United States Department of the Interior

FISH AND WILDLIFE SERVICE

Washington Fish and Wildlife Office
510 Desmond Dr. SE, Suite 102
Lacey, Washington 98503

AUG 26 2016

In Reply Refer To:
01EWFW00-2016-F-0121

Michelle Walker
U.S. Army Corps of Engineers, Seattle District
ATTN: Regulatory Branch (Bennett)
P.O. Box 3755
Seattle, Washington 98124-3755

Dear Ms. Walker:

This letter transmits the U. S. Fish and Wildlife Service's Biological Opinion (Opinion) addressing the proposed Programmatic Consultation for Shellfish Activities in Washington State Inland Marine Waters, located in portions of fourteen counties (Clallam, Grays Harbor, Island, Jefferson, King, Kitsap, Mason, Pacific, Pierce, San Juan, Skagit, Snohomish, Thurston, and Whatcom Counties, Washington), and its potential effects on the bull trout (*Salvelinus confluentus*), designated critical habitat for the bull trout, and the marbled murrelet (*Brachyramphus marmoratus*). Formal consultation on the proposed action was conducted in accordance with section 7 of the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq.*).

Your October 30, 2015, request for formal consultation was received on November 5, 2015. The enclosed Opinion is based on information provided in your Biological Assessment and other sources of information cited in the Opinion. The enclosed Opinion analyzes the effects of shellfish operations and activities in coastal bays and the inland marine waters of Washington State over the next 20 years (2016 to 2036). A complete record of this consultation is on file at the Washington Fish and Wildlife Office in Lacey, Washington.

Your Biological Assessment included a request for our concurrence with "not likely to adversely affect" determination(s) for certain listed resources (western snowy plover, *Charadrius nivosus nivosus*; and, designated critical habitat for the western snowy plover). The enclosed document includes a section separate from the Opinion that addresses your concurrence request(s). The rationale for this concurrence is included in the concurrence section.

If you have any questions regarding the enclosed Opinion, our response to your concurrence request(s), or our shared responsibilities under the Endangered Species Act, please contact Ryan McReynolds at 360-753-6047, or Martha Jensen at 360-753-9000.

Sincerely,

For Eric V. Rickerson, State Supervisor
Washington Fish and Wildlife Office

Enclosure(s)

Endangered Species Act - Section 7 Consultation

BIOLOGICAL OPINION

U.S. Fish and Wildlife Service Reference:
01EWFW00-2016-F-0121

Programmatic Consultation for Shellfish Activities in Washington State Inland Marine Waters

Clallam, Grays Harbor, Island, Jefferson, King, Kitsap, Mason, Pacific, Pierce, San Juan, Skagit, Snohomish, Thurston, and Whatcom Counties, Washington

Federal Action Agency:

U.S. Army Corps of Engineers – Seattle District

Consultation Conducted By:

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

for
Eric V. Rickerson, State Supervisor
Washington Fish and Wildlife Office

8/26/16
Date

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ACRONYMS AND ABBREVIATIONS

APN	anti-predator netting
ATV	All-terrian vehicle
BA	Biological Assessment
BOD	biochemical oxygen demand
CFR	Code of Federal Regulations
Corps	U.S. Army Corps of Engineers
dB	Decibel
DNR	Washington State Department of Natural Resources
DO	dissolved oxygen
Ecology	Washington State Department of Ecology
ESA	Endangered Species Act of 1973, as amended (16 U.S.C. l531 *et seq.*)
FLUPSY	Floating Upwelling System
FMO	Foraging, Migrating and Overwintering
FR	Federal Register
GIS	Geographic Information System
HCP	Habitat Conservation Plan
km^2	square kilometers
MBTA	Migratory Bird Treaty Act
MHHW	Mean Higher High Water
MLLW	Mean Lower Low Water
NMFS	National Marine Fisheries Service
NWFPEM	Northwest Forest Plan Effectiveness Monitoring Plan
Opinion	Biological Opinion
PAHs	Polycyclic Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
PCE	Primary Constituent Element
PCSGA	Pacific Coast Shellfish Growers Association
PSAMP	Puget Sound Ambient Monitoring Program
PVC	polyvinyl chloride
RUIP	Recovery Unit Implementation Plan
Service	U.S. Fish and Wildlife Service
Services	U.S. Fish and Wildlife Service and National Marine Fisheries Service
SLOPES	Standard Local Operating Procedures
SPM	solid particulate matter
TMDL	Total Maximum Daily Load
TS	Threshold Shift
TSS	total suspended solids
WDFW	Washington State Department of Fish and Wildlife

INTRODUCTION

This document represents the U. S. Fish and Wildlife Service's (Service) Biological Opinion (Opinion) based on our review of the proposed Programmatic Consultation for Shellfish Activities in Washington State Inland Marine Waters, located in portions of fourteen counties (Clallam, Grays Harbor, Island, Jefferson, King, Kitsap, Mason, Pacific, Pierce, San Juan, Skagit, Snohomish, Thurston, and Whatcom Counties, Washington), and its potential effects on the bull trout (*Salvelinus confluentus*), designated bull trout critical habitat, and the marbled murrelet (*Brachyramphus marmoratus*), in accordance with section 7 of the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq.*)(ESA).

The U.S. Army Corps of Engineers, Seattle District (Corps) submitted a September 12, 2014, request for formal consultation, which was received on September 15, 2014. A revised Biological Assessment (BA), dated December 29, 2014, was received on December 30, 2014.

On April 27, 2015, the Service met with the Corps and National Marine Fisheries Service (NMFS) to discuss unresolved questions about the proposed action, including implementation of the proposed conservation measures, and several related issues and concerns voiced by Tribal and Native American Indian Nations, representatives of the shellfish industry in Washington, and the general public. On June 8, 2015, the Corps provided notice to the U.S. Fish and Wildlife Service and National Marine Fisheries Service (collectively, the Services) that it intended to review and revise the previously submitted BA.

On November 5, 2015, the Corps submitted a final revised BA and new request for formal consultation (dated October 30, 2015). The enclosed Opinion is based on information provided in the final revised BA (dated October 30, 2015), and other sources of information cited in the Opinion. A complete record of this consultation is on file at the Washington Fish and Wildlife Office in Lacey, Washington.

The Corps made "no effect" determinations for additional species and critical habitat that are known to occur in Clallam, Grays Harbor, Island, Jefferson, King, Kitsap, Mason, Pacific, Pierce, San Juan, Skagit, Snohomish, Thurston, and Whatcom Counties. Your determinations that the action will have no effect on these listed species and critical habitat rest with the federal action agency. The Service has no regulatory or statutory authority for concurring with "no effect" determinations, and no consultation with the Service is required. We recommend that the Corps document their analyses and maintain that documentation as part of their files.

CONSULTATION HISTORY

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

- The Corps submitted a BA and initial request for consultation on September 15, 2014.

- On October 27, 2014, the Services received a letter from the Pacific Coast Shellfish Growers Association providing written comments and suggestions regarding the Corps' regional, special permit conditions for shellfish activities (Plauche' and Carr 2014).

- The Corps submitted a revised BA on December 30, 2014.

- During March 2015, the Service received copies of two letters sent to the Corps by the Pacific Coast Shellfish Growers Association (PCSGA 2015) and Washington State's Congressional Delegation (U.S. Congress, House of Representatives, 6th District, Washington 2015).

- On June 8, 2015, the Corps provided notice to the Services that it intended to review and revise the previously submitted BA; the consultation was put on hold.

- The Corps submitted a final revised BA and new request for formal consultation on November 5, 2015. Formal consultation on the proposed action was initiated on November 5, 2015.

- A copy of the draft Opinion was provided to the Corps on May 13, 2016.

- Comments for the draft Opinion were received from the Corps on June 20, 2016.

- The Corps and Service corresponded via email (on July 28 and August 17, 2016) regarding implementation of the programmatic.

CONCURRENCE

Western Snowy Plover and Western Snowy Plover Critical Habitat

The western snowy plover (*Charadrius nivosus nivosus*) is a small shorebird, about 6 inches long, with a thin dark bill, pale brown to gray upper parts, white or light belly, darker patches on its shoulders and head, white forehead and supercilium (eyebrow line). Their dark gray or black legs are useful characteristics when comparing them to other plover species (Page *et al*. 1995a).

The Pacific Coast population of the western snowy plover is defined as those individuals that nest adjacent to tidal waters of the Pacific Ocean, and includes all nesting birds on the mainland coast, peninsulas, offshore islands, adjacent bays, estuaries, and coastal rivers (USFWS 2004a,b). The breeding range of this population extends from the south-central Washington coast to Bahia Magdalena, Baja California, Mexico (USFWS 2004a,b). Western snowy plovers that nest at inland sites are not considered part of the Pacific Coast population, although a few individuals may migrate to coastal areas during the winter months.

The Pacific Coast population of the western snowy plover was listed as threatened on March 5, 1993. Primary threats that warranted listing include loss and modification of habitat resulting from European beach grass (*Ammophila arenaria*) encroachment, shoreline stabilization and development, human disturbance (including recreational activities), and predation exacerbated by development and human activities. On September 24, 2007, the Service published a final recovery plan for the Pacific Coast population of the western snowy plover.

The Service has also published a final rule designating critical habitat for the western snowy plover (77 FR 36727; June 19, 2012). The designation includes 60 units totaling 24,526 acres along the coasts of California, Oregon, and Washington. Recovery Unit 1 includes four units in Washington and nine units in Oregon. The four units in Washington are: WA 1 Copalis Spit (407 acres), WA 2 Damon Point (673 acres), WA 3 Midway Beach (697 acres) and Shoalwater/Graveyard Spit (696 acres), and WA 4 Leadbetter Spit (2,700 acres) and Gunpowder Sands Island (904 acres).

The Corps issues permits and permit verifications authorizing shellfish activities on the tidelands and in the inland marine waters of the State of Washington. While they may be issued for a variety of purposes (i.e., commercial aquaculture, tribal and commercial wildstock harvest, recreational enhancement, and restoration), the majority of these permits and permit verifications (both by number and acreage) are issued to parties engaged in commercial aquaculture (i.e., farming and production of shellfish for human consumption)(Corps 2015, pp. 40-49). Issuance of permits and permit verifications establishes a nexus requiring consultation under section 7(a)(2) of the ESA.

Shellfish culturing activities and practices are diverse (Corps 2015, pp. 11-38):

- The culturing of mussels and oysters suspended from floating rafts or longlines.
- Ground-based bottom culturing of oysters and clams, including geoduck clams (*Panopea generosa*).
- Ground-based rack-and-bag, stake, and longline culturing of oysters. And,
- Ground-based bag culturing of clams.

Most shellfish culturing and harvest methods, practices, and techniques are used to some extent across portions of each geographic sub-area (Willapa Bay, Grays Harbor, Hood Canal, south and north Puget Sound), and many farm operators culture multiple species using a variety of practices and techniques. Although shellfish activities are not always conducted for the purposes of commercial aquaculture, the industry's methods, practices, and techniques are also fairly typical of those used in support of wildstock harvest, recreational enhancement, and restoration.

When viewed from a landscape perspective, shellfish activities are variable in density and spatially discontinuous. At some locations, cultured tidelands extend with only occasional interruption along extended lengths of the nearshore. At other locations, cultured tidelands are interspersed along shorelines that support a range of other uses (residential, recreational, etc.). Where cultured tidelands extend with only occasional interruption, interspersed uncultured areas may experience direct or indirect effects, and are therefore considered part of the action area. Regulated shellfish activities in Washington State, specifically those for which this Opinion provides programmatic coverage, are likely to directly or indirectly affect more than 45,000 acres of nearshore marine habitat (45,000 to 50,000 acres in total; Willapa Bay: approx. 30,000 acres; Grays Harbor: approx. 4,000 acres; north Puget Sound: approx. 5,000 acres; south Puget Sound: approx. 5,000 acres; and, Hood Canal: approx. 3,000 acres). Regulated shellfish activities in Washington State also include subtidal wild geoduck harvest (a maximum of 6,050 acres per year in Hood Canal and Puget Sound).

