultation. The issue for each of these activities and the benthic environment is whether and to what extent they influence the functional condition of the nearshore marine bottom environment, and whether any influence is significant enough to impair normal behaviors of listed fish in the action area. Several activities that are part of shellfish aquaculture involve proximal contact with the bottom. This implies some effect on benthic processes; specifically those processes that contribute to the production of food for listed fish. However, the intensity and duration of these habitat disturbances are local, small, and brief. However, several small disturbances may occur within close temporal proximity in a large waterbody such as Willapa Bay, where combined effects of the disturbances are measurable at the scale of the waterbody, but not necessarily the immediate area of disturbance. We also considered the benefits to biota of minor benthic disturbance, which exposes infauna to predation and increases the depth of oxygenated sediments. During this consultation, we found no evidence that such disturbances interfere with benthic productivity or otherwise decrease the availability of forage for salmon, steelhead, rockfish, or sturgeon to such a degree that would it impair normal behavioral patterns of listed fish in the action area. Because prey base and forage areas are abundant in the action area, any temporary disturbance caused by aquaculture activities are insignificant to Canary rockfish, green sturgeon, PS Chinook salmon, and HCSR chum salmon.

The primary issue for listed fish caused by benthic disturbance is whether or not bottom interactions from any source change conditions affecting the function of the benthic food web. The effects of those interactions on benthic function to produce forage for listed fish are variously reported. Straus et al. (2008) reported increased benthic species at mussel culture sites, decreased benthic species richness at oyster culture sites, and no significant differences in benthic species (infauna) between mussel farms, oyster farms, and reference sites. Dumbauld (1997), in a review of studies on the impacts of oyster aquaculture, reported that species abundance, biomass, and diversity are often enhanced in areas where oysters are cultured. ENVIRON 2008a, in a review of recent studies found that Fleece et al. (2004) reported that species richness of macroinvertebrates was higher in areas seeded with geoduck than in unseeded areas. ENVIRON 2008a also found that Pearce et al. (2007) reported similar results in species richness of benthic infauna two months after geoduck were seeded in an aquaculture site in British Columbia, Canada. Increased densities of benthic infauna at intertidal geoduck clam aquaculture sites may persist even after removing the protective PVC tubes and netting. For example, at one aquaculture site in Southern Puget Sound, ENVIRON 2008a found the average number of infaunal benthic organisms per sediment core from an unprotected seeded area was greater than the density of infaunal benthic organisms found in a reference area located outside of the aquaculture site. Thuesen and Brown (2011) observed an increase in biodiversity of benthic fauna in an intertidal geoduck farm using PVC tubes and predator nets, and species richness was significantly higher compared to a control site and compared to a geoduck farm without tubes and netting.

Some of the various hand or mechanical harvest or harrowing methods used in shellfish aquaculture involve a physical disturbance of the bottom that affects sediment and benthic fauna (Johnson 2002). In most cases, bottom disturbance reduces the number and abundance of benthic species in the disturbed area, although the extent of such reductions has been reported variously, including no effect at all. For example, hand raking and digging for various shellfish in Yaquina Bay, Oregon, did not impact infaunal species number and abundance as reported by Straus et al. (2008). Furthermore, while post-harvest reductions of some taxa have been observed at intertidal geoduck aquaculture sites in Southern Puget Sound, sites recover after harvest. The recovery rates of benthic communities following physical disturbance depend on a variety of physical, chemical, and biological factors (Dernie et al. 2003), but in general, they recover fairly quickly. Data developed by Chris Pearce (DFO Canada), as reported by ENVIRON (2008a) suggests that species richness and relative abundance of benthic fauna at a geoduck aquaculture site in British Columbia, Canada were restored to pre-harvest levels within six months.

Straus et al. 2008 cited other research that examined the return to pre-disturbance conditions. For example, a study that assessed sediment grain size as a metric of disturbance found that while bottom patches at which disturbance resulted in reduced or no fauna differed considerably in sediment grain size distribution, sediment grain size distribution (which presumably encouraged recolonization by local infauna) returned to ambient levels after about two months at the disturbed sites. Similarly, benthic fauna population abundances for most species returned to ambient levels two to three months after benthic disturbance, and the community structure returned to ambient conditions after four months. In Scotland, a high level of disturbance at suction-dredged intertidal cockle sites had an average of 30 percent fewer benthic species and 50 percent fewer benthic individuals, immediately after harvest (Straus et al. 2008). But within 56 days after harvest, the faunal assemblages at these disturbed sites were not significantly different from control sites. A similar study in southeast England examined the sediment structure and benthic community immediately following and seven months after suction-dredge harvesting for

Manila clams at an aquaculture site. Harvest suspended the sandy layer but left the underlying clay substrate and substantially reduced both infaunal diversity and the mean number of individuals per sample. However, after seven months, neither the sediment composition nor the benthic fauna were significantly different from control sites. Straus et al. (2008) report that the authors of these studies concluded that method of clam cultivation does not have long-term effects on the substrate or the benthic community at that location.

Additional shellfish aquaculture activities with benthic interactions include bed preparation such as “frosting,” which involves spraying gravel or oyster shell onto the intertidal area to make the bed firmer and to minimize predation on the bottom culture of clams and oysters. Frosting an intertidal region shifts the benthic community from polychaetes to amphipods and copepods, which are important prey items for juvenile salmonids (Jamieson et al. 2001), making this a beneficial result for salmonid forage production. Similar findings have been observed by Simenstad and Fresh (1995), and Thompson (1995), who observed an increase in density of both gammarid amphipods and nemertean worms on graveled plots, in addition to the presence of shore crabs not found on control plots. The greater diversity of biota is expected to indirectly benefit rearing habitats for juvenile fishes, including ESA-listed species.

As mentioned above, and summarized in Straus et al. (2008), benthic recovery typically follows disturbances for shellfish aquaculture. The stability and recolonization rates of benthic fauna can range dramatically depending on physical conditions (sediment type and stability, wave action, current), season, location, scale of disturbance, and whether recolonization occurs primarily through adult movement or larval settlement. Small benthic invertebrates produce more than one generation per year and thus have rapid recolonization rates. Intertidal species have adapted to habitat changes, and so chronic low intensity or sporadic medium intensity intertidal substrate disturbances are within the range of “behavioral or ecological adaptability” (Jamieson et al. 2001). The best available information on the resilience of benthic populations after geoduck harvest is limited and this subject has begun to be studied in Puget Sound (WSG 2013). geoducks are harvested once every five or six years, a period of time that is reasonably likely to allow full benthic community recovery in between harvests based on the information presented in the studies cited by Straus, et al. 2008.

In summary, intertidal and nearshore shellfish aquaculture activities cause minor disturbance of benthic habitat affecting the availability of benthic food resources for listed fish for a short period of time following disturbance. However, when these disturbances are combined they can represent a larger scale disturbance, and can occur at frequency that precludes complete benthic recovery in several discrete locations across a waterbody. Bottom-disturbing activities that could temporarily reduce or increase benthic resources occur every 1-7 years, depending on the species cultured. Nevertheless, these activities which can be considered at a large scale when taken cumulatively, effect only relatively small portions of the total tidelands in an sub-region at any one time. Percentages of total tideland in shellfish culture can be found in Table 2. In the Puget Sound sub-regions shellfish percentages of tideland range from 3.2% in NPSAA to 8.2% in Hood Canal. As such, regardless of sub-area, shellfish culture constitutes less than 10% in each sub region in Puget Sound. Grays Harbor and Willapa Bay have shellfish culture at 4.7% and 19.4% of tidelands, respectively. Any foraging or migrating fish would use surrounding areas while benthic resources are recovering at the disturbed site. In places with normal benthic diversity, with regular flows and normal nutrient balance, benthic items rapidly recolonize after disturbance, making food available again at the disturbed site. The consultation process revealed no evidence to support the argument that forage productivity is limited in and around managed sites. In fact, based on the currently available evidence, the level of benthic disturbance from existing shellfish aquaculture in Washington State is well within the range of normal benthic processes and slight effects on productivity are likely to be so limited in space (the footprint of the shellfish bed plus some down drift area to account for current) and duration (from a few hours to days, and certainly less than a year), that they are insignificant.

Water Quality—Change in Nutrient Balance.
Molluscan aquaculture is relatively benign in terms of effects on water quality compared to fish and shrimp culture which discharge high volumes of effluent. Because no organic inputs are added (the mollusks filter their food directly from the water), the impacts on water quality from changes in nutrient content are, if anything, small, low intensity, and of brief duration. However, mollusks concentrated on a farm still consume oxygen, produce carbon dioxide, and produce ammonia as an excretory product; the extent to which these accumulate depends on natural tidal flushing of water around the farm. While most of the ammonia diffuses into the water column, some will bind to local sediments and become subject to chemical conversions described below.

Rhode Island's Coastal Resources Management Council (CRMC 2008) described the fate of ammonia excreted by oysters, which is quickly taken up by phytoplankton, macro algae and eelgrass as a nutrient source. The report also found that oysters studied in a laboratory significantly increased rates of sedimentation to the bottoms of the tanks and altered the phytoplankton composition in the tanks (presumably because of selective feeding on one particular phytoplankton species). The CRMC report (2008) also points out that oysters are one of the mollusk species particularly useful in clearing phytoplankton from the water column because they continue to feed even when food concentrations are high and they presumably have enough food. The excess, undigested phytoplankton (along with other less digestible particulate matter) is incorporated into pseudofeces that sink more quickly to the bottom than would the phytoplankton particles themselves. And pseudofeces are a food source for many invertebrates that live next to oysters growing in situ.

The fate of the nutrients such as organic nitrogen in the sediment resulting from the presence of farmed shellfish depends to some degree on the amount of local sedimentation in relation to the absorptive capacity of the benthic microbial community. Microbes and nearby invertebrates and plants break down the organic material residual to the presence of the farmed shellfish (e.g. pseudofeces). Under normal conditions, aerobic bacteria will decompose that material into ammonia, which enters the process of nitrification to be converted to nitrite and nitrate, which in turn can be used as nutrients for benthic algae, SAV, or phytoplankton (if suspended again into the water column). In addition, deposition of organic nitrogen to the sediments may increase denitrification. Denitrification is the process by which nitrate or nitrite is converted to nitrous oxide or free nitrogen. This denitrification process represents a primary shellfish effect on estuarine nitrogen cycling and is the principal process by which shellfish can attenuate or reverse eutrophication processes in estuaries (Newell et al. 2002, Newell 2006, Rice 2007). The process can be completed by either aerobic or anaerobic bacteria and production of free nitrogen in particular represents a way by which nitrogen can be fixed by plants or returned to the atmosphere as nitrogen gas. The CRMC report (2008) also reported that most of sediment nitrogen is fixed by benthic algae (in the presence of light) and that substantial amounts of nitrogen are not released back to the water column as nutrients for phytoplankton.

In the most extreme situations of altered water quality from shellfish culture, when amounts of organic material are deposited in excess of what local micro-flora and fauna can process, anaerobic processes will dominate once the deposited material exhausts the oxygen available for aerobic decomposition. Results of extensive anaerobic decomposition are evident as the water above the sediments can become anoxic and ammonia, hydrogen sulfide and methane can be released into the water column. One such study conducted in the River Exe estuary in England found a thinning of the aerobic zone and minor changes in the benthic community under rack and bag oyster cultivation (Nugues et al. 1996). However, this situation is probably unique to that study area (relative to the action area for this consultation) as a partially enclosed estuary, and a drainage channel from a nearby village delivers stormwater and associated nutrients directly to the culture site (Cefas, 2013). While we are aware of discrete instances where anoxic conditions have occurred under mussel rafts, we are not aware of any instances of shellfish culture in the action area where anaerobic conditions have become dominant and effected ESA-listed organisms from shellfish culture.

In some cases, anoxic conditions in sediment have been reported below mussel rafts (Hargrave et al. 2008; Heffernan 1999). However, it was noted that in those cases studied, it was noted that better siting of the rafts could have minimized or removed these conditions. We have not evidence that anoxic conditions have occurred near mussel farms in Washington State. As such, shellfish aquaculture is not likely to change the balance of nutrient materials given the absorptive capacity of local microbial communities, the covered activities are unlikely to cause anoxia, excessive denitrification, or any of the results described above at levels expected to adversely affect listed fish or mammals. Therefore, these effects will be insignificant to the listed species and critical habitat.

Primary Productivity-Carrying Capacity.
Because shellfish are filter feeders, their primary food source is phytoplankton in the water column. As such, we considered whether increases in bivalve production may be so great as to lead to reductions in phytoplankton communities. Therefore, we looked at the potential for large shellfish operations growing large numbers of shellfish to cause a shift in the food web through reducing prey for primary consumers at the base of the food web. This is more likely to occur in sheltered embayments where flushing rates are low and foraging habitat for juvenile fish is limited or discontinuous. Many conditions influence the availability of phytoplankton in areas with shellfish aquaculture. In many inlets and bays where shellfish are cultured heavily, phytoplankton levels are high due to increased nutrient loads from: natural and human sources; naturally slow circulation: shallow depths; shading, and other reasons (PSEMP 2014). While these conditions are ideal for growing shellfish, studies of potential decreases in phytoplankton found no indications of large scale or even minor range-wide reductions in phytoplankton have been observed where shellfish are grown (Ruesink et al, in prep). Conversely, phytoplankton "blooms" have become more frequent in recent years throughout Puget Sound, as observed by PSEMP (2013, 2014).

One example of a confined or isolated embayment is Totten Inlet in South Puget Sound, which has the most concentrated aquaculture cultivation in Puget Sound, with over 2,100 acres in production. Totten inlet is also home to one of Washington State's largest fall chum salmon (*O. keta*) runs. Annual returns of 20-80,000 adult chum salmon enter Totten Inlet en route to Kennedy Creek to spawn. Juvenile chum salmon consume zooplankton within a food chain built on both plant detritus and phytoplankton (Groot and Margolis, 1991). The consistently high productivity of juvenile fall-rum chum here supports the premise that shellfish farming has had little to no effect on the availability of forage for juvenile chum salmon in Totten Inlet. Clearly, a reduction in overall carrying capacity is controlled by numerous factors that vary on a site specific basis. Dumbauld et al. (2009) conducted a study in Willapa Bay which documented a reduction in phytoplankton of 10 percent per 100 meters as water moves over oyster beds there. A similar study conducted by Ruesink et al. (in prep) in the south Puget Sound region of Totten Inlet have documented no such reduction in this more confined and aquaculture-intensive region. It should be noted that oysters and other shellfish are grown in Totten Inlet and other water bodies of south Puget Sound at higher densities than other areas of Puget Sound (Table 4).

Any discussion of carrying capacity for aquaculture in Puget Sound should acknowledge that the commercial fishery of wild stocks has extracted large quantities of geoducks annually since 1970. This may represent a slight net loss of the commercially available geoduck even with the addition of geoduck culture at the present level (Straus et al. 2009). But WDNR notes that wild geoducks are common at depths below the -70 feet where they are now harvested. Known maximum depths extend to -360 feet for dense stocks of wild geoduck.

WDNR and WDFW manages the subtidal wildstock fishery on state lands to harvest no more than about 2.7 % each year. Wild geoduck harvesting has occurred in North Totten Inlet, with 860,000 geoducks removed from the area in the 1980s (Newfields 2009). Carrying capacity in bivalve aquaculture is often dictated by the amount and availability of food in the water column. It should be noted that there is a high level of non-living organic seston in the waters of Totten Inlet to provide sustenance for the shellfish. Marine fish do not directly utilize this resource, and there is no evidence of a direct food chain connection. Primary production by phytoplankton in Totten Inlet was estimated to be 44,777 tons of carbon per year (t C/yr) during the spring/summer period, plus another 3,380 t C/yr during the fall/winter (Newfields 2009). As such, even if the consumption by clams and geoducks increased by 10 fold and with the addition of the estimated North Totten Inlet mussel farm consumption of 107,348 kg C/yr (118.35 t C/yr), the percentage of use would only be 1.5 percent of the calculated spring/summer phytoplankton production within Totten Inlet. With such a small percentage of the total phytoplankton used by these bivalves, the risk that there would be a significant effect on zooplankton abundance (a forage fish prey species), and hence that forage fish, or other organisms that forage on phytoplankton or zooplankton, would be affected, is insignificant.

Finally, the information reviewed during consultation suggested that shellfish aquaculture adversely affects forage fish species; including surf smelt, sand lance, and herring, in Washington State to the detriment of listed salmonids (Pentilla, 2007). Surf smelt and sand lance spawn at elevations above those where most shellfish culture is generally practiced. However, clam culture is typically found at +5 to +7 ft MLLW, which overlaps with surf smelt and sand lance spawning elevations. Herring do spawn on eelgrass, anti-predator nets, oyster beds, and hard substrates such as geoduck tubes in areas subject to shellfish culture. To minimize and avoid effects on forage fish species, specific, mandatory conservation measures are included in the proposed action. Conservation Measures 8 prohibits new activities from occurring above tidal elevation of +5 feet (MLLW) if the area is documented as Pacific Sandlance spawning habitat by the WDFW. Conservation measure 9 requires a herring spawn survey if conducting certain activities outside of the COE approved work window, and conservation measure 10 requires a spawn survey for sand lance or surf smelt prior to bed preparation or other activities outside of the approved COE work window.

Application of Imazamox

In 2014, the Washington State Department of Ecology issued a 5-year National Pollution Discharge Elimination System (NPDES) permit for shellfish growers to apply imazamox (trade name Clearcast™) to non-native Japanese eelgrass (*Zostera japonica*) (*japonica*) on clam culture beds only (not authorized for geoduck or oysters) in the Willapa Bay subregion. The Washington State Noxious Weed Control Board registered japonica as a Class C noxious weed on commercially managed Willapa Bay shellfish beds in 2011. *Japonica* in an aggressive eelgrass in the upper intertidal zone that forms dense beds that reduce clam condition (meat weight per clam on tideflats) (Tsai 2010). The extensive root and rhizome network as well as the foliage interfere with the cultivation and harvest of shellfish (Fisher Bradley and Patten 2011). Other data also show that dense beds of *japonica* provide cover for shellfish seed predators, and the fine sediments that accumulate in the beds promote changes in conditions more suitable for other predators of shellfish (Patten 2013 and Ruesink 2013). Ecology anticipates treatment with imazamox of approximately 3,000 acres of clam beds under this permit, all within Willapa Bay.

Studies have shown that, starting on bare mud flats, *japonica* typically grows into dense beds that retain organic matter and sediment that contributes to the general productivity of nearshore environments. These habitat modifications from conversion of bare mudflat communities to vegetated communities reduce native mudflat invertebrate communities (Merrill 1995, Ruesink et al. 2010). Further, Tsai et al. (2010) reported a reduction in flows of surface water across the tideflats up to 40% by Japanese eelgrass introduced into mudflats of Willapa Bay. In addition to *japonica* interfering directly with clam culture, field data indicate that green sturgeon feeding pits may occur less frequently in areas of *Z. japonica* (Corbett, Faist, Lindley, Moser 2011) (Fisher Bradley and Patten 2011). Results of a separate field experiment suggests that juvenile Chinook salmon (*Oncorhynchus tshawytscha*) have a preference for the native *Z. marina* over *Z. japonica* (Semmens 2008), perhaps because *marina* grows at lower tidal levels.

Prior to issuing the permit, several documents were produced by Ecology discussing the toxicity of imazamox and its potential effects on a variety of marine organisms, including green sturgeon, waterfowl, other vegetation, and species with EFH. According to the risk assessment and other literature, imazamox is practically non-toxic to fish because the acetolactate synthase (ALS) inhibitor pathway, the mechanism by which imazamox is absorbed into plants, does not exist in animals. At the highest imazamox concentration tested, there were no observed acute adverse effects on fish or aquatic invertebrates, including crabs and other crustaceans. Also, imazamox does not bioaccumulate in fish and other organisms and imazamox is rapidly degraded to biologicall inert when exposed to sunlight (Ecology, 2012). The total area of Willapa Bay is approximately 88,000 acres. Ruesink et al. (2010) reported that, as of 1997, Z. *marina* occupied

9.6% of Willapa Bay and Z. *japonica* occupied 7.7%. Ten years later, in a 2006/2007 survey of Willapa Bay, Dumbauld and McCoy (2007) estimated that there were approximately 13,762 acres of Z. *marina* (15.6% of Willapa Bay) and 12,183 acres of Z. *japonica* (13.8% of Willapa Bay). Areas of dense *japonica* were observed to stimulate nearby *marina* beds to grow at slightly high tidal elevations and mix with *japonica*, compared to sites with only *marina* (Ruesink et al. submitted).