The action area includes approximately 34,000 acres of tidelands located in Willapa Bay and Grays Harbor. As working tidelands, where shellfish activities have for many years and will continue to affect habitat conditions, most of the action area cannot be regarded as pristine in its current state. Also, at some locations this habitat exhibits the effects of shoreline development and alteration. Armored and hardened shorelines, marine and estuarine fill, and navigational features are characteristic of the action area. At some locations these features impair important natural processes that create and maintain functional western snowy plover habitat.

Shellfish culturing and harvesting activities have direct and indirect effects to nearshore marine habitat structure, function, and productivity. These effects may have significance for how well these habitats support the essential behaviors and needs of listed species, including the western snowy plover.

Shellfish activities result in temporary elevated sound levels and visual disturbance. Most shellfish activities associated with ground-based culturing are conducted as bouts of intermittent activity, with each bout lasting a few hours. While some activities (e.g., frosting or graveling, mechanical harrowing, mechanical harvest, dive-harvest, and suspended culturing techniques) may be relieved or partially relieved of strict timing constraints, many still target specific tidal elevations and therefore proceed as bouts of intermittent activity. Effects to the sound and visual environment are temporal and limited in both physical extent and duration.

Shellfish culturing and harvesting activities result in measurable, temporary impacts to water quality. Where these temporary impacts to water quality are concerned, our primary focus is on four biologically and behaviorally relevant water quality parameters: turbidity, dissolved oxygen (DO), biological oxygen demand (BOD), and nutrients (e.g., nitrogen and ammonium). ENVIRON International Corp. (2011, p. 41) has observed that water quality conditions typically reflect the pervasive influence of oceanic conditions, residence time, and other human activities in these same nearshore environments and watersheds. Forrest *et al*. (2009, p. 5) have observed, "…the potential for adverse water quality-related effects … is low, which is perhaps not surprising considering that intertidal farm sites are substantially or completely flushed on every tidal cycle." Temporary impacts to water quality are localized, limited in physical extent, and low intensity.

Bivalves and other filter-feeding shellfish, whether occurring naturally or in farmed/cultured settings, provide important benefits in the form of ecosystem services. The Service expects that shellfish activities will generally, and in the majority of cases, provide long-term benefits in the form of improved water quality and sequestration of carbon and nutrients. These ecosystem services may be important as a means to control and prevent the effects of excess nutrient additions occurring elsewhere in the contributing watersheds and may lessen or counteract the potential for climate-induced ocean acidification and hypoxia.

Interactions between benthic/epibenthic communities and shellfish activities are complex and not easily characterized with simple generalizations. Culturing equipment and materials placed on and over the bed (including nets, bags, racks, stakes, longlines, and tubes), and the intensively cultured shellfish (many of which are non-native species), modify habitat and may create new habitat types (or habitat variants). The benthic community interacts with, and is influenced by, equipment and materials placed on and over the bed, currents, wave action, patterns of sediment transport, and the intensively cultured shellfish. Over the long-term (i.e., "grow-out" and cycles of production), benthic community structure and composition may be strongly influenced by these interactions.

Interactions between submerged aquatic vegetation, such as native eelgrass (*Zostera marina*) or rooted kelp (attached brown algae in the order Laminariales), and shellfish activities are complex and not easily characterized with simple generalizations. These interactions include competition for space, competition for light (or shading), and physical damage that results from some activities, practices, and techniques. However, not all of these interactions are detrimental to the health of native eelgrass and rooted kelp. For instance, shellfish culturing provides a source of nutrient enhancement, which supports plant growth and vigor, and frequently improves water quality. The variety of factors influencing eelgrass recovery suggests the potential for significant site-by-site and temporal variability. Culturing methods and techniques have variable effects to patterns of eelgrass disturbance, recovery, and persistence, but the majority of these temporal impacts are not likely to be persistent at the estuarine landscape scale.

Regulated shellfish activities occur in the vicinity of designated western snowy plover critical habitat, but are generally located at a distance of at least one mile. The Corps has stated that "…no activity would occur within 0.25 mile of … critical habitat" (Corps 2015, p. 120). The Corps has included a total of 28 conservation measures as elements of their proposed action (Corps 2015, pp. 49-53). Permits and permit verifications issued by the Corps will incorporate these measures as enforceable terms and conditions.

Effects of the Proposed Action

Willapa Bay is protected from the Pacific Ocean by Long Beach Peninsula, a long barrier spit. Shellfish activities are located within the bay (east of the Long Beach Peninsula), while known western snowy plover nesting areas and designated critical habitat are located west (i.e., on the ocean side) of the spit. In Grays Harbor, known western snowy plover nesting areas and designated critical habitat are located on protected state-owned lands (i.e., designated wildlife areas and natural area preserves). The exposed intertidal zones (sand and mudflat) and ephemeral sand spits present in both Willapa Bay and Grays Harbor provide suitable foraging habitats. Therefore, there is a limited potential for foraging western snowy plovers to be exposed to shellfish culturing and harvesting activities.

Although the Corps has included a number of conservation measures addressing the security of culturing equipment (Corps 2015, pp. 49-53) and many growers and farm operators invest significant time and resources to prevent the loss of culturing equipment, equipment such as nets and tubes occasionally become dislodged and moved from farmed areas by wind and waves. However, because regulated shellfish activities are located some distance from the beaches, spits, and islands used intensively by western snowy plovers, and there is little overlap between shellfish culturing and harvesting activities and suitable western snowy plover nesting and foraging habitat, the Service expects that few, if any, western snowy plovers will be directly exposed to shellfish activities. Also, to our knowledge, there have been no reported instances of western snowy plovers becoming entrapped or entangled in shellfish culturing equipment, and the foraging behaviors of this species make it extremely unlikely that individuals would become entrapped or entangled in culturing equipment or gear. The Service concludes that the potential for western snowy plover injury or mortality is discountable.

The Service concludes that the proposed action, consisting of the issuance of Corps permits and permit verifications for the operation of existing and proposed new shellfish activities and farms, will have no measurable adverse effects to the western snowy plover, its habitat, or prey resources. The distances to suitable nesting habitats (i.e., generally, if not always, a distance of at least one mile and often separated by land) should preclude any adverse effects to nesting individuals, their nests, or young. The proposed action will not damage, degrade, or disturb suitable habitats located above the high tide line, will not degrade or impair the function of suitable foraging habitats, or measurably reduce the availability of cover or essential sources of food. The Service concludes that shellfish culturing and harvesting activities will not result in a significant disruption of normal western snowy plover behaviors (i.e., the ability to successfully feed, move, and/or shelter). With successful implementation of the proposed conservation measures, the Service concludes that the foreseeable direct and indirect effects to individual western snowy plovers, their habitat, and prey resources are insignificant.

The primary constituent elements (PCEs) of designated western snowy plover critical habitat (i.e., the physical and biological features essential for conservation of the species) include:

1. Areas that are below heavily vegetated areas or developed areas and above the daily high tides;

2. Shoreline habitat areas for feeding, with no or very sparse vegetation, that are between the annual low tide or low water flow and annual high tide or high water flow, subject to inundation but not constantly under water, that support small invertebrates, such as crabs, worms, flies, beetles, spiders, sand hoppers, clams, and ostracods, and other essential food sources;

3. Surf- or water-deposited organic debris, such as seaweed (including kelp and eelgrass) or driftwood located on open substrates that supports and attracts small invertebrates described in PCE #2 for food, and provides cover or shelter from predators and weather, and assists in avoidance of detection (crypsis) for nests, chicks, and incubating adults;

4. Minimal disturbance from the presence of humans, pets, vehicles, or human-attracted predators, which provide relatively undisturbed areas for individual and population growth and for normal behavior.

[Note: New critical habitat regulations (81 FR 7214; February 11, 2016) use physical or biological features (PBFs) rather than PCEs. The shift in terminology does not change the approach used in conducting a “destruction or adverse modification” analysis, which is the same regardless of whether the original designation identified PCEs, PBFs, or essential features. References here to PCEs should be viewed as synonymous with PBFs.]

None of the continuing shellfish activities and farms are located within designated critical habitat for the western snowy plover. It is extremely unlikely that proposed new shellfish activities and farms would be located in designated critical habitat.The proposed action will not damage, degrade, or disturb suitable habitats located above the high tide line, will not degrade or impair the function of suitable foraging habitats, or measurably reduce the availability of cover or essential sources of food. The distances to suitable nesting habitats and designated critical habitat (i.e., generally, if not always, a distance of at least one mile and often separated by land) should preclude any measurable effects. With successful implementation of the proposed conservation measures, the Service concludes that shellfish culturing and harvesting activities will not measurably degrade or impair the current function of the PCEs. Foreseeable direct and indirect effects to the PCEs of designated western snowy plover critical habitat are therefore considered insignificant.

BIOLOGICAL OPINION

DESCRIPTION OF THE PROPOSED ACTION

A federal action means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by federal agencies in the United States or upon the high seas (50 CFR 402.02).

This Biological Opinion (Opinion) addresses permits and permit verifications issued by the U.S. Army Corps of Engineers, Seattle District (Corps), for shellfish activities conducted on the tidelands and in the inland marine waters of the State of Washington. The Corps issues permits and permit verifications, under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act, authorizing shellfish activities for the purposes of commercial aquaculture (i.e., farming and production of shellfish for human consumption), wildstock harvest, recreation, and restoration. This Opinion analyzes the effects of shellfish operations and activities in coastal bays and the inland marine waters of Washington State over the next 20 years (2016 to 2036).

Issuance of permits and permit verifications establishes a nexus requiring consultation under section 7(a)(2) of the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq*.)(ESA). This Opinion addresses the Corps' shellfish permits and permit verifications, and related or resulting potential effects to ESA-listed species and designated critical habitat that are under the jurisdiction of the U.S. Fish and Wildlife Service (Service).

The Corps issues permits and permit verifications authorizing shellfish activities on the tidelands and in the inland marine waters of the State of Washington. While they may be issued for a variety of purposes (i.e., commercial aquaculture, tribal and commercial wildstock harvest, recreational enhancement, and restoration), the vast majority of these permits and permit verifications (both by number and acreage) are issued to parties engaged in commercial aquaculture (i.e., farming and production of shellfish for human consumption)(Corps 2015, pp. 40-49).

Historically, commercial shellfish aquaculture has been important to both the state and regional economies. This importance continues today, and the industry is both well established and diversified. Commercial aquaculture farms operating on the Washington coast (Willapa Bay, Grays Harbor), in Hood Canal, and the Puget Sound (Figure 1) culture and harvest more than a dozen commercially viable varieties of clams, oysters, and mussels.