Requirements (below) for use of imazamox in Willapa Bay are provided on pages 8, 9, and 10 of the NPDES Permit.

The Permittee must ensure that:

1. ***Direct supervision*** of the application of imazamox is performed by an aquatic licensed pesticide applicator.
2. All pesticide applicators must have current training in the use of equipment necessary to apply herbicides correctly.
3. Appropriately trained personnel calibrate the application equipment prior to each application.

The Permittee shall:

1. Only apply imazamox, or another herbicide if the Permittee is also covered under an experimental use permit (special condition S4.H), to commercial clam beds, excluding geoduck beds.
2. Not apply other pesticides to commercial clam beds during the four days before and after application of imazamox.
3. Apply imazamox to its commercial clam beds once *Z. japonica* levels meet or exceed the ***action threshold(s)*** in its DMP based on at least one pre-treatment survey.
4. Apply imazamox from April 15 through June 30 (dates inclusive).
5. Not treat a commercial clam bed more than once per year. Treatment of a commercial clam bed may be completed over multiple days if each area within the clam bed is only treated once per year.
6. Treat only after the commercial clam bed is exposed by the falling tide. After imazamox application there must be at least one hour of dry time before tidal inundation.
7. Aerial application of imazamox is prohibited. Ground based applications must not be made when wind speed exceeds 10 miles per hour.
8. Not directly apply imazamox into any ***drainage*** that contains *Z. marina* and is moving water off the treatment site.

The permit also includes provisions for posting signage during and after treatment, monitoring for efficacy, spill prevention and spill notification and clean up requirements. A 10-meter property line buffer must be observed during application. Per the Permit, imazamox may only be applied from April through June 30. All application of imazamox must be done by hand, with no aerial or other 'broadcast' type application allowed. Hazards from imazamox were estimated where the toxicological testing conducted did not produce significant adverse health effects in test animals and no dose response could be generated.

Japonica occupies a higher tidal elevation compared to the native eelgrass, *Z. marina*, so patches at medium density do not generally overlap (Harrison 1982, Bando 2006). Where dense beds overlap, as in large parts of Willapa Bay, *marina* tends to better retain its above-ground biomass and beds appear to expand higher in the tide zone by *japonica*'s ability to hold water on the tideflat (Ruesink et al. submitted). As such, distinct patches of *marina* can be found in dense fields of japonica, and at tidal elevations where z. marina would not typically occur. A screening-level risk assessment (SLERA) was prepared by Environ (2012) to assess the relative risk to a large variety of plants, animals, and environmental conditions in Willapa Bay. The SLERA found that risks are not significant for non-target fish, invertebrates, wildlife, and macroalgae as a result of the use of imazamox to control *japonica*. While risks to non-target aquatic vegetation are of potential concern, no effects on the native eelgrass *marina* were observed when it was covered with 20 to 30 cm of water, or at a distance of 6 meters from the spray zone during field testing and monitoring (ENVIRON 2012). But, in the absence of measures to minimize impacts to *marina*, risks to non-target vascular plants, could be significant. Use of the proposed 10-meter buffers to avoid unnecessary impacts to native eelgrass should provide sufficient margin of safety to minimize impacts to native eelgrass. Nevertheless, in areas where imazamox is applied, a small amount of *marina* will be killed. Because marina grows in dense beds throughout preferred tidal elevations in Willapa Bay, and beds typically expand or shrink by as much as 1 meter per year, any *marina* killed by inadvertent application of imazamox will likely fully recover within a few years. Further monitoring, as outlined in the Ecology draft permit, will enable adaptive management refinement, if needed.

Adult and sub-adult green sturgeon are common in the seawater and mixing zones of Willapa Bay during high salinity periods, with the highest abundance from July through early October when freshwater runoff and tidal ranges are least (Moyle et al. 1992). In a 2006/2007 survey of Willapa Bay, Dumbauld and the U.S. Department of Agriculture estimated that there were approximately 13,762 acres of Z. *marina* (15.6% of Willapa Bay) and 12,183 acres of Z. *japonica* (13.8% of Willapa Bay) (Dumbauld and McCoy 2006/2007). Application of imazamox will only occur during low tide and will be applied by hand on clam culture areas. As of 2012, growers in Willapa identified 6,000 acres as suitable for clam culture, although only 1,100 of those acres are currently in clam production (Ecology, 2014).

Co-occurrence of imazamox and green sturgeon is expected during application or shortly after tidal inundation of a treated area. Because green sturgeon are highly mobile, and because imazamox would be applied on only about 8% of the bay and not all at one time, this exposure is likely to be temporary for a few hours at higher tides after nearby applications. As such, considering the low toxicity and temporary exposure, effects from imazamox exposure are not expected to kill, injure, or significantly alter behavior patterns of green sturgeon, and are therefore unlikely to rise to the level of take. Any minor effects to green sturgeon will far too small to cause any populations level impacts to this species. Effects on salmonids from the application of imazamox are discussed in Section 2.11.

2.4.2 Effects on Critical Habitat

This PBO relies on the definition of "destruction or adverse modification", which "means a direct or indirect alteration that appreciably diminishes the value of critical habitat for the conservation of a listed species. Such alterations may include, but are not limited to, those that alter the physical or biological features essential to the conservation of a species or that preclude or significantly delay development of such features" (81 FR 7414).

Effects on CH for species in Table 11, including CH for canary rockfish are discussed in Section 2.11.

PS Chinook Critical Habitat in Puget Sound and Hood Canal. When designating CH for West Coast salmonids in 2005, NMFS identified the nearshore marine as important. This feature was defined as "nearshore marine areas free of obstruction and excessive predation with: (i) Water quality and quantity conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation; and (ii) Natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels." Nearshore marine areas are designated for PS Chinook. The action area contains elements of the nearshore marine PBF. Additionally, estuarine areas are designated for PS Chinook salmon.

Intertidal habitat occupied by existing and potential future shellfish aquaculture as well as eelgrass and sub-tidal eelgrass habitat, constitutes a small proportion of the intertidal salmonid habitat that exists in the action area. Critical habitat for salmonids has not been designated in Willapa Bay or Grays Harbor., The intertidal zone of Puget Sound, including Hood Canal, the San Juan Islands, Whidbey Island and Strait of Juan de Fuca, is roughly 125,736 acres of which 8% will have shellfish activity under the proposed action, all of which are designated CH for PS Chinook salmon. Current active continuing shellfish culture in greater Puget Sound totals approximately 4654 acres, with 1,201 acres of growth (9371 total) anticipated over the next 20 years in these areas. As such, current and future shellfish aquaculture will cover about 1 percent of nearshore habitat in greater Puget Sound. The COE estimates 8,170 of these acres in CH are continuing (cultivated and fallow) shellfish areas. This constitutes about 6 percent of total 161,800 acres designated CH for PS Chinook salmon, and less than 1 percent of the total 1,029,193 acre nearshore zone as described by Simenstead et al. (2011).

Shellfish Cover Nets

Loose cover nets could block nearshore migration corridors (PBF # 4) for juvenile PS Chinook salmon. While this is considered an adverse effect on critical habitat, it is not expected to occur on a regular basis but rather to occur a few times over the 20 year lifetime of the proposed action.

Submerged Aquatic Vegetation (Eelgrass).

The main mechanism through which the proposed action is likely to affect PS Chinook CH is through effects to eelgrass. As discussed above, eelgrass provides both habitat for forage fish on which salmonids feed, and cover for juvenile salmonids. Both of these functions are elements of the nearshore marine PBF.

As described in the Species analysis above, the primary effects on eelgrass related to aquaculture would be disturbance and suppression of eelgrass in existing culture areas, and in areas where shellfish culture is introduced into fallow lands where eelgrass has colonized. When considered in the context of the nearshore areas comprising the action area for this consultation, site-level effects on eelgrass and similar SAV are likely to slightly diminish the quality and function of PBFs of the nearshore marine environment in those HUCs.

Although shellfish aquaculture does not prevent eelgrass growth or its spread to sites next to or near managed sites, the historic and ongoing activities of shellfish aquaculture limit the formation of high density eelgrass beds within currently cultivated aquaculture sites, depending on the culture type (Tallis, 2009). In contrast, perhaps with the exception of turbidity produced by mechanical harvest, harrowing, and other ground-disturbing activities, there is nothing inherent in shellfish aquaculture that impairs or prevents the growth of eelgrass and formation of functional beds adjacent to or near active shellfish aquaculture sites (Cziesla, et al. 2015). So, the issue for this consultation is whether reduced density of eelgrass beds within the footprint of existing, new, and expanded aquaculture sites are likely to adversely affect critical habitat and if so, what will be the magnitude of those impacts on the quality of critical habitat PBFs.

As discussed above, areas under active shellfish culture may provide forage and cover similar to eelgrass. It does appear that shellfish culture results in temporary disturbances to eelgrass beds, and depending on the type and frequency of culture, may suppress the full development of eelgrass beds. Based on this, we conclude the existing shellfish culture and future conversion of fallow areas with eelgrass to shellfish culture areas in Samish bay and throughout Puget Sound including Hood Canal, as well as the preclusion of eelgrass colonization in new culture areas will result in some temporary adverse effects on designated critical habitat for PS Chinook salmon, in those locations where fallow areas are modified by aquaculture. However, because eelgrass appears able to recolonize areas in which shellfish culture is occurring and under some circumstances able to develop to nearly undisturbed densities; because shellfish aquaculture occupies a limited portion of designated PS Chinook CH that does or could contain eelgrass; and because these areas are distributed such that they are interspersed with undisturbed eelgrass; we conclude that these effects are minor.

Forage.
Bottom-disturbing activities have the potential to affect the availability of salmonid forage species. As discussed earlier, disturbance of eelgrass is one pathway through which forage may be affected. Bottom-disturbing activities outside of eelgrass beds may also affect forage. (See discussion in Species Effects). Surf smelt and sand lance spawn at elevations above those where most shellfish culture is generally practiced. Herring do spawn on eelgrass, anti-predator nets, oyster beds, and hard substrates such as geoduck tubes in areas subject to shellfish culture. Conservation measure 9 requires growers practice avoidance of these areas until the herring eggs have hatched. Herring eggs in shellfish culture areas is rare in many shellfish areas (e.g., South Sound) and obvious where it does occur, leaving masses of sticky adhesive eggs (Pentilla, 2007).

As discussed above, invertebrates that serve as forage for juvenile PS Chinook salmon have been well documented colonizing shellfish cultivation areas. Dumbauld (1997) found both eelgrass beds and oyster culture sites provide similar species richness and habitat utilization by salmonids compared with adjacent mud flat habitats. Simenstad (1991) found elevated densities of harpacticoid copepods and other important forage invertebrates in some shellfish farms. Similar results with rack and bag culture found were reported in a tidal estuary in Southern Rhode Island (DeAlteris et al. 2004). While some types of aquaculture reduces density of eelgrass within the footprint of an active culture area, the presence of shellfish culture and gear provides a level of forage that is comparable or greater than undisturbed eelgrass. Production of invertebrates suitable for forage by salmonids, and perhaps juvenile rockfish, comes from complex structure in the shallow sub-tidal and nearby organic detritus (e.g., salt marsh plants, riparian litter, algae, and eelgrass) (Washington Sea Grant 2015).

To the extent that each type of shellfish-culture influences structure, and rates and amounts of detritus-processing at a site-scale, production of forage may be affected. Based on the literature and extensive observations of several types of culture across the inter- and sub-tidal habitats in the action area, we believe there is a wide spectrum of forage production. Highest forage is associated with dense artificial structure and high local sources of detritus. Lowest forage is where few sources of detritus are available and beach conditions are simple with uniform grain-sizes of sediments. Cultures sites without cover-nets and near disturbed eelgrass would be intermediate in forage.

The cycle of shellfish culture can include many small-scale impacts (harvest and maintenance) in a given waterbody that when taken cumulatively, could have real effects on forage that can persist for up to 6 months. Even at this scale, shellfish activities that disrupt benthic forage occur on small percentages of overall tidelands in each waterbody, particularly in Puget Sound (Table 2).We conclude that, in terms of providing forage for juvenile PS Chinook salmon, the presence of active aquaculture which increases forage greatly offsets potential diminished forage resultant from suppression of eelgrass. Therefore, overall forage is not likely to be reduced such that juvenile salmonids are displaced or experience reduced survival. Therefore, while the proposed action may increase or reduce the availability of forage at the local scale, ample forage would continue to be available in the given waterbody, and as such, these activities are unlikely to appreciably reduce the quality of the forage PBF of critical habitat.

Cover.
Current and future suppression of native eelgrass has a negative effect on the natural cover PBF. As discussed above, the proposed action is likely to maintain conditions limiting eelgrass beds within the footprint of managed sites. Further, expansion into fallow areas colonized by eelgrass will cumulatively exacerbate this effect. As such, the quality and function of the natural cover PBF will be diminished by the proposed action.

As described above, activities that would occur under the proposed action have both beneficial and adverse effects on water quality, forage, cover, and aquatic vegetation, each of which are components of the nearshore marine, and estuarine PBF. As also described above, none of these essential elements are limited in the action area and effects on water quality, food, and places that produce food are likely to be too diffuse and short term to have any meaningful effect on the conservation role of critical habitat in the basins in which the action area lies.

Cover Nets

Critical Habitat for HCSR chum salmon
PBFs for designated CH for HCSR chum salmon are the same as those for PS Chinook salmon, discussed above. Loose cover nets could block nearshore migration corridors (PBF # 4). While

this is considered an adverse effect on critical habitat, it is not expected to occur on a regular basis but rather to occur a few times over the 20 year lifetime of the proposed action.

General Disturbance
Shellfish activities that occur in the shallow nearshore in Hood Canal during the late winter, early spring out-migration of HCSR chum salmon could hinder migration (PBF #4) through a number of mechanisms including vehicle traffic, foot traffic, vessel grounding, other machinery, and other effects associated with typical shellfish practices. This is considered an adverse effect on critical habitat for HCSR chum salmon.

Critical Habitat for Green Sturgeon
Similar to effects on CH from cover nets discussed above, loose cover nets could result in a migration barrier for green sturgeon in both Willapa Bay and Grays Harbor. While cover nets aren't currently used in Grays Harbor, we expect there could be some usage of cover nets over the 20-year period of the proposed action. Willapa Bay currently has approximately 3,380 acres of culture using cover nets, with an addition 2,637 fallow acres that could have cover nets under the proposed action, for a total of 6,017 acres. While conservation measure 19 is intended to minimize the occurrence of loose nets, we expect loose nets to occur occasionally over the 20-year period of the proposed action, causing entanglement and blockage of migration. As such, this is considered an adverse effects on their critical habitat.

As explained in detail above, the water quality PBF 4 for Green sturgeon would be temporarily adversely affected from the application of imazamox. Water quality impacts from the project will be minimal and temporary and are not likely to affect the ability of PBF 4 to provide for the recovery of SDPS green sturgeon. The projects will have no effect on migratory corridors, substrate type or size, water depths, food resources, or sediment quality.

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). 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.

For this consultation, NMFS identified two general groups of actions to conduct the cumulative effects analysis. These groups include the environmental results of climate change and tribal, state, and local government actions related to salmon recovery planning.

Climate Change
One of the likely cumulative effects on aquatic habitat throughout the action area is future climate change. Fluctuations in climate and sea level play a role in determining the suitability of nearshore and estuarine aquatic habitats through their influence on circulation and water properties. Given the increasing certainty that climate change is occurring and is accelerating, climate conditions in the future will not resemble those in the past. The following discussion is based on "Uncertain Future: Climate Change and its Effects on Puget Sound," prepared for the

Puget Sound Action Team by the Climate Impacts Group (Snover et al. 2005). This discussion is focused on Puget Sound, but the findings are also appropriate for Willapa Bay and Grays Harbor.

Climate warming will shape the Puget Sound ecosystem from both the bottom-up (via impacts on phytoplankton and other marine plants that comprise the base of the food web) and the top-down (via direct impacts on top predators such as salmon and marine mammals). Taken together, these changes could be dramatic. In the coastal ocean, for example, broad reorganizations of the marine ecosystem have been associated with the subtle decade-to-decade changes in climate associated with the Pacific Decadal Oscillation (PDO). This has resulted in salmon in the coastal waters of Washington, Oregon, California, British Columbia and Alaska returning in relatively large or small numbers, depending on the phase of the PDO.

Future climate-related changes in the environment will be accompanied by changes in other factors such as human activities that are also very difficult to predict. The ultimate impact on each individual species that calls Puget Sound home will depend on how each of these changes reverberates across the food web, how each change interacts with every other change, and on the ecosystem's ability to adapt to a rapidly changing chain of estuarine and oceanic conditions.

Fish and other animals will be affected by climate change in many ways—directly via changes in habitat and indirectly via changes in the availability of food. Temperature is a dominant controlling factor of growth rates of most cold-blooded marine organisms. Increasing water temperatures can increase growth rates, providing many benefits, but only to a certain point. Temperatures that are too warm can stress an organism, causing decreased growth and survival and weakened immune systems, which have been linked to disease epidemics in marine populations (e.g., sea urchins) and seabirds and disease-related marine mammal strandings.

The consequences of warmer temperatures may be especially severe for species unable to seek out cooler temperatures, especially at vulnerable life stages. For this reason, increasing water temperatures above the optimum level for stationary shellfish, for example, could have more severe impacts than increasing water temperatures above the optimum level for salmon that could presumably move to pockets of cooler water.

The earth's oceans are also warming, with considerable interannual and interdecadal variability superimposed on the longer-term trend (Bindoff et al. 2007). Historically, warm periods in the coastal Pacific Ocean have coincided with relatively low abundances of salmon and steelhead, while cooler ocean periods have coincided with relatively high abundances (Scheuerell and Williams 2005; Zabel et al. 2006; USGCRP 2015).

Ocean Acidification

Ocean acidification resulting from the uptake of carbon dioxide by ocean waters threatens corals, shellfish, and other living things that form their shells and skeletons from calcium carbonate (Orr et al. 2005; Feely et al. 2012). Such ocean acidification is essentially irreversible over a time scale of centuries (Royal Society 2005). Increasing carbon dioxide concentrations are reducing ocean pH and dissolved carbonate ion concentrations, and thus levels of calcium carbonate saturation. Over the past several centuries, ocean pH has decreased by about 0.1 pH units (an approximately 30 percent increase in acidity), and is projected to decline by another 0.3 to

0.4 pH units (approximately 100 to 150 percent increase in acidity) by the end of this century (Orr et al. 2005; Feely et al. 2012). As aqueous carbon dioxide concentrations increase, carbonate ion concentrations decrease, making it more difficult for marine calcifying organisms to form biogenic calcium carbonate needed for shell and skeleton formation. The reduction in pH also affects photosynthesis, growth, and reproduction. The upwelling of deeper ocean water, deficient in carbonate, and thus potentially detrimental to the food chains supporting juvenile salmon has recently been observed along the U.S. west coast (Feely et al. 2008).

Acidification in Washington State coastal and estuarine waters is compounded by a combination of factors (Feely et al. 2012). Upwelling of carbon dioxide-rich offshore waters with naturally low pH from respiration processes exacerbates the effects of anthropogenic carbon dioxide. Inputs of nutrients such as nitrogen, silicate, and phosphorus from upwelling and surface runoff stimulate the growth of marine algae, temporarily decreasing carbon dioxide and increasing pH. As these blooms die and decompose, carbon dioxide is released and pH values are driven down in deeper waters. Similarly, carbon dioxide is released via bacterial respiration from decaying organic matter delivered to coastal and estuarine waters from freshwater rivers and streams. All of these forces converge and interact at the coasts, making these areas particularly sensitive to the impacts of climate change. Puget Sound Chinook salmon and their CH could be effected from acidification a number of ways, including declines in forage such as zooplankton and invertebrates, and declines in range as areas unsuitable for their survival. Similarly, canary rockfish could become displaced and as their deep-water habitat pH is lowered through the increase in carbon dioxide, which would also result in a decrease of dissolved oxygen, further impeding survival of canary rockfish and their prey.

Other Effects

Washington's population grew by over one million people between 1990 and 2000 (Washington State Office of Financial Management 2007). The Washington State Office of Financial Management projects the population will increase another 41 percent by the year 2030, primarily in the counties along Puget Sound and adjacent to metro areas. This increase is expected to result in some activities that are likely to adversely affect canary rockfish and salmon critical habitat within the action area, such as development, recreational activities, and road construction and maintenance.

The most common activities reasonably certain to occur in or affect the action area are agricultural activities, urban and suburban development, recreational activities, and road construction and maintenance. These activities are often not Federal actions and may result in adverse effects on canary rockfish and their habitat as well as salmon critical habitat. These adverse effects can include water quality impairments that lead to pre-spawn mortality or poor survivability, loss of food source from habitat destruction, migration barriers, overfishing, and others. Some of the activities, such as development, are subject to regulation under state programs, and the effects on fish and stream habitats are reduced to varying degrees under these programs compared to past effects reflected in the environmental baseline.

When considered together, these cumulative effects are likely to have a small negative effect on canary rockfish population abundance and productivity, and some short-term negative effects on spatial structure. Similarly, cumulative effects are likely to have some negative impacts on the quality and conservation value of critical habitat of PS Chinook salmon in the action area.

2.6 Integration and Synthesis

The Integration and Synthesis section is the final step in our assessment of the risk posed to species and critical habitat as a result of implementing the proposed action. In this section, we add the effects of the action (Section 2.4) 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) reduce the value of designated or proposed critical habitat for the conservation of the species.

<u>Canary Rockfish</u>

Canary Rockfish are listed at threatened, and the primary driver for this status is overfishing, rather than habitat impairment. As discussed in Section 2.2, there is no single reliable population estimate for canary rockfish, but catch data provides evidence that each species' abundance has dramatically declined. The total numbers of adult rockfish (all 17 species) in the Puget Sound region is estimated to have declined by 3 percent per year for the past several decades, which corresponds to an approximate 70 percent decline from 1965 to 2007 (Drake et al. 2010). When we consider the effects of the proposed action in the context of the status of the species and the baseline, we determine that because canary rockfish juveniles are at low abundance throughout North Puget Sound, it is unlikely that juvenile canary rockfish would occupy any one area in significant numbers (Palsson et al 2007).

Given the patterns of rockfish life history, only larval state rockfish will be encountered during aquaculture practices, and we expect very minor reductions in juvenile canary rockfish abundance when mechanical harvest occurs. There is no likelihood of effects on the adult fish or breeding populations with potential to alter the DPS' productivity. With de-minimus effect on abundance of adult populations, it is reasonable to assume the proposed action will have effectively no impact on spatial structure and diversity on the DPS of canary rockfish.

The major effect of the project on listed canary rockfish is that a few canary rockfish might be injured or killed each year of the proposed action, when mechanical oyster harvest occurs, and from entanglement in shellfish cover nets. It is impossible to predict when and where juvenile canary rockfish may occupy harvest areas during mechanical harvest or areas with cover nets, but NMFS can use the estimated acreage of mechanical harvest in the NPSAA to define the area of effect. We assume the effect from cover nets could occur any time juvenile canary rockfish are in the vicinity of cover nets. Mechanical harvest could occur on up to 200 acres of ground culture in the NPSAA. When this is taken into account with the large geographic range of canary rockfish DPS, and their dispersal pattern during their larval stage, and the expected acreage of likely mechanical harvest, indicate that the overlap between the areas to be harvested and the concentration of larval rockfish indicates that the number of canary rockfish likely to be injured or killed is minimal.

PS Chinook Salmon

The PS Chinook salmon ESU is listed as threatened, and rangewide abundance and productivity have decreased in recent years. All extant populations are considered to be at high risk, and all PS Chinook salmon populations are still well below planning ranges for recovery escapement levels. The primary drivers for their status is degradation of freshwater habitat, unfavorable ocean conditions, and habitat conditions in Puget Sound which include degraded water quality, and modified shoreline habitats throughout extensive areas.

Over the 20-year period of the proposed action, NMFS assumes a few juvenile PS Chinook salmon could become entangled in aquaculture cover nets where they would be injured or killed. The NMFS expects this would happen on a very limited basis in discrete locations. We also find that future eelgrass disturbance and suppression from new culture and culture in 2,464 acres of fallow areas in Hood Canal and Puget Sound will also negatively affect the success of PS Chinook salmon survival among some juvenile fish. However, while eelgrass is an important habitat feature for juvenile Chinook, who rely on it for forage and cover, this habitat feature is not considered a limiting factor. Because disturbed eelgrass areas at least partially recover during the growth cycle of the shellfish, the reduction of habitat quality in the nearshore marine environment caused by disturbance of eelgrass is not expected to be permanent. Further, the effects of disturbance repeated every 1 to 7 years on eelgrass is not expected to cause significant impairment on the growth or survival of juvenile PS Chinook salmon given the relatively small area affected and availability elsewhere in the affected areas of functioning eelgrass beds. As such, we expect the proposed action will not result in discernible effects on PS Chinook salmon population abundance or productivity.

PS Chinook Salmon Critical Habitat

The quality of critical habitat for PS Chinook salmon is alluded to above, and has been diminished by several factors unrelated to shellfish culture. The most notable impairments to CH are in freshwater environments are due to land use practices, manmade fish passage barriers, and water use, and the nearshore marine component of critical habitat suffers from pervasive systemic reductions in function caused by nearshore development, such as bank armoring, overwater structures, dredging, and upland sources of water pollution.

The degree to which Puget Sound Chinook salmon designated critical habitat will be adversely affected by the chronic disturbance and suppression of native eelgrass from the expansion of shellfish culture areas in Hood Canal and Puget Sound, is, as indicated in the effects section of this opinion, is low. This suppression will affect features of critical habitat including natural cover and forage, but this will occur over a number of different locations over time, and the relevant habitat feature – eelgrass – will typically recover over a period of 1 – 3 years in each location disturbed. There are no published data or any other indication that in the long-term, presence of shellfish culture has negatively influenced population viability of any species in Puget Sound, suggesting that conservation values are not diminished. However in Hood Canal and Puget Sound in general the future suppression of eelgrass related to shellfish aquaculture, along with long-term overall decreases in eelgrass acreage, will likely decrease the quality of habitat, in specific locations, for moderately brief periods. The essential functions of PBFs needed to support Chinook juvenile salmonid nearshore life history stages will be affected by this pattern of decrease. We find it reasonable to assert that chronic suppression of eelgrass in

Puget Sound will adversely affect PS Chinook salmon designated critical habitat, and will result in minor, but potentially reversible, reductions conservation value over the 20-year period of the proposed action, as discussed above. The presence of loose shellfish culture nets will also slightly reduce the quality of the nearshore migration PBF in specific locations over the 20-year period of the proposed action.

HCSR Chum Salmon

Over the 20-year period of the proposed action, NMFS assumes a few HCSR chum salmon could become entangled with aquaculture cover nets where they would be injured or killed. The NMFS expects this would happen on a very limited basis in discrete locations, and will not result in discernible effects on HCSR chum salmon population abundance or productivity. The NMFS also expects a small number of HCSR chum to be injured or killed as a result of general disturbance during out-migration in the shallow nearshore area of Hood Canal. Similarly, this effect is not expected to occur often and only in discrete locations where and when shellfish activities are taking place. These effects will not result in discernible effects on HCSR chum salmon population abundance or productivity.

HCSR Chum Critical Habitat

Loose cover nets will result in adverse effects to designated critical habitat for HCSR chum salmon, slightly reducing the conservation value of the nearshore migration PBF. Again, this effect would occur on a very limited basis in discrete locations, and will not result in a significant loss of quality or function of critical habitat. General disturbance from shellfish activities will also slightly degrade the quality of nearshore migration PBF. This effect is expected occur along the nearshore in areas that are unavoidable for this species. However, these effects on migration are not expected to be wide-spread at one time, but rather occur occasionally where and when shellfish activities are taking place. These effects will not result in a significant loss of quality or function of critical habitat.

Southern DPS Green Sturgeon

Over the 20-year period of the proposed action, NMFS assumes a few green sturgeon could become entangled with aquaculture cover nets where they would be injured or killed. The NMFS expects this would happen on a very limited basis in discrete locations, and will not result in discernible effects on green sturgeon population abundance or productivity. The NMFS also expects a very small number of green sturgeon to be injured or killed as a result of contact with a mechanical oyster harvester or harrowing device. Again, this will not result in discernible effects on green sturgeon population abundance or productivity.

Southern DPS Green Sturgeon Critical Habitat

The occasional occurrence of loose cover nets will result in adverse effects and slightly diminish the quality of the on the estuarine migration PBF for green sturgeon. Because this effect is only expected on limited occasions and in discrete locations, it is not expected to result in a significant loss of quality or function of designated critical habitat.

Baseline and Cumulative Effects

When performing an analysis to evaluate jeopardy and/or adverse modification of critical habitat, we must include, together with considering the effects of the action in the context of the baseline and status of the species, the anticipated cumulative effects that are reasonably likely to occur in the action area. As described in earlier sections, the baseline conditions and cumulative effects of state and private actions that are reasonably certain to occur within the action area may vary from sub-action area to sub-action area. In the greater Puget Sound, population growth is expected to continue to outpace the rest of the state. While actions are being undertaken to address needs stipulated by recovery plans for PS Chinook salmon and HCSR chum salmon, it is likely that these restoration and enhancement efforts will gradually improve conditions for these species in freshwater habitats.

However, the greatest effects on nearshore habitats are associated with baseline conditions such as armored shoreline and other nearshore development, which is increasing. Development and associated impacts to aquatic marine areas will continue, adding to the effects of existing structures and activities and making recovery challenging. These conditions are currently part of the baseline and have contributed to the current condition of habitat in the action area. Also part of the baseline is shellfish aquaculture. Information on shellfish aquaculture reports both negative and beneficial effects on habitat conditions.

On balance we expect both positive and negative effects will occur within the action area, retaining the overall character of the habitat, and therefore also retaining the current level of viability for HCSR chum salmon, green sturgeon, Canary rockfish and PS Chinook salmon. The low level of effects anticipated from the proposed action, based either on the nature or scale of effects, or a combination of these, is not expected to affect the status of listed species or critical habitat.

In summary, when taking into account the species critical habitat status, environmental baseline, effects of the action, and cumulative effects, the adverse effects on critical habitat for PS Chinook salmon, green sturgeon, canary rockfish and HCSR chum salmon will not appreciably reduce the conservation value of this species' CH, nor result in a reduction in the viability parameters for either species. The disturbance of eelgrass in Hood Canal and Puget Sound may cause a slight decrease in survival for some juvenile PS Chinook salmon, but it will be so small that it will be impossible to calculate, and is not expected to reduce productivity, and it will not affect the abundance of adult populations. Likewise, the loss of a few green sturgeon, canary rockfish, and HCSR chum salmon juveniles each year will not affect the abundance of adult populations.

2.7 Conclusion

After reviewing the current status of the listed species, the environmental baseline within the action area, the effects of the proposed action, any effects of interrelated and interdependent actions, and cumulative effects, it is NMFS' opinion that the proposed action is not likely to jeopardize the continued existence of Puget Sound Chinook salmon, HCSR chum salmon, green sturgeon, or Puget Sound/Georgia Basin canary rockfish, and will not destroy or adversely modify critical habitat of any of these species.

Conclusions of effects on critical habitat for canary rockfish and species effects on PS steelhead, LCR Chinook salmon, CR chum salmon, southern resident Killer whale, boccacio, and eulachon can be found in Section 2.11.

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). “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 incidental take statement.

We found take is reasonably certain to occur from mechanical oyster harvest and harrowing in the north Puget Sound for canary rockfish and in Grays Harbor and Willapa Bay for green sturgeon. We also found take is reasonably certain to occur for green sturgeon, PS Chinook salmon, canary rockfish, and HCSR chum salmon from entanglement with loose shellfish cover nets, as discussed in the following section. We also found take is reasonably certain to occur for a few PS Chinook salmon from loss of cover due to suppression of eelgrass in Puget Sound and Hood Canal. Finally, we found take of a few HCSR chum salmon from shellfish-related disturbance in the nearshore during the HCSR chum salmon juvenile migration.

2.8.1 Amount or Extent of Take

NMFS determined that incidental take would occur as follows:

Mechanical Harvest

Canary Rockfish
A small but undetermined number of juvenile canary rockfish is likely to be injured or killed as a result of coming into contact with a mechanical oyster harvester.

Given that a numeric estimate of larval rockfish that are likely to be affected by this project cannot be ascertained because any death or injury to this species would occur over a very large area, sporadically, over the course of many years. Also, there is no feasible monitoring protocol that would be able to detect when juvenile canary rockfish were injured or killed during mechanical oyster harvest. In these circumstances, NMFS can rely instead on a threshold defined by a maximum area of mechanical harvest in the NPSAA as estimated by the COE (2015) of 200 acres per year. This threshold is proportional to the amount of take we expect for canary rockfish because even though the total number of fish injured or killed is expected to be low, the chance of fish being injured or killed increases as the area harvested mechanically increases. This is because we expect canary rockfish to distribute evenly across nearshore area in the NPSAA. As such, the extent of take will be exceeded upon reaching a total of 200 mechanically harvested acres in NPSAA in any given year. Exceedence of 200 mechanically harvest acres will trigger reinitiation of consultation. This threshold is a valid reinitation trigger because the COE can require monitoring and reporting that would allow them to track this threshold in any given year.

<u>Green Sturgeon</u>
A small but undetermined number of adult and subadult green sturgeon are likely to be injured or killed as a result of coming into contact with a mechanical oyster harvester or harrow in Grays Harbor and Willapa Bay.

Given that a numeric estimate of sub adult and adult green sturgeon that are likely to be affected by this project cannot be ascertained because any death or injury to this species would occur over a very large area, sporadically, over the course of many years. Also, there is no feasible monitoring protocol that would be able to detect when green sturgeon were injured or killed during mechanical oyster harvest or harrowing. In these circumstances, NMFS can rely instead on a threshold defined by a maximum area of mechanical harvest in Willapa Bay of 18,367 acres per year, and 2,763 acres per year in Grays Harbor as estimated by COE (2015). These thresholds are proportional to the amount of take we expect for green sturgeon because even though the total number of fish injured or killed is expected to be low, the chance of fish being injured or killed increases as the area harvested mechanically increases. This is because we expect green sturgeon to distribute evenly across harvested area in both embayments. As such, the extent of take will be exceeded upon reaching a total of 18,367 mechanically harvested acres in Willapa Bay in any given year, and 2,763 in Grays Harbor. Exceedence of these mechanically harvested acres will trigger reinitiation of consultation. This threshold is a valid reinitation trigger because the COE can require monitoring and reporting that would allow them to track this threshold in any given year.

Suppression of Eelgrass

<u>Puget Sound Chinook Salmon</u>
A small but undetermined number of juvenile PS Chinook salmon are likely to be harmed by future suppression and preclusion of eelgrass in new culture areas and in fallow areas of Hood Canal and Puget Sound. While it is impossible to predict the exact number of fish to be affected, NMFS relies on the number proposed acres of new farms and of fallow acres of eelgrass in Hood Canal and Puget Sound that could be brought into shellfish production as the extent of take. We estimate take will occur when effects of continuing active sites are combined with cumulative, widespread reductions in eelgrass densities from shellfish culture moving into fallow areas colonized by eelgrass. The COE estimates approximately 2,464 acres of fallow lands in Puget Sound potentially contain eelgrass. New farms will be required to observe a 16-foot buffer from eelgrass. As such, maximum take will be reached upon full development of 2,464 acres of fallow culture area for shellfish. Exceedance of 2,464 acres will trigger reinitiation. This threshold is proportional to the amount of take we expect for PS Chinook salmon because the number of fish that would be harmed through the loss of eelgrass density would increase with the number of eelgrass acres where suppression occurs. This threshold is a valid reinitation trigger because the

COE can require monitoring and reporting that would allow them to track this threshold in any given year.

Cover Nets

Additionally, a few PS Chinook, HCSR chum salmon, green sturgeon, and canary rockfish are likely to be injured or killed by entanglement in cover nets. As noted in the effects section, this source of take is only documented to have happened one time, killing surf smelt. For this reason we reasonably expect this type of injury or death to happen no more than 5 times over the life of the permit. As such, five reported entanglements of PS Chinook, HCSR chum salmon, green sturgeon, or canary rockfish are the limit of take, and any visually confirmed entanglements beyond five will trigger reinitiation.

General Disturbance

A few HCSR chum salmon are likely to be injured or killed from striking or being crushed by equipment, crushing, predation, or other effects as a result of shellfish activities in the shallow nearshore during the migration of juvenile HCSR chum salmon from approximately February through April. Because not all fish affected by this form of take will die at the site of the effect, and because numerous juveniles are passing through the area at the time period in question, it is not possible to estimate or monitor the number of fish affected. Therefore we are using a surrogate for the extent of take.

Ongoing, ongoing fallow, and new shellfish activities located in and around river mouths are the most likely places for these effects to occur. However, because these fish can migrate several miles per day, we expect this effect could occur anywhere on the shoreline in Hood Canal where shellfish aquaculture occurs, totaling 1,887 acres. As such, maximum take will be reached upon full development of 1,887 acres of culture area for shellfish in Hood Canal. Exceedance of 1,887 acres will trigger reinitiation. This threshold is proportional to the amount of take we expect for HCSR chum salmon because the number of fish that would be harmed through disturbance would increase with the number of acres in shellfish production.

2.8.2 Effect of the Take

In the PBO, NMFS determined that the amount or extent of anticipated take, coupled with other effects of the proposed action, is not likely to result in jeopardy to the species or destruction or adverse modification of critical habitat.

2.8.3 Reasonable and Prudent Measures

"Reasonable and prudent measures" are nondiscretionary measures that are necessary or appropriate to minimize the impact of the amount or extent of incidental take (50 CFR 402.02).

1. Minimize take of canary rockfish from mechanical harvest by minimizing mechanical harvest to the extent practicable in waters of the North Puget Sound and Hood Canal Action Areas.

2. Minimize take of green sturgeon from mechanical harvest by minimizing mechanical harvest to the extent practicable in the waters of the Willapa Bay and Grays Harbor.

3. Minimize take of green sturgeon, HCSR chum salmon, canary rockfish, and PS Chinook salmon from entanglement with shellfish cover nets.

4. Minimize take of PS Chinook salmon by limiting the types of culture methods in fallow areas colonized by native eelgrass (*Zostera marina*). Monitor and report annually on the acreage of shellfish aquaculture moving into fallow areas in each sub-basin with critical habitat for PS Chinook salmon.

5. Minimize take of HCSR chum salmon by limiting activities in Hood Canal from February through April.

6. Monitor and report as incidents occur, any loose nets, and any entangled fish, regardless of species, and collect specimens of the entangled fish.

7. Monitor and report real-time implementations of the proposed action.

2.8.4 Terms and Conditions

The terms and conditions described below are non-discretionary, and the COE or any applicant must comply with them in order to implement the reasonable and prudent measures (50 CFR 402.14). 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 incidental take statement (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.

The following terms and conditions implement the reasonable and prudent measures:

1. To implement RPM 1, mechanical dredge harvest shall not be conducted in NPSAA between April 1 through August 31, to avoid those months when canary rockfish are known occupy nearshore areas prior to moving to deeper water towards the end of summer.

2. To implement RPM 2, limit mechanical dredge harvest to 18,367 acres per year in Willapa Bay, and 2,763 in Grays Harbor.

3. To implement RPM 3, ensure clam and other shellfish cover nets are secured to the extent practicable. Report and loose cover nets regardless of whether fish were entangled. If fish are entangled, record and report species, time, and location of entanglement. Collected specimens of fish entangled shall be preserved in a freezer, and reporting shall be to the NMFS' Lacey Office in order to determine appropriate steps to ascertain the entangled species. Contact the NMFS Central Puget Sound Branch Chief by telephone or email

4. To implement RPM 4, only oyster long lines (with flip bags ok) spaced laterally at 10 feet intervals shall be used in fallow areas that have been colonized by eelgrass. Flip bags must be suspended above the substrate so they do not rest on substrate at low tide. Noother culture methods shall be used in fallow areas colonized by eelgrass.

5. To implement RPM 5, limit shellfish activities in shallow nearshore (the first 15 feet of water) to the extent practicable during the months of February through April in Hood Canal to minimize effects on HCSR chum salmon.

6. To implement monitoring requirements of RPM 5, in its annual report, the COE should include an account of any entangled fish from any of the action areas, regardless of species. These reports should be made available to the Lacey, Washington NMFS office, attn: Matt Longenbaugh 510 Desmond Drive, Suite 103, Lacey Washington, 98503

7. Report implementations of this programmatic opinion as described in Appendix B.

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).