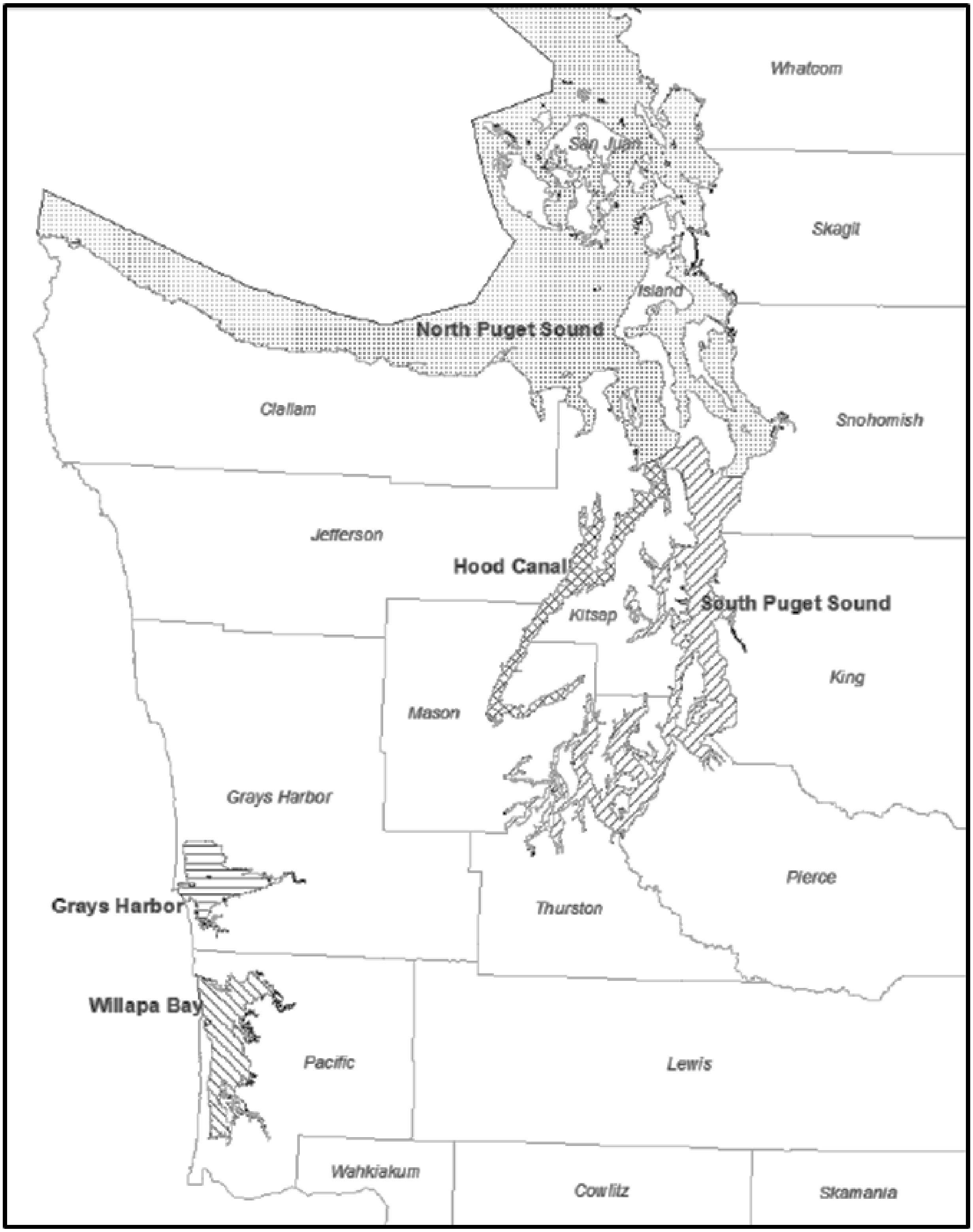

Figure 1. Washington tidelands, coastal bays, and inland marine waters.
(Corps 2015, p. 10)

Shellfish culturing activities and practices are correspondingly diverse and include (Corps 2015 pp. 11-38):

- The culturing of mussels and oysters suspended from floating rafts or longlines.
- Ground-based bottom culturing of oysters and clams, including geoduck clams (*Panopea generosa*).
- Ground-based rack-and-bag, stake, and longline culturing of oysters. And,
- Ground-based bag culturing of clams.

Farm operators generally choose to culture those species, and generally choose to select from those culturing methods or practices, that are best suited to the tidal elevations, substrates, and other physical and biological conditions or factors found at specific sites (e.g., exposure to prevailing wind and wave action, predation pressure). Market conditions and the desired marketable product are also important considerations. Some shellfish culturing activities and practices are better established, better suited and more profitable, in one or another geographic locality. For example, across Washington's marine waters, intertidal geoduck culturing and harvest is concentrated on the suitable mud- and sand-dominated tidelands of the south Puget Sound (Corps 2015, p. 45).

However, most shellfish culturing and harvest methods, practices, and techniques are used to some extent across portions of each geographic locality (Willapa Bay, Grays Harbor, Hood Canal, south and north Puget Sound), and many farm operators culture multiple species using a variety of practices and techniques. Although shellfish activities are not always conducted for the purposes of commercial aquaculture, the industry's methods, practices, and techniques are also fairly typical of those used in support of wildstock harvest, recreation, and restoration.

The sub-sections that follow describe sequentially: ground-based bottom culturing of geoduck clams; ground-based culturing of clams (bottom, bag); ground-based culturing of oysters (bottom, rack-and-bag, stake, longline); and suspended culturing of oysters and mussels. Each briefly describes hatchery and nursery operations, site/bed preparation, seeding or planting, maintenance, and harvest. For a fuller description of these methods, practices, and techniques, the reader is referred to documentation prepared by the Corps (Corps 2015, pp. 11-38).

Ground-Based Bottom Culturing of Geoduck

The Pacific geoduck is a large native clam found in soft intertidal and subtidal substrates from California to Alaska, to depths of more than 60 meters (Goodwin 1976 *in* Straus *et al*. 2013, p. 1). Lucrative commercial geoduck fisheries exist in Washington and Alaska, British Columbia, and Baja California (Hoffmann *et al*. 2000 and Aragon-Noriega *et al*. 2012 *in* Straus *et al*. 2013, p. 1). In Washington, geoduck are typically cultured on intertidal beds, from +5.0 to -4.5 mean lower low water (MLLW)(Corps 2015, p. 30). For a full description of the life history, reproduction, distribution, and habitat of this species, the reader is referred to an available Washington Sea Grant publication (Straus *et al*. 2013, pp. 1-5).

Hatchery and Nursery Operations

Hatcheries are typically corporate and off-site, serving many customers. They are often located in the uplands and their operations do not require a Corps permit. Shellfish seed is grown and matured in hatcheries to a size where it is less vulnerable to either predation or desiccation, before being outplanted. Operation of upland hatcheries is not part of the Corps' proposed action.

Floating Upwelling Systems, or FLUPSYs as they are commonly called (Figure 2), provide a means for maturing large quantities of seed (Corps 2015, p. 16). FLUPSYs are typically placed in the lower intertidal or shallow subtidal zones. Seed is placed in bins with screened bottoms, lowered into openings in a floating frame, and suspended in the water column. A paddle wheel or pump continuously draws seawater through the system, feeding the shellfish seed, and flushing feces and pseudofeces. FLUPSY floating platforms are typically equipped with overhead hoists and, because they also typically require a source of electrical power, they are commonly positioned next to a dock or pier (Corps 2015, p. 16).

Once purchased by a grower/farm operator, seed is often allowed to further mature before being outplanted. Some growers use upland tanks for this purpose, while others use elevated trays or bins, placed on and above the intertidal substrates of their farm footprint (Corps 2015, p. 15). These trays, bins, and racks are typically composed of plastic, angle iron, and/or rebar; wood and plywood materials are less commonly used. "Seed boosting" on the intertidal bed is a widespread and well-established practice, and is typical of many or most farms that practice ground-based shellfish culturing.

Site/Bed Preparation

Preparation of a geoduck bed or farm plot typically includes the following activities: pre-harvest of marketable product; removal or relocation of coarse wood, unrooted algae (e.g., sea lettuce, *Ulva lactuca*), and native and non-native shellfish predators; and, hand raking (Corps 2015, p. 30). Some growers/farm operators may use a mechanical harrow, often pulled on the exposed intertidal bed with a small tractor or all-terrain vehicle (ATV), to remove marketable product (e.g., pre-harvest of clams). Leveling and harrowing of the bed may in some instances result in measurable impacts to submerged aquatic vegetation, including native eelgrass and/or rooted kelp.

Native shellfish predators, which are sometimes actively removed from farm plots, include moon snails (*Polinices lewisii*), sea stars (*Pisaster brevispinus* and *Pycnopodia helianthoides*), and sand dollars (Clypeasteroida), including the eccentric sand dollar or sea-cake (*Dendraster excentricus*). The non-native eastern oyster drill (*Urosalpinx cinerea*) and Japanese oyster drill (*Ocinebrellus inornatus*) are not typically a problem for cultured geoduck, but are commonly removed from oyster beds.

Figure 2. A Floating Upwelling System, or FLUPSY.
(Corps 2015, p. 16)

A mechanical harrow is a skidder with many tines, towed along and through the shallow surface of the substrate. The harrow's tines penetrate the substrate a few inches, break up oyster clusters, and move clams and oysters upward toward the surface (Corps 2015, p. 17). Mechanical harrowing typically plays a small role in preparing some cultured geoduck beds, but plays a significant role on many farms that practice ground-based clam and oyster culturing.

Seeding or Planting

Until more fully matured and embedded in the substrate, geoduck seed is vulnerable to both predation and desiccation. The geoduck culturing practices and techniques that are in widest use employ tubes and nets placed on the intertidal bed to prevent and minimize losses of seed and immature clams.

The most common method uses inert (i.e., chemically inactive) 6-inch diameter by 9-inch long polyvinyl chloride (PVC) pipe; exact dimensions vary (Corps 2015, p. 30). The pipe sections, or tubes, are typically inserted in the substrate by hand, at low tide. Tubes are typically installed at a density of approximately 1 tube per square foot, or about 42,000 tubes per acre (Figure 3).

Two to four geoduck seeds are placed in each tube, and the top of each tube is often covered with a small, plastic mesh covering, which is secured with a rubber band. Some growers have begun to use flexible net tubes (composed of Vexar®) instead of PVC pipe (Corps 2015, p. 30). Many, perhaps most, geoduck growers/farm operators also install large, anti-predator, cover nets over the field of tubes (Figure 4).

Figure 3. Geoduck tubes.
(Corps 2015, p. 31)

Figure 4. Anti-predator cover nets placed over a field of geoduck tubes
(Corps 2015, p. 32)

Anti-predator, cover nets may be composed of either plastic or organic fibers, and are typically anchored at the periphery with embedded rebar or metal staking. Cover nets minimize predation losses, but also serve to prevent tubes from becoming dislodged under wind and wave action, and keep dislodged tubes on the farm plot (Corps 2015, p. 30). Anti-predator, cover and exclusion nets are available from a variety of commercial sources, in varying mesh size and dimensions (Washington Sea Grant 2005, pp. 10, 17). Mesh size varies by application and/or preference, typically ranging from ¼ x ¼ inch to ¾ x ¾ inch or larger (Figure 5).

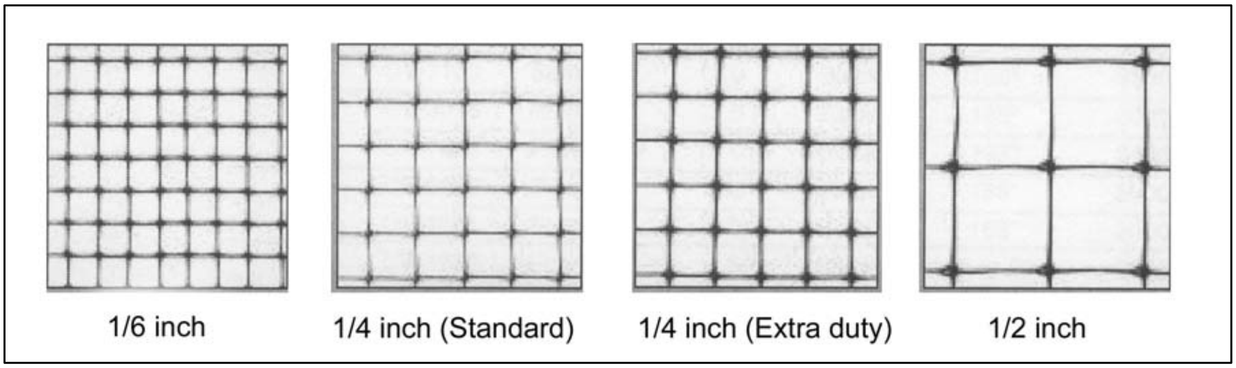

Figure 5. Common clam aquaculture net mesh sizes
(InterNet® Inc., 2004 *in* Ayers 2006, p. 5)

Another method being used to exclude predators on cultured geoduck beds. "Net tunnels" are composed of narrow and long polyethylene nets, placed over a rebar frame (Corps 2015, p. 30). The edges of the tunnels are embedded in the substrate and anchored. The mesh opening is typically either 1/4-inch or 3/8-inch, and the typically 24-inch to 48-inch wide net is held a few inches above the substrate by the rebar frame (Figure 6).

Maintenance

Geoduck farm plots are patrolled by crews on a regular basis. Cover nets and net tunnels may become fouled with algae and other organisms (especially during warmer summer months), and are therefore typically removed and/or cleaned with some frequency. Nets may be taken to an upland location for drying and cleaning, or (less commonly) fouling organisms may be removed from the nets while they remain in place (Corps 2015, p. 33).

Geoduck tubes and nets are typically removed after one or two growing seasons, after the young clams have buried themselves to a depth sufficient to evade predators (approximately 14 inches). Used tubes and nets are dried, cleaned, and re-used. Worn-out tubes and nets are handled as waste, and are disposed of at appropriate upland facilities and locations.

The Corps commonly requires that (Corps 2015, p. 51): "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 nets, identification markers shall be placed with a minimum of one identification marker for each 50 ft of net."

Figure 6. Geoduck net tunnels over rebar frames (Corps 2015, p. 32).

Harvest

Cultured geoduck clams are typically harvested 4 to 7 years after planting, when individuals reach approximately 2 pounds in weight. Geoduck clams are harvested from intertidal beds at low tide ("beach harvest"), or by divers at middle or high tides from intertidal and subtidal beds ("dive harvest")(Corps 2015, p. 33). In either case, the clams are typically harvested using hand-operated water jet probes. Seawater pumped at a pressure of approximately 40 pounds per square inch, and 20 gallons per minute, is injected at the vicinity of each harvestable geoduck, liquefying the substrate and allowing extraction of the clam by hand.

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 and absence of suitable low tides for daytime beach harvests (Corps 2015, p. 33). Because market conditions for geoduck clams are most favorable during the winter months, dive harvests probably account for 75 percent or more of the total geoduck harvest effort. A dive harvest is typically supplemented with a follow-up beach harvest, and both dive and beach harvests are conducted by most growers. Farm operators typically make several sweeps of the geoduck bed to ensure that all marketable geoduck clams are removed before the bed is prepared for a new crop.

Subtidal Wild Geoduck Harvest

The Corps' BA also describes subtidal wild geoduck harvest (Corps 2015, pp. 3, 5, 30, 34, 46, 47, 80, 84, 89, 92, 93, 99, 100). The Corps has indicated that they are seeking programmatic coverage for this activity. The Corps is seeking programmatic coverage for subtidal wild geoduck harvest on a maximum of 6,050 acres per year, at depths to -70 ft MLLW in Hood Canal and the Puget Sound.

During 2008, the Service and NMFS approved a low-effect Habitat Conservation Plan (HCP) developed in coordination with the Washington State Department of Natural Resources (DNR) for their commercial geoduck fishery. The HCP and corresponding Opinion (USFWS 2009b) assessed effects of the State's program for commercial harvest of wild geoduck clams at depths between -18 and -70 ft MLLW, across approximately 400 harvest tracts and more than 30,000 acres (separate from the Tribal harvest areas) in the Puget Sound, Hood Canal, San Juan Islands, and eastern Strait of Juan de Fuca. That record of HCP approval indicates minor and small-scale effects resulting from elevated turbidity and sedimentation during harvest activities (Service Ref. No. PRT-TE187810-0). The low-effect HCP and corresponding Opinion (USFWS 2009b) found that deep subtidal harvest of wild geoduck has at most a low potential for any significant effects on listed species and critical habitat.

While to date the Corps has seldom, if ever, applied its authorities and jurisdiction to regulate subtidal wild geoduck harvest, it has consistently requested that the Services provide coverage for the activity (Corps 2015, pp. 3, 5, 30, 34, 46, 47, 80, 84, 89, 92, 93, 99, 100). This Opinion addresses the potential effects of subtidal wild geoduck harvest because it is included as part of the Corps' proposed action.

Ground-Based Culturing of Clams (Bottom, Bag)

Several species of clams are commercially cultured and harvested in Washington State, including the Pacific littleneck clam (*Leukoma staminea*), Manila clam (*Venerupis philippinarum*), butter clam (*Saxidomus gigantea*), Eastern soft shell clam (*Mya arenaria*), horse clam (*Tresus nuttallii* and *Tresus capax*), and cockle (*Clinocardium nuttallii*)(Corps 2015, p. 23). The most commonly and widely cultured clam, the Manila clam, is not native to Washington State. Clams are typically cultured on the intertidal bed, from +7.0 to –4.5 MLLW.

Hatchery and Nursery Operations

An earlier sub-section discussed hatchery and nursery operations typical of geoduck culturing (p. 11). Clam growers and farm operators use all or most of the same methods, practices, and techniques. However, reliance upon natural set and seeding is also a fairly common practice among both clam and oyster growers. Where wild populations and natural spawning occur, viable seed can be acquired by creating substrate conditions that foster larval attachment and survival.

Site/Bed Preparation

Where clams are cultured directly on the substrate (bottom culture) graveling or frosting is a very common practice (Corps 2015, p. 24). Washed gravel, shell, and shell fragments are distributed over the substrate surface in thin layers. The most common method for graveling or frosting uses a floatable barge deck, from which piles of gravel and shell are sprayed or sluiced onto a tidally-inundated bed (Figure 7). Several thin layers of material are typically placed over a period of days. Some growers/farm operators gravel or frost their clam beds on an annual basis, while others do so less frequently. These decisions generally reflect site-specific physical conditions and needs.

An earlier sub-section discussed methods of site/bed preparation typical of geoduck culturing (p. 11). Clam growers and farm operators use all or most of the same methods, practices, and techniques. Preparation of a ground-based culture clam bed or farm plot typically includes the following activities: pre-harvest of marketable product; removal or relocation of coarse wood, unrooted algae (e.g., sea lettuce), and native and non-native shellfish predators; and, hand raking (Corps 2015, p. 24). Some growers/farm operators may use a mechanical harrow to remove marketable product (pre-harvest). Larger, contiguous clam and oyster tracts are sometimes leveled mechanically, most commonly by dragging a chain or bag from a vessel traveling at slow speed (Corps 2015, p. 17). Leveling and harrowing of the bed may in some instances result in measurable impacts to submerged aquatic vegetation, including native eelgrass and/or rooted kelp.

Seeding or Planting

Where hatchery-produced clam seed is used, methods for seeding bottom culture clam beds or farm plots vary depending on site-specific factors (including predation pressure). Methods include (Corps 2015, p. 24): hand-spreading seed at low tide upon bare, exposed substrate; hand-spreading seed on an incoming tide at water depths of approximately 4 inches; hand-spreading seed on an outgoing tide at water depths of approximately 2 to 3 ft; and, spreading seed at high tide from a boat or barge.

Immediately after planting, anti-predator cover nets are typically placed over the entire seeded clam bed. These nets may be composed of either plastic or organic fibers, and are typically anchored at the periphery with embedded rebar or metal staking. Mesh size varies by application and/or preference, typically ranging from ¼ x ¼ inch to ¾ x ¾ inch or larger (Figure 5, p. 14). Some growers bury the net edges, or weigh-down the edges with a lead line (Corps 2015, p. 25). Once placed over a seeded clam bed, anti-predator cover nets typically remain in place until harvest.

Clams cultured in plastic mesh bags are typically placed directly on the substrate (Figure 8). The bags contain washed gravel, shell, shell fragments, and clam seed, and are closed with a plastic or metal fastener (Corps 2015, p. 29). Prior to setting bags on the intertidal bed, shallow trenches (typically 2 to 4 inches deep) may be dug, typically during low tide and with hand tools, to establish a secure foundation for the bags. Where tidal, wind, or wave action is strong, bags may be held in place with metal stakes or rebar.

Figure 7. Graveling (frosting) over a clam bed
(Corps 2015, p. 25)

Figure 8. Manila clam bags placed on an exposed intertidal bed
(Corps 2015, p. 29)

Maintenance

Farm plots are patrolled by crews on a regular basis. Surveys are conducted seasonally, to assess seed survival and distribution, and to estimate potential yield (Corps 2015, p. 25). Depending upon survey results, bottom cultured clam beds may be seeded again. Crews also monitor clams cultured in plastic mesh bags. The bags are commonly turned and de-fouled to optimize growing conditions.

Cover nets may become fouled with algae and other organisms, and are therefore typically removed and/or cleaned with some frequency. Nets may be taken to an upland location for drying and cleaning, or (less commonly) fouling organisms may be removed from the nets while they remain in place (Corps 2015, p. 25).

Harvest

Bottom cultured clams are typically dug by hand at low tide, using a clam rake and/or shovel. A given clam bed may contain multiple year classes of clams, and therefore only the market-size clams (typically corresponding to 3 years of age) are selectively harvested, placed in buckets, bagged, tagged, and removed from the farm plot (Corps 2015, p. 25). Once sorted, any undersized clams are typically returned to the beds. Those that are that are retained for sale are typically bagged and placed in wet storage elsewhere on the farm footprint. Clams are typically held in wet storage for a period of approximately 24 hours, to facilitate purging of sand and grit, and thereby improve the marketable product.

Clams cultured in bags are harvested by hand, typically when the bed is covered by one or two ft of water (Corps 2015, p. 29). Sand and mud is shaken from the bags before they are removed for sorting.

Bottom cultured clams are sometimes harvested mechanically, most notably in Samish Bay (Corps 2015, p. 26). Mechanical clam harvesters are driven or pulled across the exposed bed at low tide, and the clams are “swept” onto a conveyor belt (Figure 9). Another type of mechanical harvesting equipment, the hydraulic escalator (Figure 10), has been mostly or completely phased out and is no longer used in Washington State. The Corps’ programmatic consultation for shellfish activities does not provide coverage for harvesting conducted with a hydraulic escalator and use of this type of machinery is specifically excluded from coverage under the Corps programmatic consultation (Corps 2015, p. 26). A complete list of the activities, methods, and practices that are excluded from coverage under the Corps programmatic consultation is provided in a sub-section that follows.