1. The COE should ensure permit applicants avoid native eelgrass and kelp species to the extent possible, particularly during mechanical harvest, to minimize effects on critical habitat for PS Chinook salmon.
2. Growers should support research on eelgrass and ESA-listed fish species interactions
3. The NMFS, along with co-managers, and local groups, has developed or is currently developing recovery plans for ESA-listed salmon, rockfish, and sturgeon. Recovery plans for salmon are currently available at: http://www.nwr.noaa.gov/Salmon-Recovery-Planning/ESA-Recovery-Plans/Index.cfm. The NMFS encourages the COE to consider the recommended actions and prioritization plans found in current and forthcoming recovery plans when planning, conducting, or permitting actions that may affect listed species.
4. We assume and expect that the COE will actively solicit information from their applicants about chemical applications prior to approving coverage under the programmatic consultation, and before issuing each permit or permit verification. Growers and farm operators who seek coverage under the programmatic consultation, but who also engage in chemical application to control undesired species, will not satisfy the requirements of their COE permit and are potentially liable under the provisions of the ESA. We recommend that the COE include relevant language in their email notifications for each authorized project.

Please notify NMFS if the COE carries out these recommendations so that we will be kept informed of actions that minimize or avoid adverse effects and those that benefit listed species or their designated or proposed CRs.

2.10 Reinitiation of Consultation

This concludes formal consultation for shellfish aquaculture activities in Washington State.

As 50 CFR 402.16 states, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained or is authorized by law and if: (1) the amount or extent of incidental taking specified in the incidental take statement is exceeded, (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion, (3) the agency action is subsequently modified in a manner that causes an effect on the listed species or critical habitat that was not considered in this opinion, or (4) a new species is listed or critical habitat designated that may be affected by the action.

If any of the direct take amounts specified in this opinion's effects analysis (Section 2.4) are exceeded, reinitiation of formal consultation will be required because the regulatory reinitiation triggers set out in (2) and/or (3) will have been met.

2.11 "Not Likely to Adversely Affect" Determinations

The NMFS anticipates the proposed action will have only insignificant or discountable effects on the species named in Table 11. Additionally, the proposed action will not take any of the species listed in Table 11. To reach this determination we reviewed the potential effects of all aspects of the proposed activity. "

The applicable standard to find that a proposed action is NLAA listed species or critical habitat is that all of the effects of the action are expected to be discountable, insignificant, or completely beneficial.[3] Discountable effects cannot be reasonably expected to occur. Insignificant effects are so mild that the effect cannot be meaningfully measured, detected, or evaluated. Beneficial effects are contemporaneous positive effects without any adverse effect to the listed species or critical habitat, even if the long-term effects are beneficial. NMFS does not concur with the COE's determination that the action is likely to adversely affect bocaccio, but does concur with the COE's NLAA determinations to the species in Table 11.

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[3] U.S Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS). 1998. Endangered Species Act Consultation Handbook: Procedures for Conducting Section 7 Consultations and Conferences. March, 1998. Final. pp. 315.

Table 13. NLAA species

ESA-Listed Species	Status	Is Action Likely to Adversely Affect Species or Critical Habitat?
Puget Sound steelhead (*Oncorhynchus mykiss*)	Threatened	No
Lower Columbia River Chinook Salmon (*O. tshawytscha*)	Threatened	No
Columbia River Chum Salmon (*O. keta*)	Threatened	No
Boccacio Rockfish	Endangered	No
Lower Columbia River Chinook Salmon (*O. tshawytscha*)	Threatened	No
Upper Willamette River Chinook Salmon	Threatened	No
Canary Rockfish	Threatened	Species-Yes CH-no
Yelloweye Rockfish	Threatened	No
Southern Resident Killer Whale	Endangered	No
Pacific Eulachon	Threatened	No

As discussed above in Section 2.3, potential effects to listed species and critical habitat from the proposed action include disturbance of and suppression of eelgrass beds, bottom disturbance that may affect forage for listed species, elevated noise, entrainment in cover nets, impacts to water quality from bottom disturbance and materials used for shellfish culture, and potential for capture during shellfish harvest. As also discussed above, most of these effects are expected to be relatively minor. For the species and critical habitat discussed here, the effects of the proposed action are of even smaller consequence than for PS Chinook and their critical habitat, HCSR chum, green sturgeon, and canary rockfish because of the life histories, habitat use, and overlap of critical habitat with the action area.

Noise

As discussed above, noise from equipment operation could temporarily disturb and displace aquatic species from the local area. To estimate noise produced by shellfish activities, an analysis was conducted using data from Wyatt (2008) for a commonly used vessel, a 21-foot Boston Whaler with a 250 horsepower Johnson 2-cycle outboard motor. Operating this vessel at full speed produced a sound measured at 147.2 decibels (dB) root mean square (RMS) re 1 microPascal at 1 meter4. Assuming a background underwater sound level of 120 dB RMS, which is the threshold established by NMFS for behavioral effects to marine mammals, and using the practical spreading loss model preferred by NMFS and USFWS, sound produced by this vessel would attenuate to 120 dB RMS within 65 meters (213 feet). Larger vessels could also be used on occasion which could potentially generate greater underwater sound levels.

The intermittent use of power equipment is likely to produce in air noise of up to 81 dBA for dive harvesting and 82 dBA for shoreline work. Over marine water, the 81 dBA value would attenuate to the background level (57 dBA) within 792 feet and over a terrestrial habitat the 82 dBA would attenuate to the background noise level of a rural environment (35 dBA) within 3793 feet (0.71 mile). Maximum surface noise levels from boat operations and dive support equipment for subtidal geoduck harvest was measured at 61 to 58 dBA at a distance of 100 feet where auxiliary equipment was housed on deck and 55 to 53 dBA where equipment was housed below deck (WDNR 2008).

While these sound levels may cause ESA listed fish to temporarily avoid the area from where sound is emitted, they do not reach levels that would cause any harm or result in take of any listed fish or marine mammal. As such, effects from noise associated with shellfish aquaculture are insignificant on all species considered in this opinion.

Puget Sound Steelhead
Juvenile Puget Sound steelhead enter Puget Sound after rearing in their natal stream for at least 2 years. As such, they are large (at least 100 mm) when they enter Puget Sound and move quickly offshore (PSBRT, 2005). PS steelhead are not known to rely on eelgrass for cover or forage. They prey on zooplankton and other pelagic food sources and occupy a greater variety of depths than other juvenile salmonids in the action area. Any co-occurrence with aquaculture and PS steelhead juveniles would be transitory and temporary, and juvenile PS steelhead would not be subject to those effects discussed above. As such, we find effects on PS steelhead to be insignificant.

Columbia River and Willamette River Salmonids
Lower Columbia River Chinook salmon and Columbia River chum are both known to occur in Willapa Bay and Grays Harbor in small numbers while migrating (Cassilas, 2009). Use of these waters by these species is transitory and temporary. Both of these embayments contain large expanses of eelgrass as well as aquaculture. These fish would migrate to these areas after they have transited and reared in Columbia River. As such, these species would be of larger size, 100 mm or more (Casillas, 2009), and would have the swimming ability to access a variety of habitats and depths. Further, there are no ESA-listed salmon stocks in any of the watersheds that feed Willapa Bay and Grays Harbor, suggesting that aquaculture, which has been in place in these areas for over 100 years, is not a limiting factor there. Even if it were a limiting factor, the transitory nature of and availability of food resources for these CR species in Grays Harbor or Willapa Bay would have insignificant effects. Therefore, any potential effects on CR chum salmon and LCR Chinook salmon arising from co-occurrence with shellfish aquaculture and any subsequent effects related to effects discussed above would be insignificant to these species.

Because LCR Chinook salmon, UWR Chinook salmon, LCR coho salmon, and CR chum salmon can occur in Willapa Bay and Grays Harbor, there is potential for entanglement with loose clam or geoduck cover nets. However, because these species use Willapa Bay and Grays Harbor as larger juveniles, and because of the transitive and temporary nature of their use of these areas, we find it extremely unlikely and we discount the potential for adverse effects on these species from entanglement with cover nets in Willapa Bay and Grays Harbor.

As discussed above, application of imazamox to clam beds to treat invasive Japanese eelgrass is likely to occur in Willapa Bay. There are no natal streams for ESA-listed salmon or steelhead within Willapa Bay. However, seasonal use of the bay is known to occur by low numbers of juvenile, ESA-listed Lower Columbia River Chinook salmon, coho salmon, Columbia River chum salmon, and Willamette River Chinook salmon (Casillas pers comm., in NMFS 2009). Because use of the bay by these species is seasonal and for a few days, and the extent of application within the bay is limited to 8% of the total acreage or less, any exposure for salmonids is expected to be minor and temporary. There would be minor short-term water quality impacts but the chance of these species encountering these effects is highly unlikely due to the transitory nature of their occurrence and the small scale of the application compared relative to the total acreage of Willapa Bay habitat. Similarly, application of imazamox will kill a small amount of *Zostera marina* where it has colonized within larger fields of japonica, and where small amounts of imazamox runoff enters areas with *marina*. Losses of *Z. marina* are expected to be too small and too widely dispersed in this large embayment such that effects on ESA listed Columbia River and Willapa River salmonids would be insignificant. Critical habitat is not designated for salmonids in Willapa Bay for any of these species

Puget Sound Steelhead Critical Habitat.
In marine waters, only estuaries areas considered CH for PS steelhead. The PBFs potentially found in the action area include:

> Estuarine areas free of obstruction and excessive predation with water quality and quantity conditions supporting juvenile and adult physiological needs, natural cover, and forage.

As discussed above, nothing about aquaculture is expected to significantly affect any of these PBFs. Steelhead juveniles are relatively large compared to other salmonids when entering salt water, and are not known to rely on eelgrass for forage or cover. Further, forage base including invertebrates and forage fish are not expected to diminish as a result of aquaculture activities. As such, NMFS concurs with the COE determination of “not likely to adversely affect” critical habitat” of PS steelhead.

Eulachon
Eulachon primarily spawn in the Columbia River system in Washington State, although occasional, sporadic spawning runs in Grays Harbor tributaries, including the Chehalis River, have been reported (WDFW (Washington Department of Fish and Wildlife) and ODFW (Oregon Department of Fish and Wildlife) 2001) and occasional spawning runs in Willapa tributaries, including the Bear River, Naselle River and one report of spawning in 1941 from Nemah River, have been reported (Gustafson 2010). Effects on eulachon would be similar to those described above for the other fish species in Willapa Bay and Grays Harbor. These effects include increased turbidity, general disturbance. Given the limited and transient eulachon presence in Grays Harbor and Willapa Bay, these effects are insignificant. Further, because of the highly transitive and temporary nature of their use of these areas, we find it extremely unlikely and we discount the potential for adverse effects on Eulachon from entanglement with cover nets in Willapa Bay and Grays Harbor. Critical habitat is not designated for Eulachon in Willapa Bay or Grays Harbor.

Boccacio

We analyzed potential impacts of the project on boccacio rockfish and determined that these animals would be extremely unlikely to be exposed to any effects of the action. This is because adult life stages of this species typically occupy waters deeper than 120 feet with high rugosity and are therefore unlikely to be within the relatively shallow waters of the shellfish culture area. While abundance of boccacio is considered low in the NPSAA, the limited exchange of waters between the Straits and Puget Sound, including waters east of Whidbey Island, suggests extremely low abundance south and east of the Straits (Ebbesmeyer et al. 1988). Juvenile bocaccio could potentially utilize deeper cobble substrates in the action area that support kelp or other aquatic vegetation, but these fish occur in very low densities in Puget Sound such that there is a discountable chance that any boccacio rockfish would occur in the intertidal and shallow sub-tidal area and be exposed to mechanical harvest or cover nets. Larval bocaccio are unlikely to occur within the action area. Larvae are readily dispersed by currents after they are born, making the concentration or probability of presence of larvae in any one location extremely small. Accordingly, any disturbance effects on larval boccacio are discountable

PS/Georgia Basin Canary Rockfish and Boccacio Critical Habitat

The proposed action includes mechanical harvest and cover nets along withother culture activities that take place in critical habitat for juvenile canary rockfish and bocaccio. Critical habitat includes juvenile settlement habitats located in the nearshore with substrates such as sand, rock or cobble compositions that also support kelp. These areas are essential for conservation because their features enable forage opportunities and refuge from predators and enable the behavioral and physiological changes needed for juveniles to occupy deeper adult habitats. Several attributes of these sites determine whether the effects of a proposed action in a section 7 consultation would adversely affect the site. These attributes include: (1) quantity, quality, and availability of prey species to support individual growth, survival, reproduction, and feeding opportunities; and (2) water quality and sufficient levels of dissolved oxygen to support growth, survival, reproduction, and feeding opportunities.

The effects discussed in the Effects on Critical Habitat section of the PBO will occur within critical habitat for PS/GB Canary and boccacio rockfish. However, attributes of critical habitat for rockfish are not the same as PBFs for salmonids. Specifically, eelgrass is not identified as an attribute to critical habitat for rockfish, and instead the condition of juvenile rockfish critical habitat hinges on the availability of prey sources and water quality. Moreover, as discussed above we found no evidence that disturbances from culture practices interfere with benthic productivity, or otherwise decrease the availability of forage. While disturbances that cause turbidity are not a discountable effect on water quality in rockfish critical habitat, we anticipate this effect will be insignificant, because as discussed above, studies have indicated that increased turbidity during geoduck harvest and mechanical oyster harvest (which produce the most turbidity out of any shellfish culture action) dissipates quickly as it moves beyond the harvest site, and is largely absent within a few feet down-current of the harvest site. Not only will the water quality effect from suspended sediment/turbidity be localized and ephemeral, the episodes of mechanical harvest are expected to be intermittent, infrequent, and restricted to isolated, independent acreages, that, when combined over the life of the project, may equal roughly 1,600 acres within proposed critical habitat for canary rockfish. When evaluated in the context of the extent of proposed critical habitat (about 1,250 square miles) where these actions may occur, areas of potential mechanical harvest equate to approximately $1/1000^{th}$ of the proposed area of critical habitat. Geoduck harvest also occurs at intermittent intervals at various acreages. And, as discussed above, nothing indicates geoduck harvest significantly effects water quality or the availability of forage. As such, we believe effects on designated rockfish critical habitat to be insignificant.

Southern Resident Killer Whales

The final rule listing SR killer whales as endangered identified several potential factors that may have caused their decline or may be limiting recovery. These are: quantity and quality of prey, toxic chemicals which accumulate in top predators, and disturbance from sound and vessel traffic. The rule also identified oil spills as a potential risk factor for this species. The final recovery plan includes more information on these potential threats to SR killer whales (73 FR 4176).

SR killer whales spend considerable time in the Georgia Basin from late spring to early autumn, with concentrated activity in the inland waters of Washington State around the San Juan Islands, and then move south into Puget Sound in early autumn. While these are seasonal patterns, Southern Resident killer whales have the potential to occur throughout their range (from Central California north to the Queen Charlotte Islands) at any time during the year.

Southern Resident killer whales do not inhabit nearshore areas where aquaculture occurs. As such, the only potential effect would be from noise impacts related to aquaculture. The activities associated with the proposed action are not expected to create a noise impact on the listed species. In-water noise impacts from the proposed action are expected to be discountable because the work in water entails nothing louder than motorized boat noise or a small pressurized water sprayer on occasion, with most work being completed with hand tools. Further, the project will have minimal take on PS Chinook salmon, the primary forage base of SRKW. Based on the information contained above, the potential for effects SRKW from the action is insignificant.

As discussed above, effects of the proposed action are ephemeral when they occur, they are diffuse over the time and spatial scales of the proposed action, they occur in limited areas when they occur, and affect features of habitat that are not identified as limiting or degraded within the action area. For these reasons the effects on critical habitat for canary rockfish, PS steelhead, HCSR chum salmon, SRKW and green sturgeon are considered insignificant.

3. MAGNUSON-STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT ESSENTIAL FISH HABITAT CONSULTATION

Section 305(b) of the MSA directs Federal agencies to consult with NMFS on all actions or proposed actions that may adversely affect EFH. The MSA (section 3) defines EFH as “those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity.” 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) also requires NMFS to recommend measures that can be taken by the action agency to conserve EFH.

This analysis is based, in part, on the EFH assessment provided by the COE and descriptions of EFH for Pacific coast ground fish (PFMC 2005), coastal pelagic species (PFMC 1998), Pacific coast salmon (PFMC 2014); and highly migratory species (PFMC (2007) contained in the fishery management plans developed by the Pacific Fishery Management Council and approved by the Secretary of Commerce.

3.1 Essential Fish Habitat Affected by the Project

The action area is designated as EFH for Pacific coast groundfish (PFMC 2005), coastal pelagic species (PFMC 1998) and Pacific coast salmon (PFMC 2014). Essential Fish Habitat guidelines published in Federal regulations identify habitat areas of particular concern as types or areas of habitat within EFH that are identified based on one or more of the following considerations:

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

Based on these considerations, the Council has designated estuaries and native seagrass as Habitat Areas of Particular Concern (HAPCs). In some cases, HAPCs identified by means of specific habitat type may overlap with the designation of a specific area. The HAPC designation covers the net area identified by habitat type or area. Designating HAPCs facilitates the consultation process by identifying ecologically important, sensitive, stressed or rare habitats that should be given particular attention when considering potential nonfishing impacts. Their identification is the principal way in which the Council can address these impacts.

Designated Habitat Areas of Particular Concern in the Action Area

Estuaries.
Estuaries are protected nearshore areas such as bays, sounds, inlets, and river mouths, influenced by ocean and freshwater. Because of tidal cycles and freshwater runoff, salinity varies within estuaries and results in great diversity, offering freshwater, brackish and marine habitats within close proximity (Haertel and Osterberg 1967). Estuaries tend to be shallow, protected, nutrient rich, and are biologically productive, providing important habitat for marine organisms, including groundfish.

Seagrass.
Seagrass species found on the West Coast of the U.S. include eelgrass species (*Zostera spp*.), widgeongrass (*Ruppia maritima*), and surfgrass (*Phyllospadix spp.*). These grasses are vascular plants, not seaweeds, forming dense beds of leafy shoots year-round in the lower intertidal and

subtidal areas. Eelgrass is found on soft-bottom substrates in intertidal and shallow subtidal areas of estuaries and occasionally in other nearshore areas, such as the Channel Islands and Santa Barbara littoral. Studies have shown seagrass beds to be among the areas of highest primary productivity in the world (Herke and Rogers 1993; Hoss and Thayer 1993).

Puget Sound.
Puget Sound contains both estuaries and seagrasses that provide beneficial habitat characteristics discussed above. As such, the entire Puget Sound is designated as a HAPC.

3.2 Adverse Effects on Essential Fish Habitat

The proposed action is issuance of a programmatic permit that will enable new, expansions, and continuation of ongoing shellfish aquaculture activities whose past effects already inform, in part, the condition of EFH throughout the affected area. Review of the literature during consultation revealed divergent findings on many relevant issues such that there remains some uncertainty regarding the likelihood of the effects of these activities on the environment and whether or not likely effects would bear on EFH and managed fish. In cases of such uncertainty, NMFS considers the breadth of findings in the literature before concluding consultation.

We believe the proposed action will affect EFH within the action area via the following mechanisms:

- Suspended Sediments effects on Water quality – Harrowing on oyster grounds and dredge harvest of oysters delivers suspended sediment to the water column. Hand racking for the harvest of hard shell clams also has the potential for a minor pulse of turbidity upon tidal inundation. Geoduck harvest in the intertidal with the aid of pumping waters into the substrate to facilitate removing the geoduck may also produce a sediment pulse to the adjacent waters.
- Temporary effects on water quality and native eelgrass from the application of imazamox in Willapa Bay.
- Temporary Reduction in prey resources – Localized and temporal effects on HAPC designated eelgrass beds and to benthic communities can be caused by bed preparation and harvest activities of shellfish species.

Impacts to Food Resources—Submerged Aquatic Vegetation

Effects on SAV (eelgrass), a HAPC designated habitat and to benthic communities can be caused by bed preparation and harvest activities of shellfish species, and will occur over the 20-year time frame of the proposed action. Various aquaculture activities described under the proposed action can directly interact with eelgrass by decreasing its extent or density within estuarine shellfish beds. However, interactions with eelgrass are generally going to occur in areas of perennial shellfish aquaculture that were providing previously altered eelgrass habitat function prior to the proposed action. Furthermore, some aquaculture activities have been shown to enhance habitat characteristics for eelgrass colonization through water clarifying filtration or provide a substitute or replacement of eelgrass habitat function. (Dumbauld et al. 2001)

Additionally, through the removal of suspended particles, shellfish improve water clarity and therefore light penetration, which can enhance the photosynthesis of eelgrass (Newell 2004).