Figure 9. Mechanical clam harvester
(Pacific Shellfish Institute 2015)

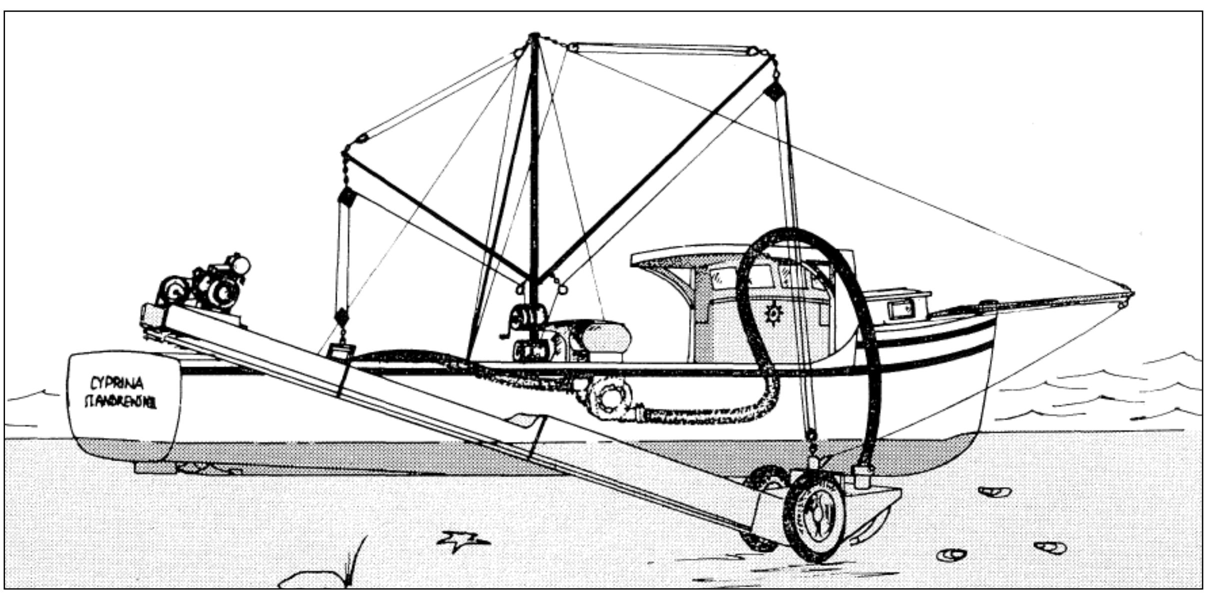

Figure 10. Hydraulic escalator
(MacPhail 1961)

Ground-Based Culturing of Oysters (Bottom, Rack-and-Bag, Stake, Longline)

Several species of oyster are cultured or harvested in Washington State, including the Pacific oyster (*Crassostrea gigas*), Kumamoto oyster (*Crassostrea sikamea*), Eastern or American oyster (*Crassostrea virginica*), European flat oyster (*Ostrea edulis*), and the Olympia oyster (*Ostrea conchaphila*)(Corps 2015, p. 14). Only the Olympia oyster is native to Washington State, and the species (because of its small size) is generally cultured for the purposes of restoration.

Oyster growers and farm operators use a wide variety of culturing methods, practices, and techniques. Where appropriate, the content that follows describes and differentiates between the practices common to ground-based bottom culturing, rack-and-bag, stake, and longline culturing. A final sub-section addresses culturing of oysters and mussels suspended from floating rafts.

<u>Hatchery and Nursery Operations</u>

An earlier sub-section discussed hatchery and nursery operations typical of geoduck culturing (p. 11). Oyster growers and farm operators use all or most of the same methods, practices, and techniques. However, reliance upon natural set and seeding is also a fairly common practice among oyster growers. Where wild populations and natural spawning occur, viable seed can be acquired by creating substrate conditions that foster larval attachment and survival.
Oyster cultch is the basis for both ground-based and suspended culturing of oysters. While the term "cultch" may refer to the mass of stone, broken shell, and grit that compose an oyster bed, where used here the term refers to aged oyster shell that has been prepared and placed in the intertidal or shallow subtidal zone with the specific goal of collecting a natural set of oyster seed (or "spat")(Corps 2015, p. 14). Cultch is sometimes seeded in a hatchery or in upland tanks, but the practice of placing bundled cultch on the intertidal bed is more common.

Washed and aged oyster shells are bundled in plastic mesh bags and then placed in the intertidal or shallow subtidal zone, either directly on the substrate or on pallets (Figure 11). After spat has settled and firmly attached (or cemented) to the shells, the seeded cultch is ready for out-planting on the bed or farm plot (Corps 2015, p. 14).

<u>Site/Bed Preparation</u>

An earlier sub-section discussed methods of site/bed preparation typical of geoduck culturing (p. 11). Oyster growers and farm operators use all or most of the same methods, practices, and techniques. Preparation of a ground-based culture oyster bed or farm plot typically includes the following activities: pre-harvest of marketable product; removal or relocation of coarse wood, unrooted algae (e.g., sea lettuce), and native and non-native shellfish predators; and, leveling and harrowing of the bed (Corps 2015, p. 16). Leveling and harrowing of the bed may in some instances result in measurable impacts to submerged aquatic vegetation, including native eelgrass and/or rooted kelp.

An earlier sub-section discussed graveling or frosting of cultured clam beds (p. 17). This same practice is used by many oyster growers/farm operators (Corps 2015, p. 17), especially where the native substrates are unconsolidated and must be “hardened” to prevent oysters from sinking and smothering. Some growers gravel or frost their oyster beds on an annual basis, while others do so less frequently. These decisions generally reflect site-specific physical conditions and needs.

Figure 11. Bundled oyster cultch stacked on pallets
(Corps 2015, p. 15)

Mechanical methods of preparing and maintaining the cultured beds, and of harvesting, are fairly common and widespread among Washington State’s oyster growers and farm operators. Larger, contiguous oyster beds are often leveled mechanically, most commonly by dragging a chain or bag from a vessel traveling at slow speed (Corps 2015, pp. 15, 17, 19). Growers use mechanical harrows to pre-harvest and prepare beds, to pull sunken and embedded oysters to the surface, and to recover oysters that have dislodged and fallen from stakes or longlines (Corps 2015, pp. 17, 20). A sub-section that follows discusses these practices in detail, including their unavoidable impacts to submerged aquatic vegetation (native eelgrass and rooted kelp). These practices are used extensively in Willapa Bay, but are far less common in all of other geographic sub-areas (Grays Harbor, Hood Canal, south and north Puget Sound).

Historically, some oyster growers have used anchored vertical fencing or nets (drift fences or oyster corrals) to stabilize and prevent oysters and oyster shell from being moved off the cultured bed. Available information suggests this practice was never widely used in Washington State, and the Corps' programmatic consultation does not provide coverage for the practice or activity; use of drift fences or oyster corrals is specifically excluded from coverage under the Corps programmatic consultation (Corps 2015, p. 39). A complete list of the activities, methods, and practices that are excluded from coverage under the Corps programmatic consultation is provided in a sub-section that follows (see *Activities Excluded from Programmatic Coverage*).

Seeding/Planting

Where oysters are cultured directly on the intertidal bed (bottom culture) seeded cultch may be cast by hand and distributed on the beds, or sluiced/sprayed from a barge deck (Corps 2015, p. 16). Oysters cultured in plastic mesh bags may be placed directly on the substrate, or hung from racks (rack-and-bag culture). Anchored wood or metal racks are used to suspend the bags above the intertidal bed (Corps 2015, p. 22), prevent smothering, and create optimal growing conditions. Bags are commonly fixed to the racks with plastic or metal fasteners.

Some oyster growers use a tumble bag system (Figure 12). Tumble bags incorporate small floats and, as the tides rise and fall, the bags are repeatedly inverted and tumbled (Corps 2015, p. 23). Tumble bags prevent smothering and harden oysters, sometimes producing a product meant specifically for the premium, raw-on-shell market.

Ground-based culturing systems that use oyster stakes and longlines are fairly common and widespread in Washington State. Stakes composed of a hard-surfaced material (e.g., metal or PVC pipe) are embedded in the substrate, typically with 2-foot spacing (Corps 2015, p. 21). Seeded cultch is attached to the stakes and suspended above the intertidal bed. Some growers attach unseeded cultch, or allow a native encrusting community to grow on the stakes, and then rely upon a natural seed set (Corps 2015, p. 21).

Where longline culturing is practiced, oysters are grown in clusters, attached to rope lines suspended above the intertidal bed between upright stakes (Corps 2015, pp. 19, 20). The rope lines are typically composed of either polypropylene or nylon, and are typically held less than three feet above the intertidal bed (Figure 13). Stakes and longlines prevent oysters from sinking and smothering, and also serve to control and minimize exposure to predators inhabiting the intertidal bed.

Maintenance

Where oysters are cultured directly on the intertidal bed (bottom culture) anti-predator cover nets may be installed and maintained. These nets may be composed of either plastic or organic fibers, and are typically anchored at the periphery with embedded rebar or metal staking. Mesh size varies by application and/or preference, typically ranging from ¼ x ¼ inch to ¾ x ¾ inch or larger (Figure 5, p. 14). Some growers bury the net edges, or weigh-down the edges with a lead line. Also, where oysters are cultured directly on the intertidal bed, the farm plot may be reseeded to either augment the natural seed set or address poor hatchery seed survival.

Farm plots are patrolled by crews on a regular basis. Nets, bags, racks, stakes, and longlines are all routinely inspected to ensure that they remain secure (Corps 2015, pp. 17-23). Culturing equipment is de-fouled, repaired, and replaced as necessary, and oysters are periodically thinned or redistributed to optimize growing conditions.

Figure 12. Oyster tumble bags
(Corps 2015, p. 23)

Figure 13. Oyster longlines
(Corps 2015, p. 20)

Farmed oysters are commonly collected and redistributed across multiple farm plots during grow-out (Corps 2015, p. 17). Some beds and farm plots provide conditions that are best suited for collecting a natural seed set, some are ideal for maturing young oysters, and others are better suited for "fattening" mature oysters prior to final harvest. Many, perhaps most, growers/farm operators transplant their oysters across multiple sites within and between individual farms, depending upon age, maturity, and rate of growth.

Growers/farm operators commonly use mechanical harrows to pull sunken and embedded oysters to the surface, and to recover oysters that have dislodged and fallen from stakes or longlines (Corps 2015, pp. 17, 21).

Harvest

Rack-and-bag, staked, and longline cultured oysters are all typically harvested by hand at low tide (Corps 2015, pp. 19-21). A given bed may contain multiple year classes of oysters, and therefore only the market-size oysters are selectively harvested, sorted, bagged, tagged, and removed from the farm plot.

Oysters cultured on longlines are sometimes harvested mechanically (Corps 2015, p. 21). Buoys are attached to the lines at low tide. Specialized equipment is used during a middle or high tide to reel the lines in to a working vessel or barge deck, and cut and remove the market-size oysters.

Where oysters are cultured directly on the intertidal bed (bottom culture) hand harvesting at low tide (Figure 14), and mechanical dredge harvesting at middle or high tides, are both common and widespread practices (Corps 2015, p. 17). Mechanical oyster dredges are deployed from one or both sides of a working vessel or barge. The dredge bag(s) are lowered to an elevation at or just below the bed surface by boom crane or hydraulic winch, and pulled at slow vessel speeds across and through the substrate. The dredge bags are emptied onto a barge deck, and then redeployed (Figure 15). A given area may be dredged twice in succession to ensure recovery of the maximum number of oysters, and the farm plot may be mechanically harrowed between the two successive dredge harvests in order to increase the recovery of oysters (Corps 2015, p. 17). A sub-section that follows discusses these practices in detail, including their unavoidable impacts to submerged aquatic vegetation (native eelgrass and rooted kelp).

Figure 14. Hand harvest of bottom cultured oysters
(Corps 2015, p. 19)

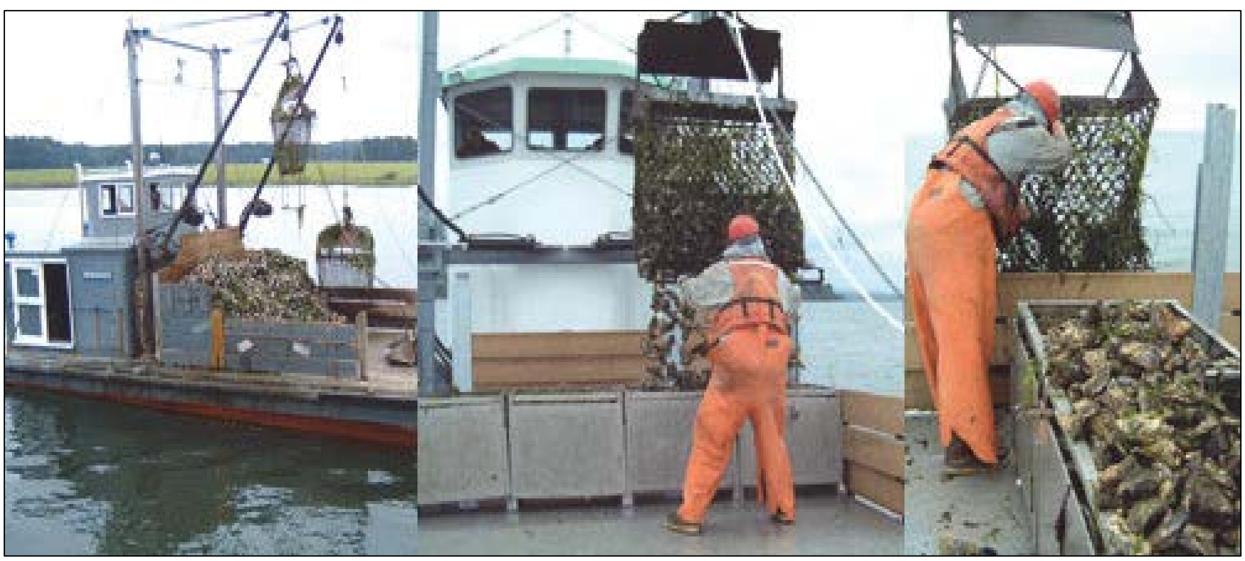

Figure 15. Oyster dredge with boom cranes and bags
(Corps 2015, p. 19)

Oyster Culturing and Native Bed Enhancement for the Purposes of Restoration

Over recent years, native oysters (*O. conchaphila*) have been cultured, and native and non-native oyster beds have been enhanced, for purposes of habitat improvement, ecological restoration, water quality improvement, and/or to increase the size of native shellfish populations (Corps 2015, p. 48). Much of this work serves the dual purpose of testing and monitoring new methods and protocols, and will provide scientific information to inform future decisions. Examples of these projects include: Puget Sound Restoration Fund - Native Oyster Enhancement Projects (Service Ref. No. 01EWFW00-2013-I-0414); Eelgrass Pilot Study - Custom Plywood Interim Remedial Action (Service Ref. No. 13410-2011-I-0435); and, Hood Canal Mariculture and Puget Sound Restoration Fund - Algae Mariculture Demonstration Facility (Service Ref. No. 01EWFW00-2016-I-0147). These activities include site/bed preparation, seeding or planting, maintenance, monitoring, and limited harvest (i.e., for the purpose of biological sampling).

Suspended (or Floating) Culturing of Oysters and Mussels

In addition to the previously mentioned oyster species, two species of mussel are cultured in Washington State: the native Pacific blue mussel (*Mytilus trossulus*), and the non-native Mediterranean or Gallo mussel (*Mytilus galloprovincialis*)(Corps 2015, p. 11). Oysters and mussels are both grown in Washington State using methods that suspend nets, screens, socks, ropes, wires, and/or longlines from floating rafts and buoys.

Hatchery and Nursery Operations

An earlier sub-section discussed hatchery and nursery operations (p. 11). Farm operators growing oysters and mussels use all or most of the same methods, practices, and techniques. Oyster cultch is the basis for both ground-based and suspended culturing of oysters.

Site/Bed Preparation

Suspended culturing of oysters and mussels is practiced over subtidal waters and there is little or no direct engagement with the bed and substrate (Corps 2015, pp. 11, 16). Floating rafts and buoyed longlines do require an anchoring system, and waste produced by the growing shellfish (feces, pseudofeces) settles on the sea bed below. However, other than the setting of secure anchors, suspended culturing does not generally require site or bed preparation.

Floating rafts are composed of lumber, aluminum, galvanized steel, and/or plywood, with some form of encapsulated flotation (Corps 2015, p. 11). Longlines are typically composed of heavy polypropylene or nylon rope, suspended from a float or series of buoys.

Seeding or Planting

Mature seed is scraped or sluiced into “socks”, with discs placed every few feet to support the weight of growing shellfish (Corps 2015, p. 12). The socks are then lashed to frames within a floating raft (Figure 16), or to longlines.

Figure 16. A typical mussel raft
(Corps 2015, p. 13)

Maintenance

Anti-predator exclusion nets are typically hung around the perimeter of the rafts (Figure 16). Depending on the farm location, these nets may only be necessary on a seasonal basis. When nets become excessively fouled (e.g., with barnacles, algae or other biological growth) they are removed and cleaned (Corps 2015, p. 12). Farm operators also de-foul other structural elements of their floating rafts. Rafts and suspended longlines are patrolled by crews on a regular basis. Anchors, nets, screens, socks, ropes, wires, and longlines are all routinely inspected to ensure that they remain secure.

Some growers/farm operators regularly sort and grade their oysters throughout the growth cycle. Every three or four months, oysters growing on suspended trays are put through a hand or mechanical grading process, trays are restocked, de-fouled, and returned to the water column (Corps 2015, p. 16). Oysters grown as clusters on suspended ropes, lines, or wires are given less attention between seeding and harvest.

Harvest

Harvest is conducted from the rafts and attending work boats or barges. Winches retrieve nets, socks, ropes, lines, wires, and bags. Sorting is conducted either on-deck or off-site (Corps 2015, p. 16).

When cultured mussels reach market-size, corresponding to approximately 12 to14 months of age, they are stripped from the suspended socks and lines, and bulk-bagged and tagged for transport to shore. Additional, more thorough cleaning and grading is typically conducted on shore. Weights are reclaimed for re-use, and used socks and lines are either recycled or disposed of at appropriate upland facilities and locations (Corps 2015, p. 14). Harvest is conducted year-round, as mussels mature.

After oysters are grown using a suspended culturing system, they are typically transplanted to an intertidal bed before final harvest. The practice, referred to as “hardening,” extends the shelf-life of oysters (Corps 2015, p. 16). The hardened oysters are subsequently re-harvested (after 2 to 4 weeks) using bottom culture harvest methods. Some growers/farm operators simply bag and hang oysters from their docks or piers, allowing tide cycles to expose and harden the oysters.

Other Related Activities

Vessel operations, farm site access, and onshore facilities are all inherent to shellfish activities conducted on the tidelands and the inland marine waters. These activities do not have independent utility, but may result in additional effects.

Vessel Operations

Shellfish activities generally require the operation of small- and medium-sized vessels. Small vessels provide the means for transporting crews, equipment, and materials, by-water, to and from cultured areas. Typical small vessels include open work boats and skiffs powered by two-or four-stroke outboard motors. Larger, medium-sized vessels are used to mechanically prepare sites, frost or gravel beds, and to mechanically harrow and harvest ground-based cultured areas. Typical larger vessels include work boats and barges with a flat fore or rear deck, an enclosed or partially enclosed cabin or deckhouse, above- and/or below-deck stowage, and mechanical equipment (including booms and winches). Larger, medium-sized vessels are typically powered by larger and stronger diesel inboard motors.

Small vessels are commonly anchored or grounded, on a temporary basis, while crews conduct their work. Farm operators and their crews typically avoid eelgrass (*Zostera* sp.) meadows, vegetated shallows, and actively cultured beds, when temporarily grounding or anchoring their small vessels. A typical pattern of site access from the water includes: temporarily grounding on exposed sand- or mudflats; off-loading of crew, equipment, and materials; and, off-shore motoring, at a short distance from the ongoing work, to temporarily anchor the vessel in deeper intertidal or subtidal waters. Larger vessels are not typically grounded (even temporarily), with the exception of flat-bottomed work barges used by some farm operators.

Fueling, maintenance, and repair of vessels are not commonly conducted at the cultured area or over the open waters. Instead, these activities are typically conducted at commercial facilities, or at designated locations where the farm operator has purpose-specific equipment, materials, and protective measures in place.

<u>Farm Site Access</u>

Crews must access and traverse over the cultured intertidal beds, and adjacent areas, when performing their work. Some cultured areas can be easily accessed, and are therefore routinely accessed from the adjacent uplands. Crews typically carry equipment and materials on-foot, or with the assistance of an ATV(s).

Where access to cultured areas is from the adjacent uplands, most farm operators and crews establish and use well-defined routes of access through the nearshore riparian buffer and high, upper-intertidal beach. Where ATVs, small tractors, or mechanical harvesters are used on the exposed intertidal bed, this equipment may be refueled on-site (subject to permit conditions and other restrictions). Equipment maintenance and repair is generally, if not always, conducted in the uplands and away from the water.

<u>Onshore Facilities</u>

Hatcheries are typically corporate and off-site, serving many customers. They are often located in the uplands and their operations do not require a Corps permit. Operation of upland hatcheries is not part of the Corps' proposed action.

Once purchased by a grower/farm operator, seed is often allowed to further mature before being outplanted. Some growers use tanks located in the uplands, a practice that may include withdrawals from and discharges to the adjacent marine waters. Discharges are sometimes, but not always, regulated under a permit(s) issued by the Washington State Department of Ecology (Ecology).

Many, perhaps most, farm operators maintain an onshore facility where they store, stage, dry, clean/de-foul, repair, and maintain their culturing equipment and materials (nets, bags, tubes, racks, stakes, longlines, etc.). Most operators accomplish these tasks with no direct discharge to the adjacent waters.

"Wet storage" refers to temporary storage of harvested shellfish, typically prior to onshore cleaning, grading, and processing. Some farm operators hold their shellstock in wet storage located on the farm footprint, some float their product in subtidal waters, and others use upland tanks for the purpose of wet storage. Tanks may be prepared synthetically, with the addition of salts to potable water, or may be filled with withdrawals from the adjacent marine waters.

Whether used to mature seed or to store harvested shellfish, tanks are regularly cleaned, disinfected, and buffered. Some operate with recirculation, minimizing the total volumes of withdrawal and/or discharge. Return water discharges generally deviate minimally from ambient marine water, with only trace and negligible additional amounts of nutrients, phytoplankton, and/or feces/pseudofeces (Corps and Seattle Shellfish 2014; Corps and BWH Seafood 2015).

Wastewaters, both fresh and saline, are byproducts of storing, cleaning, grading, and processing harvested shellfish. However, most or all of these facilities are located in the uplands, and their operations do not require a Corps permit. Resulting wastewaters are typically collected and reused or recycled. Processing operations, and State regulations and requirements, dictate methods of wastewater disposal at each facility.

Shell and shell fragments are the main byproducts of processing harvested shellfish. Whole oyster shell is valuable and commonly reclaimed for use as cultch. Shell may also be crushed and sold or marketed for other purposes (e.g., landscape surfacing and aggregate).

Activities Excluded from Programmatic Coverage

The Corps and Service have determined that some shellfish activities and practices are not appropriate for programmatic coverage, either because: a) The activity or practice results in potential effects, of a kind, extent, or severity, that warrant case-by-case consideration (and individual section 7 ESA consultation); or, b) The activity or practice extends sufficiently beyond the jurisdiction of the Corps' regulatory program, or is regulated under the authorities and jurisdiction of another Federal agency (Corps 2015, p. 38, 39). Table 1, below, represents the Corps' list of shellfish activities, methods, and practices (or other, interrelated activities) that are specifically and intentionally excluded from coverage under the programmatic consultation.

The Service expects that the Corps will actively solicit information from their applicants about all of the excluded activities 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 an excluded activity (or activities), will not satisfy the requirements of their Corps permit and are potentially liable under the provisions of the ESA.