Eelgrass beds provide cover for some species of juvenile salmonids, and structure for the spawning of species on which juvenile salmonids prey. Eelgrass and eelgrass patches are a foundational element in the inter-tidal environment, throughout the action area, supporting the base of the food web. Throughout most of the Puget Sound region, eelgrass is of primary importance as a herring spawning substrate (WDNR 2015; Blackmon et al. 2006). Eelgrass patches also cover and forage for growth of herring (and other forage fish species) (Blackmon 2006) on which juvenile salmon and steelhead feed. In a small fraction of documented herring spawning areas, atypical spawning substrates are used (Mumford 2007), including shellfish aquaculture apparatus

The existence of continuing active footprints impairs the development of dense beds of eelgrass s. And although eelgrass growth recovers following disturbance, the proposed action is likely to maintain conditions limiting dense eelgrass beds within the footprint.. Eelgrass spreads from seed source or from rhizome growth. Where sufficient rhizome nodes remain intact following disturbance, eelgrass can recover (Cabaco et al. 2005), although recovery may take an extended period of time and eelgrass density may be initially lower. Eelgrass typically regrows on a shellfish bed following aquaculture activities that have removed existing eelgrass, but cyclical management activities probably limit the functional condition of eelgrass in managed sites. Depletion or decreased function of eelgrass in shellfish beds is also probable for off-bottom culture as well, as it limits conditions favorable to eelgrass growth. Off-bottom, stake (Griffin 1997), and rack culture can cause erosion or sedimentation in some places, which appears to be the primary cause of eelgrass depletion in areas where this type of aquaculture is practiced (Everett et al 1995). Various aspects of geoduck culture (presence of tubes and disturbance after harvest, for example), also results in a lower density of eelgrass (Ruesink and Hacker 2005, WSG 2013). Since the effects of the action include the persistence of these types of conditions within the footprint of managed sites, the recovery of dense eelgrass in managed sites in unlikely.

Rumrill and Poulton (2003), in Humboldt Bay, CA, investigated the effects of long-line culture on eelgrass. Generally, when line spacing reached 5 feet they found an increase in cover and density of eelgrass. They did caution that a longer study period should be considered to understand the differences in interannual and monthly variability.

Juvenile salmonids utilize a variety of habitats during their emigration through Puget Sound. Chinook salmon often use eelgrass because it provides cover, refuge and a prey base for small fish at this vulnerable life stage. While we expect shellfish activities to maintain low density of eelgrass within the continuing active and fallow footprints, we believe the magnitude is not likely to be of such an extent, either individually or cumulatively to impair forage production or cover within these areas. Nothing about the proposed action impairs or prevents the presence of eelgrass beds adjacent to, or near shellfish activity footprints.

It seems unlikely that juvenile salmon or rockfish would seek these functions at locations of limited function when they are surrounded by otherwise highly functioning habitat off the beds themselves. Furthermore, Dumbauld et al (2001) found that when comparing oyster bottom culture to eelgrass beds and mud bottom habitat, both eelgrass and oyster culture provide species richness and habitat utilization by salmonids at an equivalent scale. These studies suggest that decreased extent or density of eelgrass at culture sites does not ensure a net negative ecological result. NMFS notes that eelgrass habitats are ecologically important and that studies have shown seagrass beds to be among the areas of highest primary productivity in the world (Herke and Rogers 1993; Hoss and Thayer 1993). While it is reasonable to presume some reduction in the ecological value of EFH from aquaculture at the site and immediate vicinity, it is less obvious to presume EFH impacts, positive or negative, beyond such a scale.

Benthic disturbance generally refers to the various activities that lead to physical interaction with the bottom. Activities that interact with the bottom under the proposed permit include site and plot preparation, grow-out, and harvest. One issue for each of these activities and the benthic environment is whether and to what extent they influence the functional condition of the nearshore marine bottom environment, and whether any influence is significant enough to impair normal EFH utilization. Some activities have contact with the bottom, which at least implies some effect on benthic processes; specifically those processes that contribute to the productions of food for EFH species, salmonids, groundfish, and coastal pelagics. In addition to contact with the bottom, the presence of managed shellfish aquaculture at a site can slightly affect the chemistry in the water and bottom sediments (Straus et al. 2008) in ways that imply effects on benthic communities. Despite interaction with the bottom environment over hundreds or thousands of acres in each sub-region, there is no evidence that such disturbance interferes with benthic productivity or decreases the availability of forage for EFH species on such a temporal to allow for a determinant conclusion of the effects.

Another issue for EFH concerning the effects of shellfish activities on benthic communities is whether or not bottom interactions from any source change conditions affecting the availability food. The effects of those interactions on benthic forage for listed fish are variously reported. Straus et al. (2008) reported increased benthic species at mussel culture sites, decreased benthic species richness at oyster culture sites, and no significant differences in benthic species (infauna) between mussel farms, oyster farms, and reference sites. Dumbauld (1997) in a review of studies on the impacts of oyster aquaculture reported that species abundance, biomass, and diversity are often enhanced in areas where oysters are cultured. The ENVIRON 2008a, review of recent studies found that Fleece et al. (2004) reported that species richness of macroinvertebrates was higher in areas seeded with geoduck than in unseeded areas. The ENVIRON 2008a also found that Pearce et al. (2007) reported similar results in species richness of benthic infauna two months after geoduck were seeded in an aquaculture site in British Columbia, Canada. Increased densities of benthic infauna at intertidal geoduck clam aquaculture sites may persist even after removing the protective PVC tubes and netting. For example, at one aquaculture site in Southern Puget Sound, ENVIRON 2008a, found the average number of infaunal benthic organisms per sediment core from an unprotected seeded area was greater than the density of infaunal benthic organisms found in a reference area located outside of the aquaculture site. VanBlaricom et al. (2013) found that structures associated with geoduck culture have little influence on community composition of resident benthic macroinvertebrates.

Some of the various hand or mechanical harvest methods used in shellfish aquaculture each involve a physical disturbance of the bottom that affect sediment and benthic fauna (Johnson

2002). In some cases, bottom disturbance reduces the number and abundance of benthic species in the disturbed area, although the extent of such reductions has been reported variously, including no effect at all. For example, hand raking and digging for various shellfish in Yaquina Bay, Oregon, did not impact infaunal species number and abundance (Straus et al. 2008). Furthermore, while post-harvest reductions of some taxa have been observed at intertidal geoduck aquaculture sites in Southern Puget Sound, sites generally recovered within 6 months after harvest. The recovery rates of benthic communities following physical disturbance depend on a variety of physical, chemical, and biological factors (Dernie et al. 2003), but in general, they recover quickly. Preliminary data from Chris Pearce, of Canada's DFO, suggests that species richness and relative abundance of benthic fauna at a geoduck aquaculture site in British Columbia, Canada were restored to pre-harvest levels within six months (*as cited in* ENVIRON 2008a).

Straus et al. 2008 also cited other research that examined return to pre-disturbance conditions. For example, a study that assessed sediment grain size as a metric of disturbance found that while disturbed bottom patches resulting in reduced or no fauna differed considerably in sediment grain size distribution, sediment grain size distribution returned to ambient levels after about two months at the disturbed cites. Similarly, benthic fauna population abundances for most species returned to ambient levels two to three months after benthic disturbance, and the community structure returned to ambient conditions after four months. In Scotland, severe disturbance from suction-dredged intertidal cockle sites had an average of 30 percent fewer benthic species and 50 percent fewer benthic individuals, immediately after harvest (Straus et al. (2008). But within 56 days after harvest, the faunal assemblages at these disturbed sites were not significantly different from control sites. A similar study in southeast England examined the sediment structure and benthic community immediately following and seven months after suction-dredge harvesting for Manila clams at an aquaculture site. Harvest suspended the sandy layer but left the underlying clay substrate. It substantively reduced both infaunal diversity and the mean number of individuals per sample. However, after seven months, neither the sediment composition nor the benthic fauna were significantly different from control sites. Straus et al. (2008) report that the authors of these studies concluded that clam cultivation does not have long-term effects on the substrate or the benthic community at that location.

The complex surface area provided by oysters and mussels offers habitat for over 100 different benthic species (CRMC, 2008). The CRMC review also found that large biomasses of cultured mussels or oysters and fouling organisms suspended from lines attached to buoys or rafts have a major beneficial effect on phytoplankton, benthic, and hydrographic conditions within the immediate area of culture activities. For example, because suspended rope culture in high current waters results in dispersal of pseudofeces, there are favorable increases in macrofaunal biomass in the vicinity of the culture operation. However, areas with low diversity (usually due to pollution from non-culture activities) and decreased flow demonstrate organic sedimentation under long lines up to two times that found in adjacent uncultivated areas (CRMC 2008).

Still other shellfish activities with benthic interactions include bed preparation like "frosting" which involves spraying gravel or oyster shell onto the intertidal area to make the bed firmer and to minimize predation for the bottom culture of clams and oysters. Frosting an intertidal region shifts the benthic community from polychaetes to amphipods and copepods. Gammarid amphipods are important prey items for juvenile salmonids (Jamieson et al. 2001), making this a beneficial result for forage production.

As mentioned above, benthic recovery typically follows disturbances for shellfish aquaculture. The stability and recolonization rates of benthic fauna can range dramatically depending on physical conditions (sediment type and stability, wave action, current), season, location, scale of disturbance, and whether recolonization occurs primarily through adult movement or larval settlement (Straus et al. 2008). Small benthic invertebrates produce more than one generation per year, considered rapid recolonization rates. Intertidal species have adapted to habitat changes, and so chronic low intensity or sporadic medium intensity intertidal substrate disturbances are within the range of "behavioral or ecological adaptability" (Jamieson et al. 2001). The best available information on the resilience of benthic populations after geoduck harvest is limited and has not been well-studied in Puget Sound. However, geoducks are harvested once every five or six years, a period of time that is reasonably likely to allow full benthic community recovery in between harvests based on the information presented in the studies cited by Straus, et al. 2008, and Washington Sea Grant (2013) .

Intertidal and nearshore shellfish aquaculture activities cause some disturbance of benthic habitat and mortality of non-target species. The factors that may have the greatest effect on benthic invertebrates relate to the timing and duration of the disruption, the shift in community structure, and the availability of other foraging habitat within migrating distance. Based on the currently available evidence, the level of benthic disturbance from existing shellfish aquaculture in Washington State is well within the range of normal sediment-disturbing processes (e.g. storm/wave activity) and that adverse effects are likely to be quite limited in space (the footprint of the shellfish bed plus some buffer to account for current) and duration (from a few hours to a few days to a few months depending on the benthic assemblages in question). Therefore, we believe that the effects of these existing, new, and expanded aquaculture activities on benthic communities unlikely to cause large scale impacts to EFH. Impacts to prey resources of EFH species would be quite limited in time and space.

Water Quality – Turbidity

The harrowing of bottom culture beds may occur at approximately annual increments. Harrowing normally involves work boats dragging a short tooth rake across the oyster beds, disturbing not more than two inches of the surface substrate. This activity normally occurs on beds with softer sediments or burrowing shrimp at high densities in Willapa Bay and Grays Harbor to ensure that the oyster crop stays on the surface. The mechanical or mechanical harvest on bottom culture beds also may occur at an interval of one to four years. Mechanical harvest is done at high tide and typically occurs on beds with a sandy bottom thus producing less turbidity plume when compared to beds with finer substrates that are more typically hand-picked during low tides (Dumbauld, Pers. Comm. 17/09/14). Dumbauld also related that when mechanical harvesting, operators attempt to keep the dredge from engaging deeply into the substrates, preferring to operate as efficiently as possible by just skimming the surface and harvesting the oyster crop. An additional element of this operational method is the effect on SAV.

During the harvest of bed reared hard shell clams, the beds are raked with hand-held rakes, or occasionally a mechanical harvester. A small amount of turbidity may be generated on the subsequent tidal inundation, with habitat effects small and generally contained to the immediate vicinity of the harvest site.

The harvest of intertidal geoduck sites also has the potential to generate a turbidity pulse to the aquatic environment. Harvesting of geoducks by pumping sea water into the substrates to loosen and allow the geoduck to be removed results in fine sediments delivered to adjacent waters. To measure this effect Entrix, Inc. (2004) collected water samples during a harvest operation. Harvesting was conducted at different distances from the water's edge and samples were collected up current, at water's edge, and down current from the harvest site. There was a definite increase in TSS or NTU measurements immediately adjacent to the harvest sites when harvest was measured at five feet from the water's edge. When harvest occurred further landward or samples were collected as little as 50 feet down current, however, TSS/NTU measurements were found to be at or near to background (up-current) levels.

Each of these activities is likely to produce a short-term increase in turbidity and to re-suspend sediments, including particulate nutrients into the water column. Because these activities are performed infrequently at any particular site, they have limited potential to impair water quality and effects are typically observed only within the footprint of the activity and immediately adjacent waters for a single tidal cycle.

These short-term effects on water quality can also be measured in contrast to the effects on water clarity that is occurring as a result of filter-feeding activity of the cultured mollusks. Phytoplankton and other water column particulates are being filtered from the water in the vicinity of the various mollusk aquaculture sites contributing to improved water clarity and to increased opportunity for SAV (eelgrass) to establish. The ammonia released by the shellfish is taken up by phytoplankton, renewing the cycle. These bio-deposits provide support to invertebrates, macroalgae, and seagrasses, including eelgrass (Newell et al. 2005). A net removal of a portion of the nutrients consumed by the shellfish occurs when they are harvested.

Water Quality, Application of Imazamox

Water quality impacts on EFH from the application of imazamox will be minimal and temporary and is not likely to affect the ability of EFH to provide for the recovery of SDPS green sturgeon. The project will have no effect on migratory corridors, substrate type or size, water depths, or sediment quality. The inadvertent loss of small amounts of native eelgrass from imazamox application will not appreciably reduce prey resources for any EFH species.

3.3 Essential Fish Habitat Conservation Recommendations

Fully implementing these EFH conservation recommendations would protect, by avoiding or minimizing the adverse effects described in Section 3.2, above, approximately 39,000 acres of designated EFH for species in Table 14, below.

1. Water Quality – The COE/permittees should utilize the conservation measures as needed to minimize TSS/turbidity contributions to the water column. Examples would be: to ensure that dredge harvest activities minimize sediment contributions by adjusting the bag to 'skim' the surface.
2. Impacts to Prey Resources - Similar to number 1 above the COE/permittees should minimize negative impacts to important HAPC habitats of native eelgrass by locating operations to avoid native eelgrass beds or patches. The COE/practitioners can also minimize impacts by avoiding activities during full foliage growth (spring and summer) or in a manner that destroys foliage or severely impacts eelgrass rhizomes.

Table 14. EFH Species found in the Action Area.

Species		**Lifestage**	**Activity**
Pacific Groundfishes			
Spotted ratfish	*Hydrolagus colliei*	Adults	All
Spotted ratfish	*Hydrolagus colliei*	Juveniles	Feeding
Soupfin shark	*Galeorhinus galeus*	Adults	All
Soupfin shark	*Galeorhinus galeus*	Juveniles	Growth to Maturity
Spiny dogfish	*Squalus acanthias*	Adults	All
Spiny dogfish	*Squalus acanthias*	Juveniles	Feeding
Spiny dogfish	*Squalus acanthias*	Juveniles	Growth to Maturity
Leopard shark	*Triakis semifasciata*	Adults	All
Leopard shark	*Triakis semifasciata*	Juveniles	
Big skate	*Raja binoculata*	Adults	All
California skate	*Raja inornata*	Adults	All
California skate	*Raja inornata*	Eggs	
Longnose skate	*Raja rhina*	Adults	All
Kelp greenling	*Hexagrammos decagrammus*	Adults	All
Kelp greenling	*Hexagrammos decagrammus*	Larvae	
Lingcod	*Ophiodon elongatus*	Adults	Feeding
Lingcod	*Ophiodon elongatus*	Eggs	
Lingcod	*Ophiodon elongatus*	Juveniles	Feeding
Lingcod	*Ophiodon elongatus*	Larvae	Feeding
Sablefish	*Anoplopoma fimbria*	Adults	All
Sablefish	*Anoplopoma fimbria*	Eggs	
Sablefish	*Anoplopoma fimbria*	Juveniles	Feeding
Sablefish	*Anoplopoma fimbria*	Larvae	
Cabezon	*Scorpaenichthys marmoratus*	Adults	All
Brown rockfish	*Sebastes auriculatus*	Adults	Feeding
Brown rockfish	*Sebastes auriculatus*	Larvae	Feeding
Copper rockfish	*Sebastes caurinus*	Adults	

Species		Lifestage	Activity
Copper rockfish	*Sebastes caurinus*	Larvae	Feeding
Splitnose rockfish	*Sebastes diploproa*	Juveniles	Feeding
Splitnose rockfish	*Sebastes diploproa*	Larvae	Feeding
Yellowtail rockfish	*Sebastes flavidus*	Adults	All
Quillback rockfish	*Sebastes maliger*	Adults	All
Black rockfish	*Sebastes melanops*	Adults	All
Black rockfish	*Sebastes melanops*	Juveniles	Feeding
Blue rockfish	*Sebastes mystinus*	Adults	Feeding
Blue rockfish	*Sebastes mystinus*	Juveniles	Feeding
Blue rockfish	*Sebastes mystinus*	Larvae	Feeding
China rockfish	*Sebastes nebulosus*	Adults	Feeding
Tiger rockfish	*Sebastes nigrocinctus*	Adults	Feeding
Bocaccio	*Sebastes paucispinis*	Juveniles	Feeding
Redstripe rockfish	*Sebastes proriger*	Larvae	Feeding
Pacific sanddab	*Citharichthys sordidus*	Adults	Growth to Maturity
Pacific sanddab	*Citharichthys sordidus*	Larvae	Feeding
Petrale sole	*Eopsetta jordani*	Adults	All
Petrale sole	*Eopsetta jordani*	Eggs	
Petrale sole	*Eopsetta jordani*	Larvae	Feeding
Pacific cod	*Gadus macrocephalus*	Larvae	
Rex sole	*Glyptocephalus zachirus*	Adults	Feeding
Flathead sole	*Hippoglossoides elassodon*	Adults	All
Flathead sole	*Hippoglossoides elassodon*	Eggs	
Flathead sole	*Hippoglossoides elassodon*	Juveniles	Feeding
Flathead sole	*Hippoglossoides elassodon*	Larvae	Feeding
Butter sole	*Isopsetta isolepis*	Adults	All
Rock sole	*Lepidopsetta bilineata*	Adults	All
Rock sole	*Lepidopsetta bilineata*	Eggs	
Rock sole	*Lepidopsetta bilineata*	Larvae	Feeding
Pacific hake	*Merluccius productus*	Adults	All
Pacific hake	*Merluccius productus*	Juveniles	Feeding
Pacific hake	*Merluccius productus*	Juveniles	Growth to Maturity
Dover sole	*Microstomus pacificus*	Eggs	
English sole	*Parophrys vetulus*	Adults	All
English sole	*Parophrys vetulus*	Eggs	
English sole	*Parophrys vetulus*	Juveniles	Feeding
English sole	*Parophrys vetulus*	Larvae	Feeding
Starry flounder	*Platichthys stellatus*	Adults	All
Starry flounder	*Platichthys stellatus*	Eggs	

Species		Lifestage	Activity
Starry flounder	*Platichthys stellatus*	Juveniles	Feeding
Starry flounder	*Platichthys stellatus*	Larvae	
Sand sole	*Psettichthys melanostictus*	Adults	All
Sand sole	*Psettichthys melanostictus*	Eggs	
Sand sole	*Psettichthys melanostictus*	Juveniles	Feeding
Sand sole	*Psettichthys melanostictus*	Juveniles	Growth to Maturity
Pacific Salmon			
Chinook salmon	*Oncorhynchus tsawytscha*	Juveniles	Feeding
Chinook salmon	*Oncorhynchus tsawytscha*	Adults	
coho salmon	*O. kisutch*	Juveniles	Feeding
coho salmon	*O. kisutch*	Adults	
Puget Sound pink salmon	*O. gorbuscha*	Juveniles	Feeding
Puget Sound pink salmon	*O. gorbuscha*	Adults	
Coastal Pelagic Species			
Northern Anchovy	*Engraulis mordax*		
Jack Mackerel	*Trachurus symmetricus*		
Pacific Sardine	*Sardinops sagax*		
Pacific (Chub) Mackerel	*Scomber japonicus*		
Market Squid	*Loligo opalescens*		

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 measures proposed by the agency for avoiding, mitigating, or offsetting the impact of the activity on EFH. In the case of a response that is inconsistent with the Conservation Recommendations, the Federal agency must explain its reasons for not following the recommendations, including the scientific justification for any disagreements with NMFS over the anticipated effects of the action and the measures needed to avoid, minimize, mitigate, or offset such effects (50 CFR 600.920(k)(1)).

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 the COE. Other interested users could include practitioners of shellfish cultivation. Individual copies of this opinion were provided to the COE. The format and naming adheres 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 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 contain more background on information sources and quality.

Referencing: All supporting materials, information, data and analyses are properly referenced, consistent with standard scientific referencing style.