Table 1. Activities excluded from programmatic coverage

(1) Vertical fencing/vertical nets or drift fences (includes oyster corrals).
(2) New berms or dikes or the expansion or maintenance of current, authorized berms or dikes.
(3) 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.
(4) Pile driving.
(5) Installation and maintenance of mooring buoys.
(6) Construction, maintenance, and operation of upland hatcheries.
(7) Cultivation of shellfish species not previously cultivated in the action area.
(8) Construction, maintenance, and operation of attendant features, such as docks, piers, boat ramps, stockpiles, or staging areas.
(9) Deposition of shell material back into waters of the United States as waste.
(10) Dredging or creating channels so as to redirect fresh water flow.
(11) Installation of new rafts, floats, or FLUPSYs, or the relocation or expansion of continuing rafts, floats, or FLUPSYs.
(12) Any form of chemical application to control undesired species (e.g., non-native eelgrass, *Zostera japonica*; ghost shrimp, *Neotrypaea californiensis*; mud shrimp, *Upogebia pugettensis*).
(13) Use of materials that lack structural integrity in the marine environment (e.g. plastic children's wading pools, unencapsulated Styrofoam®).
(14) Unauthorized activities.

(Corps 2015, p. 39)

On April 2, 2014, and April 16, 2015, Ecology issued National Pollutant Discharge Elimination System permits allowing the application of a selective aquatic herbicide for the control of non-native Japanese eelgrass (*Zostera japonica*; multiple Permit No.s), and allowing the application of imidacloprid, a neonicotinoid pesticide, for the control of burrowing shrimp (Permit No.

WA0039781) on commercial oyster and clam beds in Willapa Bay and Gray Harbor. On May 3, 2015, the Willapa-Grays Harbor Oyster Growers Association and Ecology announced an agreement to withdraw and cancel the permit issued for use of imidacloprid.

These practices (i.e., the application of herbicides or pesticides to the bed or waters) do not have coverage under the Corps' programmatic consultation (Corps 2015, pp. 39, 54). The Service assumes and expects that the Corps will actively solicit information 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 Corps permit and are potentially liable under the provisions of the ESA. In the event that a Corps applicant or group of applicants has been issued a valid State permit(s) to engage in application of herbicides or pesticides to the bed or waters, the Service expects that the Corps will confirm compliance with the procedural requirments of the ESA before issuing a permit or permit verification.

Conservation Measures

The Corps and Services developed the following conservation measures through a Standard Local Operating Procedures (SLOPES) process, and the Corps has included the following conservation measures as elements of their proposed action (Corps 2015, pp. 49-53). Permits and permit verifications issued by the Corps will incorporate these measures as enforceable terms and conditions. If a Corps permit applicant or group of applicants cannot or will not commit to fully implementing the following measures, the issuance of that permit or permit verification cannot be covered under the programmatic consultation, and case-by-case consideration and individual section 7 ESA consultation will be required. Corps permit applicants who seek coverage under the programmatic consultation, but who also fail to fully comply with these conservation measures (where applicable), will not satisfy the requirements of their Corps permit and are potentially liable under provisions of the ESA.

Shellfish activities will be conducted in a manner consistent with the following conservation measures (Corps 2015, pp. 49-53):

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.

   [*Note: Where the conservation measures refer to native eelgrass, they refer to and use the definition, description, and methods of delineation that have been endorsed and adopted by the Corps’ Seattle District (Corps 2016).]

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 ft 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 to 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 ft MLLW if the area is listed as documented surf smelt (*Hypomesus pretiosus*) spawning habitat by the Washington State Department of Fish and Wildlife (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 ft MLLW if the area is listed as documented Pacific sand lance (*Ammodytes hexapterus*) spawning habitat by 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* 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.

    [*Note: For information on how to become an "approved biologist" for the purpose of conducting forage fish surveys parties should contact WDFW.]

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 area landward of mean higher high water (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 conservation measure does not apply to the wet storage of harvested shellfish.]

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

13. 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).

14. Land vehicles shall be stored, fueled, and maintained in a vehicle staging area located 150 ft 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.

15. For boats and other gas-powered vehicles or power equipment that cannot be fueled in a staging area 150 ft 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.

16. All vehicles operated within 150 ft 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 documented in a record that is available for review on request by the Corps and Services.

17. The direct or indirect contact of toxic compounds including creosote, wood preservatives, paint, etc. with the marine environment shall be prevented.

18. 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 ft of net.

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

20. 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.

21. 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 currently being used for floatation shall be replaced with inert or encapsulated materials, such as plastic or encased foam, during maintenance or repair of the structure.

22. 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 escapes 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 and Services: date of patrol, location of areas patrolled, description of the type and amount of retrieved debris, other pertinent information.

23. 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 a fish, bird, or mammal is found entangled, the grower shall: 1) provide immediate notice (within 24 hours) to WDFW (all species), the Services (ESA listed species), or the 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.

24. 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 disturbance to a very small footprint.

25. 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.

26. 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. [Note: Any alternative to using an embedded anchor must be approved by the NMFS.]

27. 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.

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

Action Area

The action area is defined as all areas to be affected directly or indirectly by the federal action and not merely the immediate area involved in the action (50 CFR 402.02). In delineating the action area, we evaluated the farthest reaching physical, chemical, and biotic effects of the action on the environment.

Geographic Distribution and Spatial Extent of Covered Activities

The Corps has compiled information from permit applications, and has obtained estimates from the DNR, WDFW, and shellfish industry representatives, to document the geographic distribution and spatial extent of continuing shellfish activities (footprints, acres, fallow acres), and "new" shellfish activities (acres)(Corps 2015, pp. 40-49, 77-82). Table 2 below, summarizes this information. All values are estimates based on the best available information.

While the Corps may issue permits and permit verifications authorizing shellfish activities for a variety of purposes (i.e., commercial aquaculture, tribal and commercial wildstock harvest, recreational enhancement, and restoration), the majority of these permits and permit verifications (both by number and acreage) are issued to parties engaged in commercial aquaculture (i.e., farming and production of shellfish for human consumption)(Corps 2015, pp. 40-45).

Applicants wishing to continue regulated shellfish activities must obtain reauthorization from the Corps every five to ten years. The majority of the Corps' shellfish permit actions (permits and permit verifications) involve reauthorization of continuing activities and farms; specifically, reauthorizations of continuing commercial, intertidal farms producing shellfish for human consumption (Corps 2015, p. 5). Over the expected 20-year timeframe of the programmatic, activities located within the same farm footprint could be reauthorized by the Corps as many as three or four times.

Under the Corps' regulatory program in Washington State, continuing shellfish activities are those activities that were granted a permit, license, or lease from a state or local agency, authorizing shellfish activities within a defined footprint prior to March 18, 2007 (Corps 2015, p. 6). "New" shellfish activities are those activities that were undertaken after March 18, 2007.

This programmatic consultation provides coverage for most culturing activities and practices on continuing farms and operations (except excluded activities; Table 1, pp. 32). This programmatic consultation extends this same coverage to most culturing activities and practices on "new" farms and operations, but does not provide coverage for some specific suspended culturing practices (i.e., initial installation of new rafts, floats, or FLUPSYs; relocation and/or expansion of continuing rafts, floats, or FLUPSYs)(Corps 2015, p. 39).

Some continuing shellfish activities include a fallowed farm footprint, or a portion of the defined farm footprint that is currently fallow (i.e., left un-farmed or un-cultured). For the purpose of defining and documenting the geographic distribution and spatial extent of fallowed farm footprints, the Corps assessed status as of March 18, 2007, and again during 2012-2013 when most continuing shellfish activities were last reauthorized (Corps 2015, p. 6).

Commercial intertidal aquaculture accounts for most of the continuing shellfish activities (99 percent), on a total of more than 36,000 acres (Table 2). Suspended commercial aquaculture, defined here to include FLUPSYs, is very limited (less than 130 acres in total). "New" shellfish activities conducted as restoration, or to enhance recreation opportunities, are also very limited (approximately 315 acres in total; Table 2).

Fallow acreage is greatest in Willapa Bay, where the Corps reports that more than 9,000 acres have been fallow (approximately 37 percent of the continuing acreage) since 2007 or earlier (Corps 2015, pp. 40-49, 77-82). However, when expressed as a percentage of the continuing acreage, fallowed farm footprints are more prevalent in Grays Harbor (approximately 61 percent) and the north Puget Sound (approximately 63 percent)(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 (Corps 2015, pp. 40-49, 77-82). These estimates suggest future increases 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.

This Opinion addresses permits and permit verifications issued by the Corps for shellfish activities conducted on the tidelands and in the inland marine waters of the State of Washington (Figure 1, p. 9). The action area includes significant portions of fourteen counties: Clallam, Grays Harbor, Island, Jefferson, King, Kitsap, Mason, Pacific, Pierce, San Juan, Skagit, Snohomish, Thurston, and Whatcom Counties, Washington. Shellfish activities are conducted across a wide range of tidal elevations, from +7 MLLW, to depths of -70 MLLW or greater. 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, pp. 40-49, 77-82).

When viewed from a landscape perspective, or even from the perspective of a single waterbody (e.g., Willapa Bay) or portion thereof (e.g., Totten Inlet or Samish Bay), shellfish activities are variable in density and spatially discontinuous. At some locations, cultured tidelands extend with only occasional interruption along extended lengths of the nearshore. At other locations, cultured tidelands are interspersed along shorelines that support a range of other uses (residential, recreational, etc.).

Where cultured tidelands extend with only occasional interruption, interspersed uncultured areas may experience direct or indirect effects, and are therefore considered part of the action area. However, where cultured tidelands occur sporadically, and lengths of intervening shore are not cultured but instead managed for other uses, these nearshore areas are unlikely to experience measurable direct or indirect effects, and are therefore not considered part of the action area.

At all locations, the action area extends a minimum of 2,000 ft from the farm footprint (active and fallow). This distance encompasses those areas of the nearshore that may experience temporary effects (e.g., temporary effects to water quality, temporary effects to the sound environment, etc.). Factoring and incorporating these other considerations, we estimate conservatively that regulated shellfish activities in Washington State, specifically those for which this Opinion provides programmatic coverage, are likely to directly or indirectly affect more than 45,000 acres of nearshore marine habitat (45,000 to 50,000 acres in total; Willapa Bay: approx. 30,000 acres; Grays Harbor: approx. 4,000 acres; north Puget Sound: approx. 5,000 acres; south Puget Sound: approx. 5,000 acres; and, Hood Canal: approx. 3,000 acres).

The Corps' BA describes subtidal wild geoduck harvest (Corps 2015, pp. 3, 5, 30, 34, 46, 47, 80, 84, 89, 92, 93, 99, 100). The Corps has indicated that they are seeking programmatic coverage for subtidal wild geoduck harvest on a maximum of 6,050 acres per year, at depths to -70 ft MLLW in Hood Canal and Puget Sound. While harvests might be conducted across a maximum of 6,050 acres per year, available information suggests that harvest schedules are typically far more limited (less than 300 acres per year) (Table 3).

Table 2. Summary information describing the geographic distribution and spatial extent of shellfish activities in Washington State.