Review Process: This consultation was drafted by NMFS staff with training in ESA and MSA implementation, and reviewed in accordance with West Coast Region ESA quality control and assurance processes.

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Appendix A. Technical Memorandum: Operational Definition of an Eelgrass (*Zostera marina*) Bed

A Summary of Workgroup Discussions and Related Analysis
October 2011

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Introduction

Proposed habitat conservation measures aimed to minimize or avoid impacts to eelgrass (*Zostera marina*) beds are currently being discussed among representatives of the Washington shellfish aquaculture industry, Washington Department of Natural Resources (DNR) management, and DNR aquatics program staff. Questions have emerged from these discussions regarding what constitutes an eelgrass bed: What minimum sized area and density of eelgrass shoots comprise a bed? Are groups of non-contiguous patches part of one larger bed, or are they treated as independent beds? Is there a minimum time that observable shoots must persist in an area to be considered a bed? The answers specified for these questions will have direct effects on activities that are constrained by proximity to eelgrass beds.

In an effort to address these questions, a technical workgroup was convened with the goal of establishing criteria for defining an eelgrass bed. Workgroup participants included scientists and technical representatives from DNR Aquatics Program, U.S. Fish and Wildlife, NOAA Fisheries, University of Washington, Northwest Indian Fisheries Commission, Point-No-Point Treaty Council, the Squaxin Island Tribe and the shellfish aquaculture industry. This technical memorandum provides a review of the information discussed at the meetings, steps through analyses of available data, proposes criteria for defining an eelgrass bed, and recommends metrics to consider for developing conservation measures with the intent to minimize and avoid impacts to eelgrass beds.

Goal

The overall goal is to determine the criteria for an operational definition of an eelgrass bed. The definition must be sufficient for site-level application for the sustainable management of eelgrass. It must allow for repeatable delineation of the beds so impacts from DNR authorized activities in marine tidelands can be avoided or minimized with application of appropriate conservation measures.

Objectives and Constraints

- The eelgrass bed criteria must be applicable at the project or site scale (on the order of 0.1-10 acres). This definition must be precise enough to provide a basis for siting of projects on state owned aquatic land parcels where eelgrass is present.

- The criteria must be feasible to apply using common survey methods and equipment by experienced environmental scientists.
- While a definition based on ecological principles is preferable, in the absence of conclusive scientific evidence, an operational definition based on best available scientific information will suffice so long as it is understood that this will be adaptively managed as information is gathered through implementation and monitoring.

Background

Currently used or proposed criteria for eelgrass bed

As scientific evidence demonstrating the importance of eelgrass to nearshore ecological function has accumulated (Phillips 1984, Orth et al. 2006), entities tasked with sustainable stewardship of coastal habitats are striving to maintain and restore eelgrass beds (Thom et al. 2008). This challenge requires the ability to delineate beds and to measure current status and change in the beds over time. Table 1 summarizes various eelgrass bed criteria and the agency or entity that has implemented or proposed each. Some of these definitions are proposed based on some local empirical data, others are based on knowledge of the specific ecological function the eelgrass provides that is of concern (e.g. fish refugia),. Some were developed for research or resource management purposeswhile others were developed for regulatory implementation.

Table 1. Existing criteria for defining eelgrass beds

IMPLEMENTATION AGENCY, ENTITY, RULE OR POLICY	EELGRASS BED CRITERIA
DNR Proposed Habitat Stewardship Measures	Contiguous separation distance ≤ 1 m Minimum shoot density 3 shoots/m^2
DNR Submerged Vegetation Monitoring Program (SVMP)	Any eelgrass presence within a 1m^2 area along the length of a video transect that is continuously sampled at approximately 1 meter intervals until no presence is detected. A single shoot within a 0.1 m^2 grab sample.
U.S. COE of Engineers Regional General Permit -6	An area of tidal substrate supporting eelgrass covering a minimum of 25% of the substrate
Tampa Bay Estuary Program-proposed definition	A "seagrass bed" is ≥10% cover within a 10-30 m long transect line. The "zone of eelgrass occurrence" is defined as 1 shoot/m^2 for at least 10 m along a line transect (Virnstein et al. 1998)
Alaska Sea Grant	A persistent patch of eelgrass from qualitative observations requires ≥50 shoots/m^2 (Wyllie-Echeverria and Thom 1994)

IMPLEMENTATION AGENCY, ENTITY, RULE OR POLICY	EELGRASS BED CRITERIA
Massachusetts Division of Marine Fisheries	The edge of the bed is defined as having two points; 1) the distance to the end of the continuous meadow, and 2) the distance to the last shoot (Evans and Leschen 2010).
Seagrass Net	To be considered within the same bed, any eelgrass present within a 1 m^2 quadrat must be within ≤ 1 m distance of a nearby eelgrass presence. The edge or transition area is indicated by the distance of the furthest eelgrass shoot that is beyond this 1m contiguous bed from a fixed point along a fixed transect. Eelgrass shoot counts (within 0.0625 m^2) and percent cover (in 0.25m^2) is estimated in 12 randomly pre-selected quadrats along a 50 m transect (Short et al. 2006)
Seagrass Watch	A single shoot within a 1 m^2 quadrat along a 50 m long transect constitutes presence. Both shoot counts and an estimate of percent cover are recorded (McKenzie et al. 2003).
Ospar Commission	A “seagrass meadow” is defined as an area of at least 2x2 meters covered in seagrass. If < 10 meters exists between patches, they are considered of the same meadow. A distance > 10 meters exists between patches they are of separate meadows (MARBIPP 2006).

Scientific literature relevant to eelgrass bed definition

Listed below are ecological functions and attributes that should be considered when developing a scientifically based definition for an eelgrass bed.

- In many areas *eelgrass* occurs as a ‘compound’ grouping of non-contiguous areas. (Fonseca and Bell. 1998). A separation distance criterion must be established to determine how to group these non-contiguous areas.
- The minimum detectable quantity of eelgrass depends on the sampling method used, but most site-scale sampling methods are able to detect eelgrass to the individual shoot. A minimum threshold that constitutes an accepted eelgrass presence (e.g. single shoot, area of specified shoot density or percent cover) must be defined.
- Eelgrass morphological structure consists of above-ground shoots as well as below-ground rhizomes. The below-ground portion of the plant is often of larger dimension and mass than the visible, above-ground portion.
- How bed size affects the scope of habitat provision (benthic invertebrates, fish, or birds) (Hirst and Atrill 2008).
- How bed size/density affects the ability of eelgrass to stabilize sediment and trap suspended particulates (Koch 2001).

- How biomass, bed size/density affects the level of primary productivity and contribution to the detrital food web.
- Persistence of vegetated area – a minimum patch size may be needed for an eelgrass unit to remain present year after year. Interannual cross- and long-shore variability of seagrass bed edges has been documented (Frederiksen et al. 2004; Marbà and Duarte 1995, Grette Associates 2005, 2008, and 2009).
- Resilience of vegetated area – a minimum residual patch size or density may be required to re-establish a bed after experiencing disturbance (natural or anthropogenic).
- Distances between patches and beds affect seed dispersal and successful gene flow.

Scientific studies with specific metrics regarding the ecological attributes listed above are summarized below. This information was reviewed and discussed in the workgroup meetings when considering development of minimum size, density and persistence eelgrass bed criteria.

Habitat

- Fonseca et al. (1998) observed that patches as small as 1-2 m^2 had greater numbers of fish, shrimp, and crab compared with adjacent unvegetated areas.
- A study comparing benthic infaunal biodiversity of *Zostera* vegetated patches (ranging in size from 0.24 m^2 to 17 m^2) and non-vegetated intertidal substrate areas found that all *Zostera* patches supported a higher level of biodiversity than bare sand, and neither the patch size or mean shoot density had any impact on the level of diversity (Hirst and Attrill 2008).
- Eelgrass fragmentation was examined for its role in benthic infauna community composition in the United Kingdom by comparing infaunal communities in a continuous 2.3 ha meadow versus the composition in patches 6-9 m^2 (Frost et al. 1999). Communities differed as a result of small changes in species abundance, but not in diversity. However, polychaetes generally associated with unvegetated habitats (e.g. *Magelona mirabilis*) were found to be more common in the fragmented bed than in continuous beds.
- Neither patch size, nor location of sampling within patches (edge or central) exerted as much influence on the infaunal community as sediment composition (Frost et al. 1999). Total abundance did not differ between patch sizes in univariate analyses, but multivariate analyses showed that the species that contributed most to the difference in assemblage composition between patches were more abundant at the edge. In particular the nematodes *Capitella capitata* and *Spio filicornis,* species tolerant of

random disturbance (stochastic events) were more abundant at the edge of beds relative to samples collected from the interior of the beds.

- An examination of fish and amphipod abundance across seagrass beds (*Halodule wrightii*) ranging 5-93 m^2 in size suggested no consistent relationship between faunal abundance and patch size (Bell et al. 2001).

- Based on a study of varying eelgrass densities (140 to 660 shoots/m^2), no significant differences in the number of fishes sampled were detected between eelgrass plots (Wyllie-Echeverria et al. 2002 as cited in Blackmon et al. 2006).

- Throughout the Puget Sound, eelgrass habitat has been shown to be utilized by juvenile salmonids, but no indication of how this habitat is used based on the density and structure of the eelgrass beds has been provided (Blackmon et al. 2006).

- Epibenthic faunal abundance was closely related to eelgrass bed development when comparing unvegetated, transplanted, recently seed-colonized, and mature eelgrass habitats in North Carolina (Fonseca et al. 1990).

- Blue crab survival in the Chesapeake Bay was found to vary with eelgrass patch size and complexity (Hovel and Lipcius 2001 as cited in Blackmon et al. 2006). Juvenile blue crab density decreased as patch size increased, and increased habitat fragmentation increased blue crab survival due to the increase in seagrass edge habitat. However, density was significantly lower in isolated patches separated by large areas of unvegetated habitats.

- In a New Zealand study, seagrass patch variables (patch size, % cover and biomass) explained only 3-4% of the variation in benthic community, while landscape variables (fractal geometry, patch isolation) and wave exposure explained 62.5% of the variation in faunal abundance data (Turner, et al. 1999).

Sediment characteristics

- Both above and below ground eelgrass structure contributes to sediment stabilization; above-ground shoots have the capacity to reduce water flow which results in lowering the velocity of the flow on the sediment substrate, thus reducing the amount of sediment that can be entrained and transported (Fonseca el al. 2002).

- Eelgrass acts as a sediment sink with above-ground shoots trapping sediment and particulates from the water column and below ground rhizomes and roots anchoring sediment. This can result in sediment accretion that changes the bathymetry – causing mounding in areas around seagrass beds (Walker 1999).

- The capacity of eelgrass to accrete sediment increases with increasing patch size. The magnitude of slowing current velocity and accreting sediment is based on the density of the bed, hydrodynamic conditions of the area, and the depth of the water column above the plants (Koch 2001). Changes in physical conditions trap nutrients and stabilize habitats that are necessary for seagrass growth and recruitment. Elimination of newly developed small patches will slow or entirely inhibit larger, more extensive patch development (Kendrick et al. 2005)

- Patches as small as 0.3 m and 1.0 m along the axis of current flow were capable of significantly reducing current velocity relative to bare mud flat habitat (Fonseca and Koehl 2006). Eelgrass has been shown to attenuate 43% of wave energy in a 1 m long bed (Fonseca and Cahalan 1992).

- A significant difference in median grain size and sorting COEfficient was observed in contiguous versus fragmented beds, and median grain size was found to be the variable best explaining multivariate community patterns (Frost et al. 1999).

Primary Productivity/contribution to food web

- Seagrasses can act as short-term sinks for refractory carbon; 1-2 years for above-ground biomass and 4-6 years for below ground biomass (Mateo 2006). Eelgrass has the capacity to survive and maintain actively growing perennial populations even in its northern-most limit by storing excess carbohydrates in the rhizomes during the dark winter. There is, therefore, important ecological function being provided by below-ground structure that may be laterally distant from the visible above ground shoots (Duarte et al. 2002).

Persistence

- In plots established outside a continuous vegetated meadow, patch mortality was observed to decrease with increasing patch size (area) and age, and only patches >32 shoots survived. The critical minimum patch area required for survivorship varied seasonally (Olesen and Sand-Jensen 1994).

- Fonseca and Bell (1998) found that eelgrass beds with <50% cover were less stable than those with greater percent cover.

Resilience

- Compared with seedlings, surviving adult plants and small patches may contribute considerably to recolonization of a dieback area as these plants have faster elongation and branching rates and lower mortality than seedlings (Greve et al. 2005).

Reproduction

There are differences in the relative importance of sexual and clonal portions of eelgrass life history that must be considered when attempting to set management standards for protection and maintenance of genetic structure.

Seed dispersal distance and transport time

- 95% of pollination occurs within 15 m of source. 83% of seeds are dispersed within 5 m of the source and 100% within 50 m (Ruckelshaus 1996).

- Pollen is viable for only 7-48 hours (de Cock 1980; Cox et al. 1992).

- Once buried in sediment, seeds of *eelgrass* can remain dormant for 1-2 months (Moore et al. 1993).

- Reproductive shoots carrying maturing seeds can be carried by currents or consumed by water fowl and transported long distances (kilometers).

- Germination rates range between 5-20%, with 80% of the seedlings germination within 5 m diameter of source (Orth et al. 1994). Germination rates were found to not be seed-density dependent, but were patch size dependent (Orth et al. 2003).

Genetic Neighborhood

- In a study of genetic diversity and patch size with patches ranging from $0.25m^2$ to $440m^2$, Ruckelshaus (1998) found genetic diversity was inversely related to patch size. Genetic diversity tended to be higher in intertidal areas that had smaller patch sizes and were more prone to disturbance.

- Ruckelshaus (1994) found that a distance of 4 m around a plant was adequate to genetically separate individual plants.

Table 2. Summary Table: values of eelgrass bed metrics associated with ecological attributes from the review of literature

ECOLOGICAL ATTRIBUTE	EELGRASS METRIC	VALUE
Benthic habitat	Minimum eelgrass bed area to effect habitat value	1-2 m^2 (Fonseca et al. 1998) 0.24 m^2 (Hirst and Attrill 2008)
Sediment stability	Minimum eelgrass bed area to significantly reduce current velocity	0.3 m^2 (Fonseca and Koehl 2006)
Seed dispersal	Seed dispersal distance	5m (Ruckelshaus 1996)
Genetic diversity	Distance at which plants can be genetically distinguished	4m (Ruckelshaus 1994)
Vegetative reproduction	Mean rhizome growth rate	26 cm/yr (Marbà and Duarte 1998, Sintes et al, 2006))
Persistence	Minimum eelgrass density associated with bed persistence	>32 shoots per patch area (Olesen and Sand-Jensen, 1994)
	Eelgrass cover associated with greater persistence	>50% cover (Fonseca and Bell 1998)

Summary of available data relevant to eelgrass bed definition

Existing eelgrass data available to DNR staff were evaluated to see if any patterns in eelgrass density, patchiness or bed persistence emerged or if perhaps there was any indication that further investigation of this data might be useful in developing eelgrass bed criteria. The four data sources described below include the Dumas Bay SeagrassNet site, the Submerged Vegetation Monitoring Program density grab samples, mitigation monitoring data from a Maury Island site and plant morphology data from the DNR Stressor Project.

Dumas Bay SeagrassNet Site

SeagrassNet is a worldwide ecological monitoring program that documents the status of seagrass resources. The program started in 2001 in the Western Pacific and now includes 115 sites in 32 countries with a global monitoring protocol and web-based data reporting system. A SeagrassNet site was established in Dumas Bay in Washington's Puget Sound in May 2008. SeagrassNet sampling protocol requires that three fixed transects be established in a seagrass bed that is representative or "typical" for the area. The fixed transects run alongshore, parallel to the beach. Transect A is located approximately 1 m into the contiguous bed from the shoreward edge.

Transect C is 1 m into the contiguous bed from waterward edge. Transect B runs through the center of the contiguous bed.

Contiguous is defined as any eelgrass shoot that is within ≤1 meter of another eelgrass shoot. Furthest shoot data was compiled and analyzed from the Dumas Bay SeagrassNet site. The furthest (last, terminal) shoot is measured from three points (0, 25 and 50 m) perpendicular from the shallow (transect A) shoreward and deep (transect C) seaward transect. The distance to the edge of the bed (area of contiguous eelgrass, ≤1 meter shoot spacing) is also measured from theses points. Data is collected quarterly.

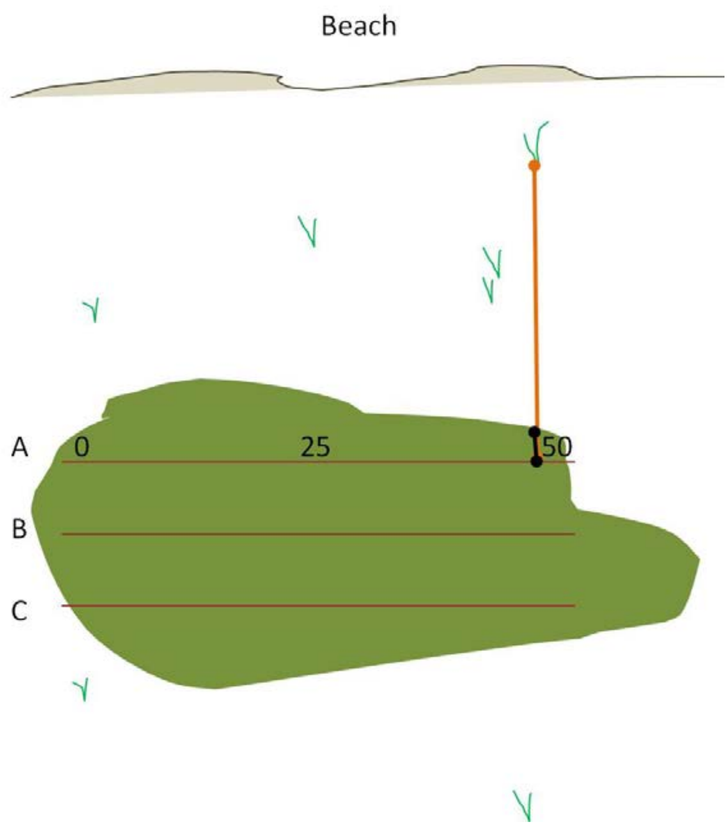


Figure 1 illustrates SeagrassNet transect placement, measurement to bed edge and furthest shoot distance.

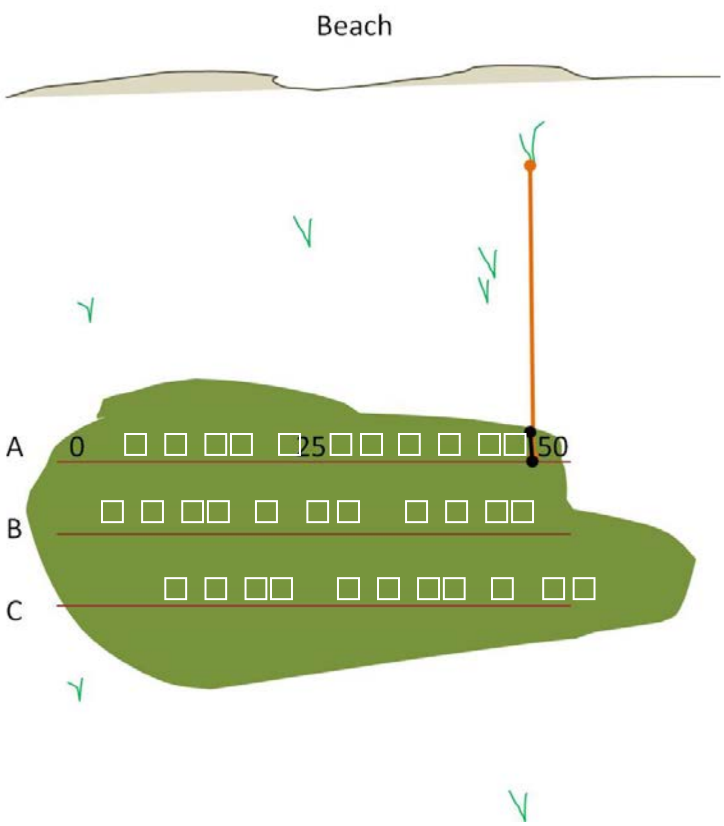


Figure 1. *Schematic of SeagressNet site and distance to edge of bed (black line) and furthest shoot distance (orange lin) (diagram not to scale)*

From May 2008 through January 2011, thirteen sampling events occurred. There were not enough sample times where furthest shoot data was collected from the deep transect (transect C) to provide any meaningful information for the analysis. A basic evaluation of the furthest shoot data collected from the shallow transect (transect A) revealed:

Furthest shoot distance- Dumas Bay

Sparse, patchy eelgrass along the intertidal edge of larger contiguous beds had been observed in the field by many of the workgroup participants. From the discussion, it seems the size, distance from the bed, and ephemeral nature of these patches vary considerably. This prompted an examination of the available data to see whether any of these parameters might be quantified. Here, the furthest shoot refers to the single furthest shoot from the central area of the bed

1) Furthest shoots were not present throughout the year; they were only present in the spring and summer sample times.

2) When furthest shoots were present, they were located near where they had been previously detected (maximum change in furthest shoot distance was 5.3 m).

3) The maximum distance of a furthest shoot from the contiguous edge was 8.9 m. 4) The change in contiguous edge location over all sampling times (through all seasons) ranged from 0.4m at the center position to 11.3 m at the left position. 5) Net change from the first spring sampling (May ’08) to the most recent spring sampling (Apr ’10) was much smaller, ranging from 0.1 m at the center position to 1.7 m at the left position. The results are summarized in **Table 3** and **Table 4**.

Table 3. Furthest shoot distance, Dumas Bay, SeagrassNet site.

	SHALLOW TRANSECT FURTHEST SHOOT DISTANCE (M)				n (# times furthest shoots present)	n (# times bed examined for furthest shoot
	Max	Min	Mean	Std dev		
SeagrassNet site, Dumas Bay May ‘08-Jan ‘11	8.9	1.8	6.6	2.3	7	34

Table 4. Change in edge and furthest shoot location Dumas Bay, SeagrassNet site

Position on Transect A	Max seasonal change in edge distance (m)	Max annual change in edge distance	Max change in furthest shoot distance(m)
center	+0.4	+0.3	+1.5
left	-11.3	-3.4	-1.7
right	-6.1	+2.2	+5.3

This analysis provided some insight into the magnitude of changes in the edge and furthest shoot location, as well as the seasonality in the expansion/contraction of the edge and furthest shoot presence at this site. In addition, a pilot investigation of the DNR Submerged Vegetation Monitoring Program (SVMP) data was conducted to see what information about furthest shoot distance from contiguous bed edge might be learned and what comparisons could be made among the different areas of Puget Sound. This preliminary analysis indicated the furthest shoot distance could not be estimated using the SVMP data. The SVMP data did not distinguish between a single blade in a square meter and thousands of shoots per meter. Further analysis of the SVMP data was abandoned.

Eelgrass Density- Dumas Bay

Eelgrass density and percent cover estimates were conducted at fixed random sites along three 50m longshore transects at +1, 0 and -1.6 MLLW tidal elevations. Seasonal variability is apparent in density and percent cover, with maximum values observed in the spring and summer (data not shown). Interannual variability is also observed. This is apparent from the range in density and the standard errors reported for just the July samplings (the SeagrassNet site is sampled quarterly) 2008-2011, documented in Table 5 below.

Table 5. Shoot density and percent cover at Dumas Bay, SeagrassNet site

Transect & elevation (MLLW)	Date	Average density (shoots/m2)	SE(n)	Average % cover	SE (n)
A, +1	July '08	597.3	277.7 (12)	28	12 (12)
A, +1	July '09	292.0	206.7 (12)	16	9 (12)
A, +1	July '10	184.0	97.9 (12)	12	6.8 (12)
A, +1	July '11	109.3	76.8 (12)	8	5 (12)
B, 0	July '08	769.6	175 (12)	46	6.6 (12)
B, 0	July '09	878.7	192.4 (12)	61	7.9 (12)
B, 0	July '10	892.0	135.6 (12)	72	9.7 (12)
B, 0	July '11	841.3	148 (12)	62	9.1 (12)
C, -1.6	July '08	210.7	32 (12)	46	6.2 (12)
C, -1.6	July '09	280.0	33 (12)	38	4.1 (12)
C, -1.6	July '10	186.7	29.6 (12)	28	4.9 (12)
C, -1.6	July '11	130.7	10.9 (12)	26	4.3 (12)

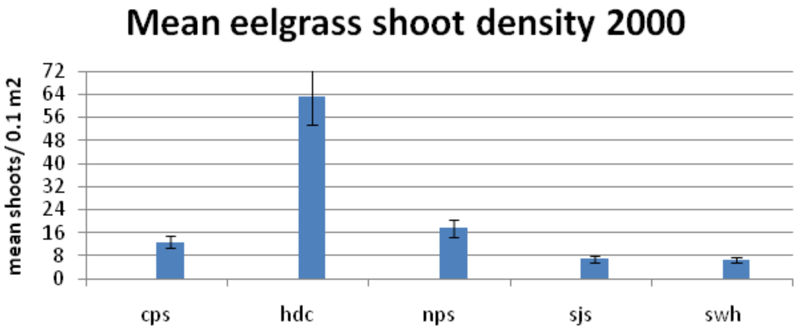
SVMP Eelgrass Shoot Density

Environmental parameters influencing eelgrass plant structure and eelgrass bed density have been reported in scientific literature (Boese et al. 2003; Turner et al. 1999). Workgroup participants have also cited field observations of geographic differences in plant structure and patch density. This encouraged an examination of the available data on eelgrass shoot density, specifically to see if regional differences or variability in eelgrass density over time might be quantified.

DNR grab sample density counts

Initial sampling for the SVMP included shoot density counts of grab samples collected with a van Veen sampler. An average of 23.9 shoots /sample with a minimum of 1 shoot per unit area was reported from 1020 samples collected from 2000-2003. Sites sampled within each region were not necessarily sampled each year, though some sites were sampled in consecutive years. Sampling did not fall in the same period for each year either. While the absolute density numbers differed each year, visual observation of the data (see plots in figure 2 below) does indicate a fairly consistent pattern of relative difference in shoot density among the five regions sampled, with Hood Canal (hdc) having the highest density, Central Puget Sound (cps) and North Puget

Sound (nps) competing for second highest, then South Whidbey (swh), and San Juan Island (sjs) with the lowest density.



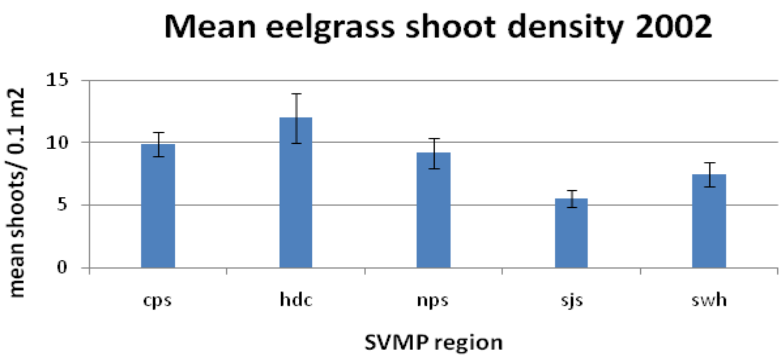


Figure 2 *Mean eelgrass shoot density from annual grab sampling by region, 2000-2002. Error bars are standard errors of the means.*

Mitigation monitoring data- Maury Island

Eelgrass at a proposed project site on Maury Island was monitored intensely in 2005 and 2008 and 2009 by the consulting firm Grette Associates LLC. Fixed grids with grid cell size of 1 x 1meter were established to encompass all the eelgrass area. Dive survey sampling included eelgrass percent cover estimates within each square meter grid cell, eelgrass density shoot counts within a 0.25 m^2 portion of each grid cell, and delineation of eelgrass presence in each square meter. Eelgrass survey maps from sample years 2005, 2008 and 2009 are reproduced in figures 3-5 below with eelgrass presence delineated and the density counts/0.25 m^2 indicated within each grid cell. Sampling occurred during July for 2005 and 2008, then in August for 2009. The images are from Northwest Aggregates: Maury Island Gravel Dock Annual Eelgrass Survey Reports, December 19, 2005, September 19, 2008, and December 15, 2009 prepared for Northwest Aggregates by Grette Associates LLC.

Eelgrass Density–Maury Island

Close examination of the data from eelgrass monitoring of the North, South and Control patches (figures 3-5 below) indicated differences in the stability of the three beds. These findings are summarized in Table 5.

Table 6. Eelgrass patch area and mean density at Maury Island Gravel site

Patch name	Year	Area (m^2)	Net change in area (m^2) from '05 to '09	Average density ($shoots/m^2$)	Net change in avg. density ($shoots/0.25m^2$) from '05 to '09
North	2005	126		77	
	2008	127		72	
	2009	85	-41	13	-64
South	2005	148		54	
	2008	152		56	
	2009	218	+70	28	-26
Control	2005	261		30	
	2008	256		37	
	2009	265	+4	26	-4

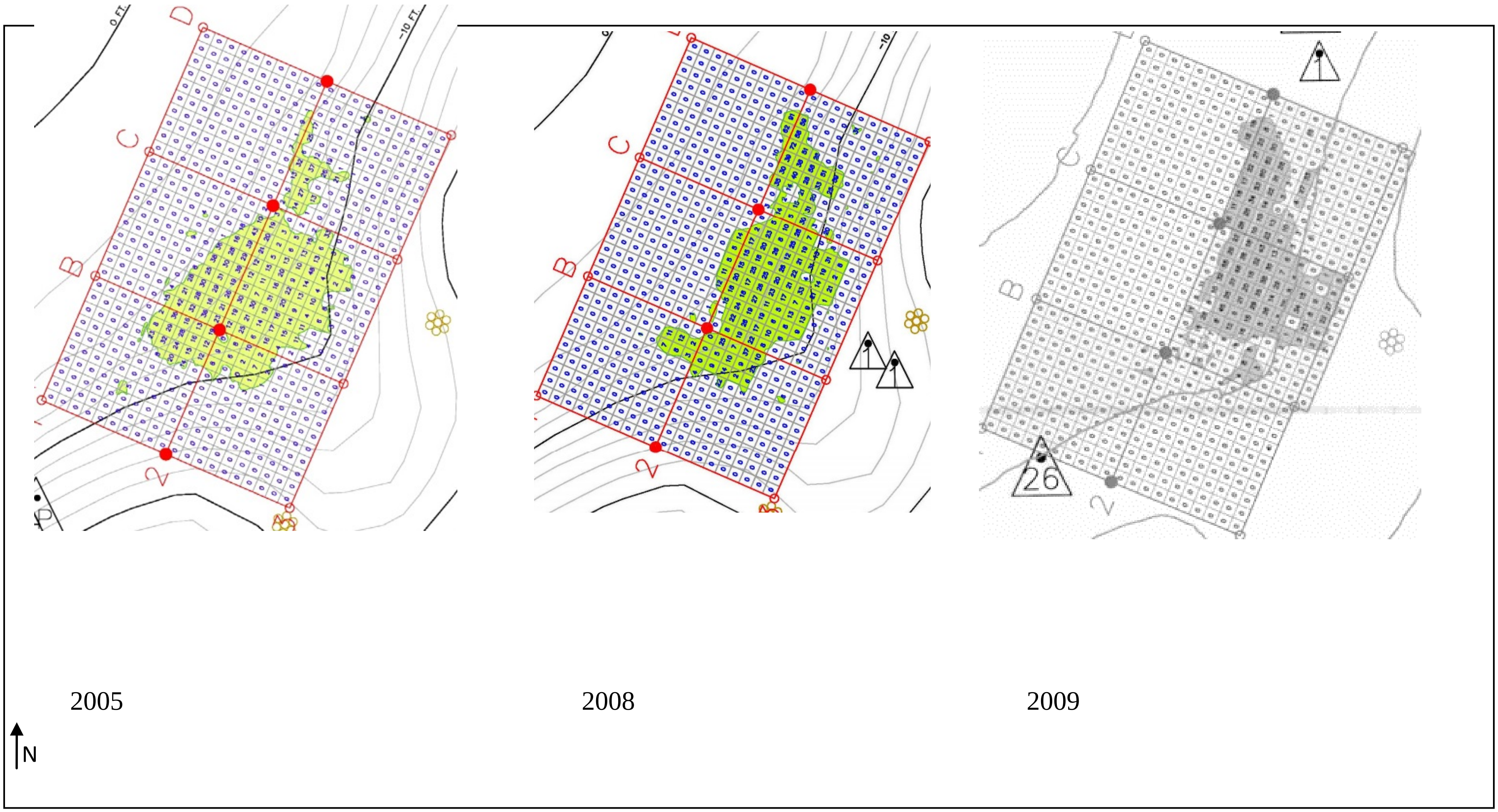


Figure 3 *Eelgrass monitoring Maury Island N. Patch 2005, 2008, 2009 (from Grette Associates 2005, Grette Associates 2008 and Grette Associates 2009)*

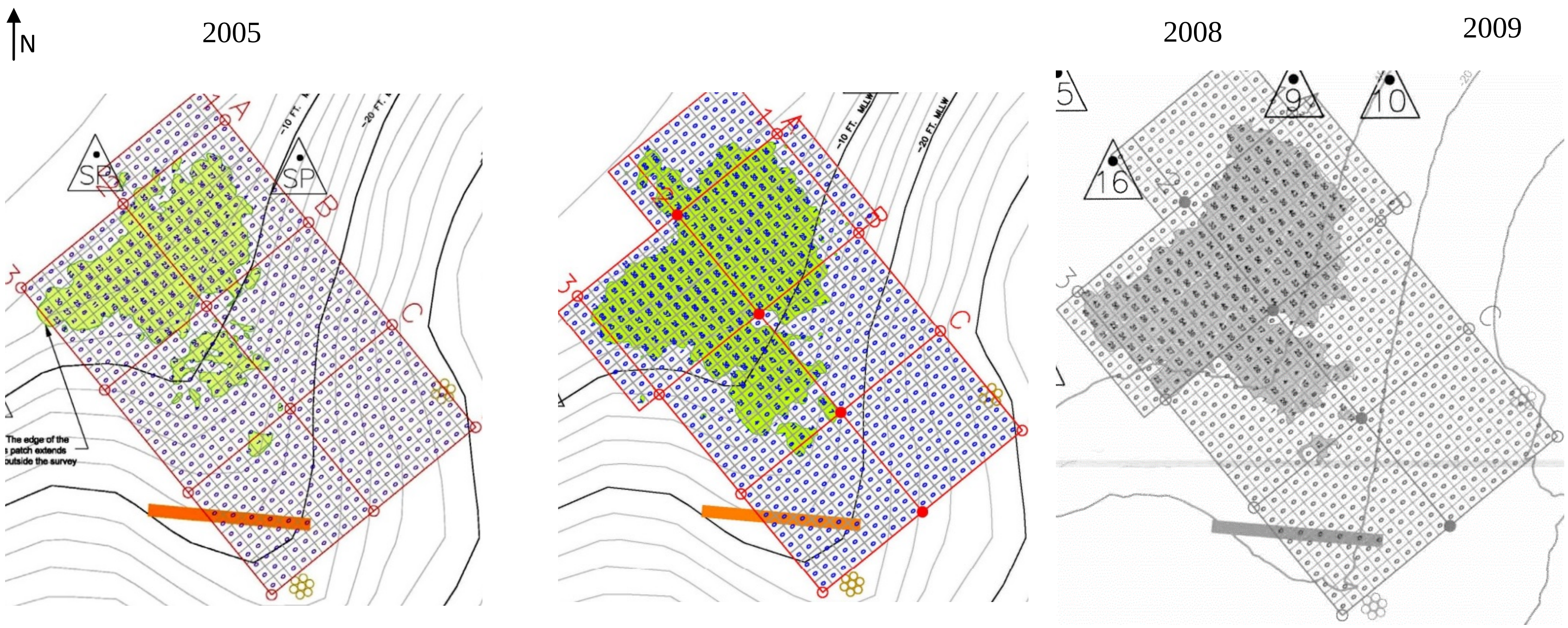


Figure 4 *Eelgrass monitoring Maury Island - S. Patch 2005, 2008 and 2009(From Grette Associates 2005, Grette Associates 2008 and Grette Associates 2009)*

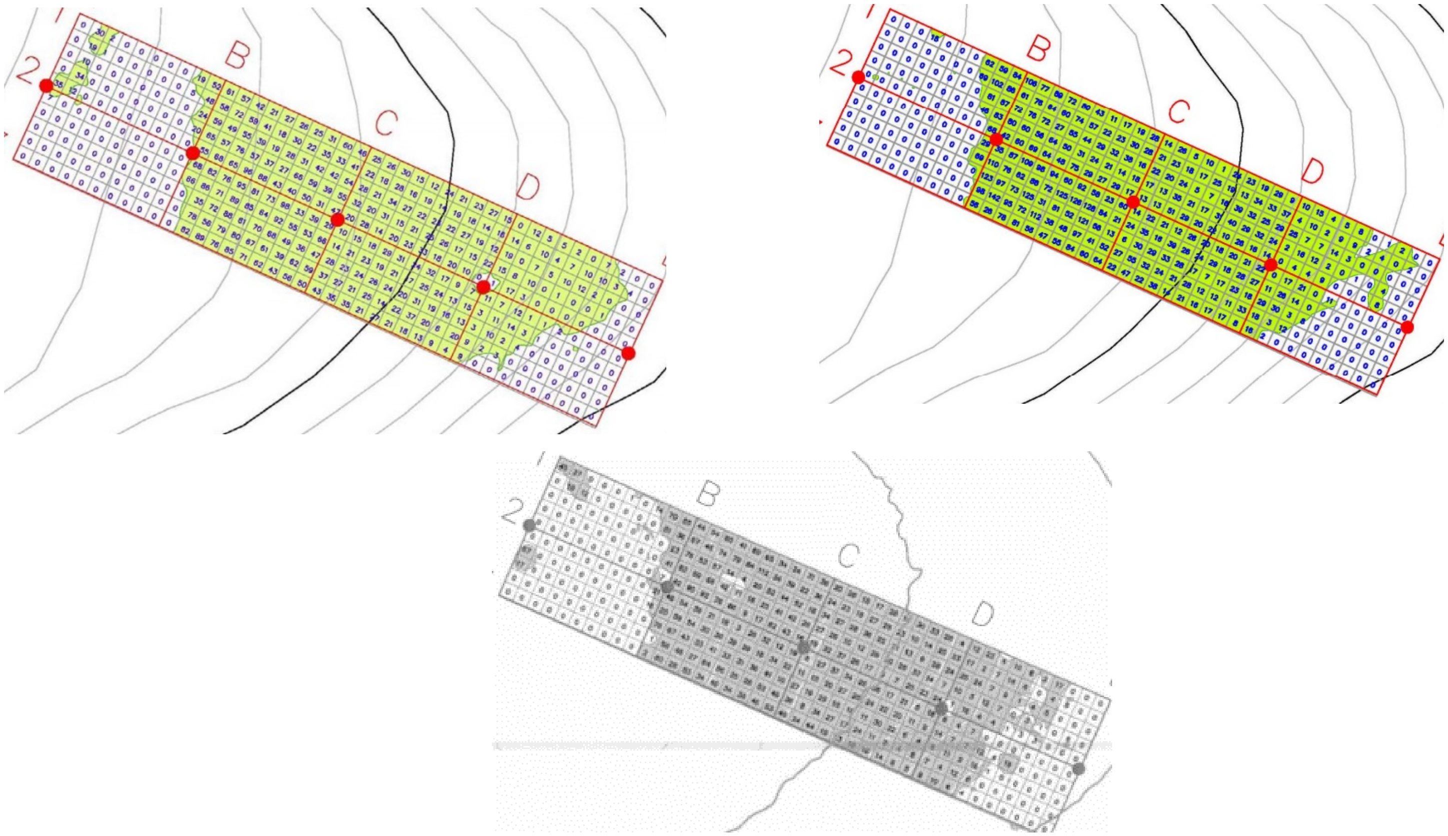

B
C
D
1
2

Figure 5 *Eelgrass monitoring Maury Island - Control. Patch 2005, 2008 and 2009(from left to right) (From Grette Associates 2005, Grette Associates 2008 and Grette Associates 2009)*

Apparent differences in bed stability from comparison of the Control patch to the other two patches may be an artifact of differences in the survey limits for Control site versus the North and South patches. The Control site survey was limited to a swath from a larger bed, while the survey extents for the North and South patches contained the entire bed in each case, and even increased if necessary to capture edge migration. Assessment of comparison between the North and South patches, and relative change for each of these two patches over time is not affected by this survey limitation.

The bed area and average shoot density remained relatively stable in the Control area (again this may be an artifact of the survey extent for this site). The bed area increased in the South patch and decreased in the North patch, while the average shoot density decreased in both North and South patches.

The North patch edge moved approximately 2 meters east between 2005 and 2008 (spreading out both north and south). The northward edge contracted approximately 5 meters from 2008 through 2009.

The western South patch migrated approximately 2 meters east (filling in the patchier northern portion) from 2005-2008. It continued to migrate another approximate 4 meters east between 2008 and 2009.

Migration of the Control patch edges cannot be accurately assessed because the monitoring area does not contain the long-shore edges of the bed. It is apparent that smaller patches in the shoreward edge were ephemeral in size and shape.

Furthest shoot–Maury Island

When looking at the pattern of density in all patches for three years, gradual tapering off of the density toward the shallow edge is never observed. In fact, some of the highest density grid cells are located directly on the shallow edge. The decrease in density is slightly more gradual on the deeper edge but only 1 to 2 meters before complete drop-off.

In the North, South and Control patches, furthest shoots were documented (shoots located beyond a meter distance of the contiguous bed) off the shallow and deep edges of the bed. A furthest shoot was not always present. When present, furthest shoot distances on the shoreward edges ranged from 1.1m to 8.0m. The Furthest shoot distances on the seaward edges (when present) ranged from 2.1 m to 3.5m. Below is a table summarizing the furthest shoot distances measured at this site.

While the beds did not migrate beyond the location a furthest shoot was found (shoreward or seaward) they did migrate along-shore to areas where no eelgrass was found at the previous sample time.

Table 7. Edge migration and shoot distance in eelgrass patches at Maury Island Gravel site

Patch name	Year sampled	Edge migration: expansion, +,	Shoreward furthest shoot distance (m)	Seaward furthest shoot distance (m)
North patch	2005		1.7	
	2008	+2 east	2.0	2.1
	2009	-5 north		
South patch	2005		1.1	3.5
	2008	+ 2 east		
	2009	+4 east		
Control patch	2005			
	2008		8.0	
	2009			

Eelgrass persistence–Maury Island

Persistence for patch size and density was evaluated in the Maury Island data for comparison with the estimates provided in the literature. Only patches that were a maximum of 2m x 2m were included in the analysis. Patches that persisted beyond a season were larger in area and had a higher average shoot density compared with patches that did not persist. Patches that persisted were at least 0.3 m^2 in area with minimum density of 3 shoots/0.25m^2.

Table 8. Minimum patch size and shoot density for eelgrass persistence at Maury Island Gravel site

Patch persistence	Shoot density (shoots/0.25m^2)				Patch area (m^2)			n
	average	min	max	SE(n)	average	min	max	
>1 season	54.4	3	124	2.44	0.9	0.3	4.0	10
<1 season	13.7	1	36	0.76	0.6	0.1	1.0	14

Plant morphology data- DNR eelgrass stressor project

Plant structure provides important ecological functions. Above ground shoots can provides three-dimensional structure for fish refugia, epiphyte and invertebrate attachment. Below ground structure provides habitat for macroinvertebrate attachment and sediment stabilization. Morphology of the above and below ground structure of *Z. marina* has been documented to differ with environmental factors (Turner et al, 1999, Frederiksen, et al 2004). Plant structure is relevant in developing bed criteria because distance between plants and bed edge is influenced by shoot and rhizome length. Plan morphology data from the DNR eelgrass stressor project was analyzed and the results are presented below.

53.1 cm was the average shoot length at four sites (SE= 1.4, n=180) in Puget Sound, with an average maximum shoot length of 89.7 cm (SE=6.5, n=45)(DNR unpublished data). Average rhizome length at these sites was 33.3 cm (SE=2.9, n=169), with an average maximum rhizome length of 68.4 cm (SE=4.4, n=43).

Table 9. Eelgrass morphology metrics.

ECOLOGICAL ATTRIBUTE	EELGRASS METRIC	VALUE
Eelgrass morphology	Shoot length	Average shoot lengths ranged from 53.1 cm to 89.7 cm (DNR unpublished data)
	Rhizome length	Average rhizome length ranged from 33.3 cm to 68.4 cm (DNR unpublished data)

Index of eelgrass densities in Puget Sound and Willapa Bay

Eelgrass bed densities measured throughout Puget Sound and Willapa are compiled and presented in the table below. In the Workshops it was suggested that it may be possible to begin developing a spatially explicit index of patch densities for comparison when pre-construction eelgrass surveys are conducted for proposed projects. A preliminary compilation of eelgrass bed density data is presented in Table 8 below, with sample size and standard error presented when known. The bulk of this data is from published scientific publications, but there are also data from DNR Aquatics Program field collection, as well as data from required environmental evaluation reports for proposed projects on state owned aquatic lands. These data may be helpful in developing mitigation performance standards and selecting reference sites. However, these data are not useful in determining minimum patch size as they are reported as means, most often with very large variation in the mean, or ranges of densities with limited or no information on sample size.

Table 10. Compilation of eelgrass bed densities measured throughout WA

Location (elevation)	Date	Average or range of densities (shoots/m^2)	SE	n	reference
Puget Sound					
Lummi Bay	Apr-May 2007	160.7		20	Yang (2011)
North Samish Bay	Apr-May 2007	157.0		20	Yang (2011)
South Samish Bay	Apr-May 2007	177.1		20	Yang (2011)
Padilla Bay	Apr-May 2007	207.8		20	Yang (2011)
Similk Bay	Apr-May 2007	78.0		20	Yang (2011)
Kayak Point	Apr-May 2007	50.7		20	Yang (2011)
North Hood Canal	Apr-May 2007	137.8		20	Yang (2011)
Dabob Bay, Hood Canal	Apr-May 2007	155.9		20	Yang (2011)
Edmonds	Apr-May 2007	89.1		20	Yang (2011)
Carkeek Park	Apr-May 2007	212.2		20	Yang (2011)
Golden Gardens	Apr-May 2007	156.4		20	Yang (2011)
Seabeck, Hood Canal	Apr-May 2007	277.1		20	Yang (2011)
Lynch Cove, Hood Canal	Apr-May 2007	76.2		20	Yang (2011)
Purdy Spit, Car Inlet	Apr-May 2007	260		20	Yang (2011)
Rocky Point, Case Inlet	April 2007	150		20	Yang (2011)
	May 2007	89		20	Yang (2011)

Location (elevation)	Date	Average or range of densities (shoots/m^2)	SE	n	reference
Union, Hood Canal	Apr-May 2007	81.5		20	Yang (2011)
Dumas Bay	Apr-May 2007	141.8		20	Yang (2011)
Dumas Bay – DNR SeagrassNet Site. (-1.6 to +1 MLLW)	April 2008	464.9	77.5	36	DNR unpublished data
	July 2008	525.9	87.6	36	DNR unpublished data
	April 2009	479.5	79.9	36	DNR unpublished data
	July 2009	483.6	80.6	36	DNR unpublished data
	April 2010	352.4	58.7	36	DNR unpublished data
	July 2010	420.9	70.2	36	DNR unpublished data
	Apr 2011	392.2	66.4	36	DNR unpublished data
	July 2011	360.4	60.1	36	DNR unpublished data
Post Point Outfall, Bellingham	2005	22-61			City of Bellingham (2005)
Golden Tides, Bellingham	June 2006	28-39			Geomatrix (2007)
	July 2008	29-88			Geomatrix (2008)
Taylor Ave Dock, Bellingham	July 1998	42-238		30	Talyor Assoc. (1998)
	2004	49-235			Anchor Env. (2004)
Shannon Pt, Bellingham	2009	5-50			ATSI (2010)
Maury Island gravel site - North	July 2005	77			Grette Assoc. (2005)
	July 2008	72			Grette Assoc (2008)
	August 2009	13			Grette Assoc (2009)
Maury Island gravel site - South	July 2005	54			Grette Assoc. (2005)
	July 2008	56			Grette Assoc (2008)
	August 2009	28			Grette Assoc (2009)
Maury Island gravel site - Control	July 2005	30			Grette Assoc. (2005)
	July 2008	37			Grette Assoc (2008)
	August 2009	26			Grette Assoc (2009)

Location (elevation)	Date	Average or range of densities (shoots/m^2)	SE	n	reference
Willapa Bay					
Oysterville	Apr-May 2007	114.4		20	Yang (2011)
Oysterville (-0.5 to +1.5 MLLW)	July 2007	290	14	20	Ruesink et al (2010)
Stackpole (-0.5 to +1.5 MLLW)	July 2007	353	39	20	Ruesink et al (2010)
Stackpole Flats	2007	22.8	5.3	44	Ruesink et al (2010)
Nahcotta (-0.5 to +1.5 MLLW)	July 2007	69	7	20	Ruesink et al (2010)
Parcel A., Willapa	Apr-May 2007	100.3		20	Yang (2011)
Willapa Bay-7 locations	July 2004	159.5	33.9	7	Ruesink et al (2006)

Summary of relevant findings

- Changes in ecological function have been observed by the presence of a very small area of eelgrass; differences in benthic community diversity were observed in a 0.24 m^2 sized area of eelgrass vegetated substrate versus unvegetated substrate. An eelgrass vegetated bed of 0.3m^2 was documented to have increased sediment trapping function when compared with unvegetated bottom.

- A minimum density of 3 shoots/0.25 m^2 was necessary for an eelgrass patch to persist from one season to the next at a Puget Sound site.

- With reported rhizome growth of 0.3 m per year, and observed average rhizome lengths ranging from 0.3 to 0.7 m , a distance of 1 m would be necessary to ensure that the below ground biomass of two adjacent shoots are captured when delineating a bed.

- Eelgrass edges at a site in Puget Sound were documented to migrate seasonally and annually. Maximum annual expansion to areas beyond the previous was documented at 4 m, and maximum annual contraction to areas previous bed interior up to 5 m.

- Edge migration shoreward or seaward always was within the distance defined by the furthest shoot, however, edges also migrate longshore where furthest shoot is not defined.

- Shoots >1m from a contiguous bed have been documented to appear and disappear seasonally and interannually.

Proposed Criteria

Based on information learned from review of the scientific literature considering minimum eelgrass bed criteria for an intact bed that demonstrate ecological function, and examination of available field data (from Puget Sound sites), the proposed criteria listed in Table 11 emerged. Note that these criteria emerged from the limited data and information available regarding ecological function of *Zostera marina* bed characteristics and dynamics and are meant to provide for an operational definition. Future sampling and further analysis may indicate that an adaption or refinement of these criteria is necessary. In particular, field data from WA outer coast estuaries may provide scientific support for establishing separate criteria for those estuaries..

Table 11. Criteria for eelgrass bed and beyond

TERMS	CRITERIA	Bed or beyond?	RATIONALE
persistent bed interior	3 shoots per 0.25 m^2	Bed	• Vegetated areas as small as 0.24 m^2 demonstrated different ecological function from unvegetated substrate. • 3 shoots per 0.25 was the minimum density necessary for an eelgrass patch to persist from one season to the next in Puget Sound.
persistent bed edge	Begin at a point within the interior of the bed (where ≥ 3 shoots/0.25m^2 within 1 m of adjacent shoots) move along any radial transect. Find the last shoot that is within 1 m of an adjacent shoot along that transect. Continue 0.5 m beyond this shoot, this is the bed edge. Both exterior and interior edges of bed can exist.	Bed	• Observed average rhizome lengths ranged from 0.3 to 0.7 m and rhizome growth rates of approximately 0.3m per year have been documented. Average shoot lengths observed ranged from 0.5 to 0.9 m. • Two adjacent shoots would require a minimum distance of 1.0 m to accommodate above and below ground plant. • A distance of 0.5 m beyond last shoot is needed to accommodate below ground rhizome of edge shoot.
shoots or patches	Single shoot or patches <3shoots/0.25m, that are >1m from adjacent shoot	Beyond	• Patches below this size and density have not been documented to provide ecological functions. • Patches below this size and density have been documented as ephemeral.
Ephemeral shoots and patches	Shoots or patches that may disappear then reappear from one season or year to the next	Beyond	• The ecological function of shoots and patches with limited temporal consistency has not been documented. • Ephemeral shoots and patches cannot feasibly be monitored for before-after effects analysis.

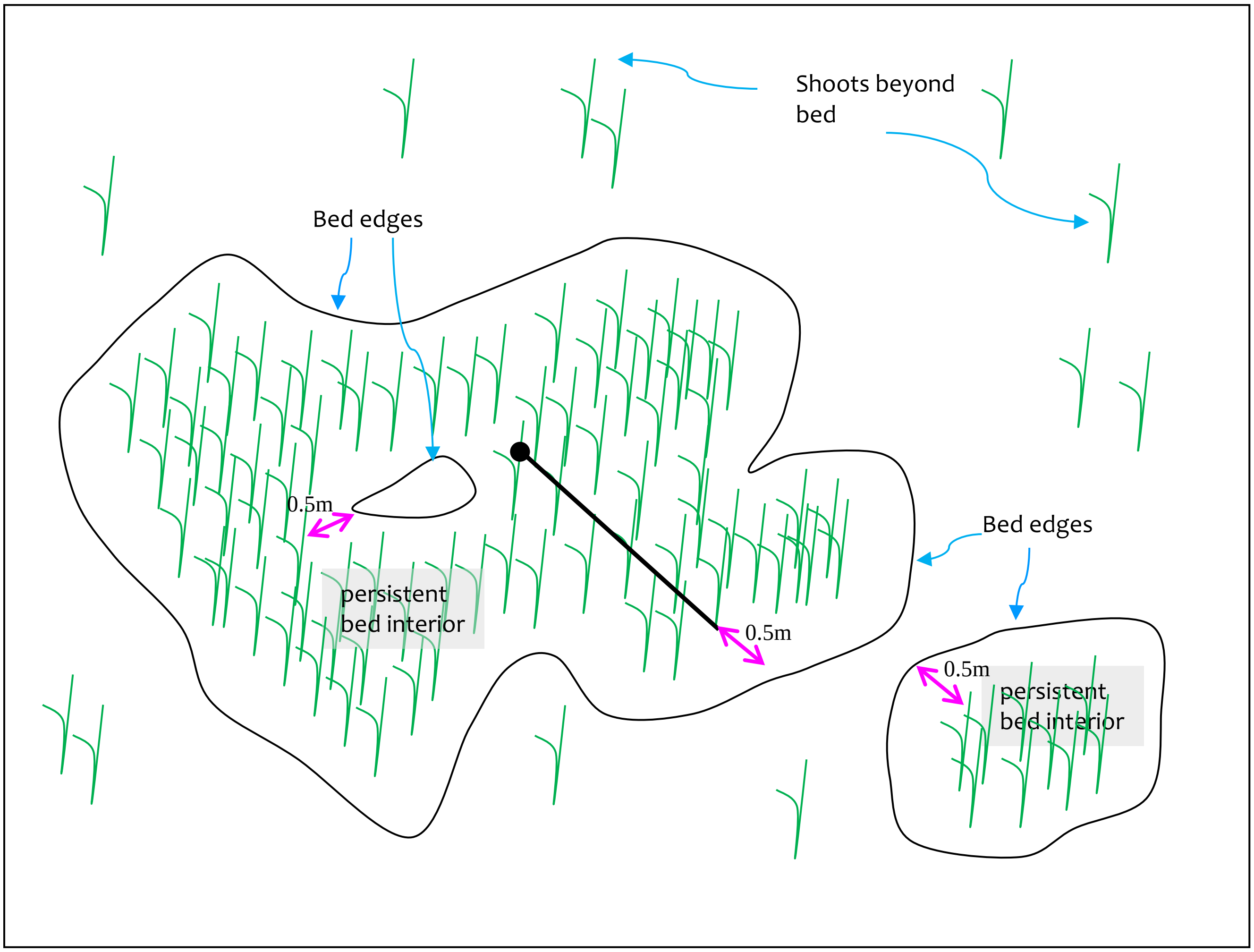


Figure 6 *Schematic depicting two distinct, intact beds. Edges are 0.5 m beyond the last shoot found within 1m of an adjacent shoot.*

Conservation Approaches

The ephemeral nature of eelgrass beds, particularly the edges of the bed, has been documented in the scientific literature, in data analyzed from Puget Sound, in data from Willapa Bay, and has been anecdotally observed in the field by shellfish growers and scientists. SeagrassNet protocol acknowledges it by requiring measurement from a fixed transect to the edge and to the furthest shoot. Eelgrass at the edge of the bed is less persistent than eelgrass near the center of a contiguous bed. This migratory characteristic of eelgrass beds makes it challenging to specify protocols for detecting change effected from a specific activity. It is also problematic in determining management decisions such as what distances from the beds might be appropriate to encourage use and access of the tidelands, while protecting sustainable eelgrass functions. Below are some metrics from published literature and the recent data analysis that may be relevant in determining these distances.

Table 12. Metrics relevant for developing buffers

RELEVANT ECOLOGICAL ATTRIBUTE	EELGRASS METRIC	VALUE
Potential migration zone	Expansion (+) or contraction (-) distance	Maximum documented annual bed expansion of +4m, and contraction of -5 m (DNR unpublished data- 2 different sites sampled over 4 year period).
Seed dispersal	Seed dispersal distance	5m (Ruckelshaus 1996)
Genetic diversity	Distance at which plants can be genetically distinguished	4m (Ruckelshaus 1994)

Recommendations

The goal described in the introduction of this memo was to "determine the criteria for defining an eelgrass bed. The definition should allow for repeatable delineation of the beds so impacts from DNR authorized activities in marine tidelands can be avoided or minimized with application of appropriate conservation measures." There was consensus early on among the workshop participants that the purpose of this effort was to apply scientific evidence to distinguish between an intact, persistent and functioning eelgrass bed from spare individual blades of eelgrass, or ephemeral patches or 'potential' eelgrass habitat. After a comprehensive review of scientific literature and analysis of available data we recommend the following:

- Apply the proposed criteria listed in Table 11 to determine eelgrass that is contained within a bed, and to delineate an edge around the bed. This distinguishes eelgrass in a bed from eelgrass that may be present at a site, but does not constitute a bed.

- Consider the values provided in Table 12 as the distance to buffer beyond an intact, persistent bed in order to avoid or minimize impacts. It is only through siting activities within this expansion, contraction and seed dispersal distance that positive or negative changes to an eelgrass beds can be effectively monitored for adaptive management.

Next Steps

It was suggested that further examination of the available data might be used to develop some "indices" of bed characteristics from different areas of the State. Various seagrass attributes (e.g. shoot density, plant architecture and colonization rates) have been shown to have a strong relationship to the physical setting of an area (Robbins and Bell 1994, Frederiksen et al., 2004, Turner et al., 1999). Monitoring interannual variability in shoot density and the contiguous bed edge location in different areas would provide information on how to best site uses so they do not conflict with sustainable ecological function of the bed.

If our intent is to develop the most effective operational definition possible, it will be useful to design initial baseline and adaptive management sampling on evaluating the practicability of the bed criteria and some of the eelgrass metrics listed in Table 2. Data relevant to longshore patch dynamics of *Zostera marina* is limited (Frederiksen et al., 2004), therefore, DNR adaptive management monitoring should include baseline sampling designed to explore interannual edge and patch migration in both the cross and longshore.

These proposed bed criteria, delineation methods, and conservation approaches are the outcome of a series of technical workgroup discussions. This information can serve as a starting point for future policy deliberations on developing effective conservation measures that will allow for management of resources while encouraging sustainable uses on state owned aquatic lands.

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Appendix B: Guidelines and Forms

EMAIL GUIDELINES

The **Shellfish Activities** programmatic e-mail box (*shellfish*.nwr@noaa.gov) is to be used for actions submitted to the National Marine Fisheries Service (NMFS) by the Federal Action Agencies for formal consultation (50 CFR § 402.14) under **Washington State Shellfish Activities.**

The COE must ensure the final project is being submitted to avoid multiple submittals and withdrawals. In rare occurrences, a withdrawal may be necessary and unavoidable. In this situation, please specify in the e-mail subject line that the project is being withdrawn. There is no form for a withdrawal, simply state the reason for the withdrawal and submit to the e-mail box, following the email titling conventions. If a previously withdrawn notification is resubmitted later, this resubmittal will be regarded as a new action notification.

An automatic reply will be sent upon receipt, but no other communication will be sent from the programmatic e-mail box; this box is used for **Incoming Only**. All other pre-decisional communication should be conducted **outside** the use of the *shellfish*.nwr@noaa.gov e-mail.

The Federal Action Agency will send only **one** project per e-mail submittal, and will attach all related documents. These documents will include the following:

1. Action Implementation Form, containing Action Notification, Action Completion, and any Forage fish survey information and eelgrass survey information.
2. Map(s) and project design drawings (if applicable).
3. Final project plan.

E-mail Titling Conventions

In the subject line of the email, clearly identify you are submitting under Washington State Shellfish Activities, the specific submittal activity (species and culture type, harvest method), the COE Permit Number, the Applicant Name, County, and specific water body.