GEOGRAPHY		Existing – Continuing Activities: FOOTPRINTS/PARCELS		ACRES	FALLOW	New Activities ACRES	NOTES
Coastal	Willapa Bay	▪ Commercial Intertidal	Approx. **251**	25,836	9,441	approx. 75	Total Marine Tideland Acres: ~49,000
		▪ Commercial Suspended (includes surface long lines)	**2**+3 FLUPSY	approx. 4	approx. 27 (long lines)	approx. 25 (long lines)	Continuing & New: ~53 % of Total
		▪ Intertidal Other/Rec./Restoration		-----	-----	-----	Continuing Acreage Now Fallow: ~37%
							No Recreation/Restoration
	Grays Harbor	▪ Commercial Intertidal	Approx. **28**	2,965	1,820	approx. 95	Total Marine Tideland Acres: ~41,000
		▪ Commercial Suspended (includes surface long lines)		-----	-----	approx. 5 (long lines)	Continuing & New: ~7.5 % of Total
		▪ Intertidal Other/Rec./Restoration		-----	-----	-----	Continuing Acreage Now Fallow: ~61%
							No Recreation/Restoration
Hood Canal		▪ Commercial Intertidal	Approx. **207**	1,323	397	approx. 421	Total Marine Tideland Acres: ~11,500
		▪ Commercial Suspended (includes surface long lines)	**6**	approx. 33	approx. 5 (long lines)	approx. 17 (long lines)	Continuing & New: ~16.5 % of Total
		▪ Intertidal Other/Rec/Restoration		-----	-----	98	Continuing Acreage Now Fallow: ~30%
Puget Sound	North Sound	▪ Commercial Intertidal	Approx. **70**	3,623	2,333	approx. 310	Total Marine Tideland Acres: ~84,000
		▪ Commercial Suspended (includes surface long lines)	**3**	approx. 64	-----	approx. 5 (long lines)	Continuing & New: ~4.8% of Total
		▪ Intertidal Other/Rec./Restoration		-----	-----	50	Continuing Acreage Now Fallow: ~63%
	South Sound	▪ Commercial Intertidal	Approx. **371**	3,111	780	approx. 426	Total Marine Tideland Acres: ~30,000
		▪ Commercial Suspended (includes surface long lines)	**10**+3 FLUPSY	approx. 22	-----	approx. 22 (long lines)	Continuing & New: ~12.5% of Total
		▪ Intertidal Other/Rec./Restoration		-----	-----	167	Continuing Acreage Now Fallow: ~25%
		TOTALS		~37,000 Ac.	~14,800 (40%)	~1,716 Ac.	

Table 3. Summary information describing subtidal wild geoduck harvest in Washington State.

GEOGRAPHY	Hood Canal	South Puget Sound	North Puget Sound	**Total**
Harvestable Acreage				
State Lands	6,503	22,176	18,454	47,133
Non-State Lands	200	500	300	1,000
Sub-Total	6,703	22,676	18,754	48,133
DNR HCP Annual Acreage				
Typical Year (State Lands)	62	137	54	253
Maximum	1,500	3,000	3,000	6,000
Corps Programmatic Annual Acreage				
Typical Year (State Lands)	62	137	54	253
Maximum State Lands	1,500	3,000	3,000	6,000
Typical Non-State Lands	10	25	15	50

ANALYTICAL FRAMEWORK FOR THE JEOPARDY AND ADVERSE MODIFICATION DETERMINATIONS

Jeopardy Determination

The following analysis relies on the following four components: (1) the *Status of the Species*, which evaluates the rangewide condition of the listed species addressed, the factors responsible for that condition, and the species' survival and recovery needs; (2) the *Environmental Baseline*, which evaluates the condition of the species in the action area, the factors responsible for that condition, and the relationship of the action area to the survival and recovery of the species; (3) the *Effects of the Action*, which determines the direct and indirect impacts of the proposed federal action and the effects of any interrelated or interdependent activities on the species; and (4) *Cumulative Effects*, which evaluates the effects of future, non-federal activities in the action area on the species.

In accordance with policy and regulation, the jeopardy determination is made by evaluating the effects of the proposed federal action in the context of the species' current status, taking into account any cumulative effects, to determine if implementation of the proposed action is likely to cause an appreciable reduction in the likelihood of both the survival and recovery of listed species in the wild.

The jeopardy analysis in this Opinion emphasizes the rangewide survival and recovery needs of the listed species and the role of the action area in providing for those needs. It is within this context that we evaluate the significance of the proposed federal action, taken together with cumulative effects, for purposes of making the jeopardy determination.

Adverse Modification Determination

The designation of critical habitat for bull trout uses the term primary constituent element (PCEs) or essential features. The new critical habitat regulations (81 FR 7214) 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 PCEs, PBFs, or essential features. Please note that references to PCEs in the following analysis should be viewed as synonymous with PBFs.

Our analysis of effects to critical habitat relies on the following four components: (1) the *Status of Critical Habitat*, which evaluates the range-wide condition of designated critical habitat for the bull trout in terms of PCEs or PBFs, the factors responsible for that condition, and the intended recovery function of the critical habitat overall; (2) the *Environmental Baseline*, which evaluates the condition of the critical habitat in the action area, the factors responsible for that condition, and the recovery role of the critical habitat in the action area; (3) the *Effects of the Action*, which determines the direct and indirect impacts of the proposed federal action and the effects of any interrelated or interdependent activities on the PCEs or PBFs, and how that will influence the recovery role of affected critical habitat units; and (4) *Cumulative Effects*, which evaluates the effects of future, non-federal activities in the action area on the PCEs or PBFs and how that will influence the recovery role of affected critical habitat units.

The proposed federal action is evaluated to determine if it would likely result in a direct or indirect alteration that appreciably diminishes the value of critical habitat for the conservation of (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.

STATUS OF THE SPECIES

Bull Trout

For a detailed account of bull trout biology, life history, threats, demography, and conservation needs, refer to Appendix A: Status of the Species Bull Trout.

Marbled Murrelet

For a detailed account of marbled murrelet biology, life history, threats, demography, and conservation needs, refer to Appendix B: Status of the Species Marbled Murrelet.

STATUS OF CRITICAL HABITAT (BULL TROUT)

For a description of the rangewide status of designated bull trout critical habitat, refer to Appendix C: Status of the Designated Critical Habitat for Bull Trout.

ENVIRONMENTAL BASELINE

Regulations implementing the ESA (50 CFR 402.02) define the environmental baseline as the past and present impacts of all Federal, State, or private actions and other human activities in the action area. Also included in the environmental baseline are the anticipated impacts of all proposed federal projects in the action area that have undergone section 7 consultation, and the impacts of state and private actions which are contemporaneous with the consultation in progress.

There is a long history of culturing shellfish and other shellfish activities in every part of the action area. Conditions prevailing in the action area exhibit the influence of these activities. However, prevailing conditions also reflect broader patterns of land use and development, in the nearshore environment, along shorelines, and in the larger watersheds that drain to these marine waters.

Active and Fallow Lands

Some continuing shellfish activities include a fallowed farm footprint, or a portion of the defined farm footprint that is currently fallow (i.e., left un-farmed or un-cultured). For the purpose of defining and documenting the geographic distribution and spatial extent of fallowed farm footprints, the Corps assessed status as of March 18, 2007, and again during 2012-2013 when most continuing shellfish activities were last reauthorized (Corps 2015, p. 6).

> "Acreage classified as *continuing active* has by definition been engaged in shellfish activity since at least 2007 and likely for much longer" (Corps 2015, p. 79).
>
> "Acreage identified as *continuing fallow* may also have been engaged in shellfish activity at some point in the past … but is not engaged in shellfish activity presently … No shellfish activity has occurred on fallow lands since at least 2007 and most for a much longer time period (e.g., decades)" (Corps 2015, p. 79).
>
> "The aquatic habitat has … been modified by shellfish cultivation and harvest activities that have been occurring for many years on the continuing active acreage. [However,] the status of the aquatic habitat on fallow acreage is unknown since shellfish activities on these lands have not occurred for many years. Based on the permit application record which indicates the fallow areas have not had active cultivation since at least 2007, it is assumed … that the fallow lands exist currently in an unmodified or 'recovered' state. A resumption of shellfish activity in these areas may therefore result in impacts to the aquatic habitat similar to the impacts that might result from aquaculture initiated in areas classified as new" (Corps 2015, p. 79).

> "Since no activity has occurred on the fallow lands for at least five years [since 2007], the habitat conditions … [are] likely different than if [they] had been engaged in aquaculture or some regular rotation of aquaculture. [The habitat] has likely 'recovered' from any prior aquaculture impact" (Corps 2015, p. 81).

We divide the action area into five geographically distinct sub-areas: 1) Willapa Bay; 2) Grays Harbor; 3) north Puget Sound; 4) south Puget Sound; and, 6) Hood Canal. We use these sub-areas to structure our discussion of the environmental baseline; we describe, in summary form, the variety of physical and biological settings where shellfish activities are conducted. Some biologically relevant characteristics of the environmental baseline are similar, while others are variable and may be very different, across the five sub-areas and individual farm sites.

Willapa Bay

Six watersheds drain to Willapa Bay: the North, Willapa, Palix, Nemah, Naselle, and Bear watersheds. The largest river systems are the North, Willapa, and Naselle drainages. In total, there are approximately 745 streams encompassing over 1,470 linear stream miles in the greater Willapa watershed (Phinney and Bucknell 1975). Approximately two-thirds of the watershed's uplands are managed as commercial forest land. Cranberry farms comprise an additional seven percent, including 1,400 acres of bogs.

Willapa Bay is relatively shallow. Approximately one-half of the estuary lies in the intertidal zone (Andrews 1965 *in* Banas *et al*. 2004, p. 2414). At low tide, expansive subtidal areas are covered by less than 10 ft of water. Three pronounced channels in the bay run to depths of 30 or 60 ft deeper than the surrounding tidelands. Tidal elevations vary by 14 to 16 ft over the course of each tidal cycle, and approximately 50 percent of the bay's volume is exchanged with the Pacific Ocean on a daily basis. Willapa Bay opens to the Pacific Ocean at its northwest corner, through a broad shallow pass extending approximately six miles between Cape Shoalwater and Leadbetter Point at the tip of the Long Beach Peninsula. There are numerous sand bars, spits, and islands, and large areas of exposed sand- and mudflat.

Major tributaries that support anadromous fish include the South Fork Willapa River, Trap Creek, Mill Creek, Wilson Creek, Fork Creek, and Ellis Creek. The greater Willapa watershed supports fall Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), fall chum salmon (*O. keta*), winter steelhead trout (*O. mykiss*), and coastal cutthroat trout (*O. clarki clarki*). The Willapa Bay estuary is vital to the health of these populations, as it provides important migratory and transitional habitat for outmigrating juvenile and returning adult salmonids. These salmonid populations are not listed under the ESA, and current information indicates that the greater Willapa watershed does not support the spawning and rearing of any ESA-listed anadromous fish species, including bull trout.

According to the Washington State Conservation Commission (Smith and Wenger 2001, pp. 7-9), primary limiting factors for salmonid productivity in each of the major sub-watersheds (North, Willapa, Palix, Nemah, Naselle, and Bear) include lack of large wood, poor riparian conditions, excess sediment inputs from landslides and the roads network, and significant loss of lower floodplain and estuary habitat due to diking and tidegates; also, the Willapa and Naselle watersheds experience seasonal high water temperatures and low dissolved oxygen levels.

The Washington State Conservation Commission reports the following regarding conditions in the estuary (Smith and Wenger 2001, pp. 83-90):

- More than 850 acres of wetland have been lost from the lower North River and estuary, approximately 30 percent of the historic total.

- More than 580 acres of wetland have been lost from the lower Willapa River and estuary, approximately 20 percent of the historic total.

- More than 810 acres of wetland have been lost from the lower Palix River and estuary, approximately 30 percent of the historic total.

- More than 500 acres of wetland have been lost from the lower Bear River and estuary, approximately 30 percent of the historic total.

- The Nemah and Naselle River estuaries are relatively intact and healthy, exhibiting wetland losses of less than 2 percent of the historic total.

Invasive cordgrass (*Spartina* spp.) was introduced from the East Coast more than 100 years ago, grows as dense meadows, displaces native eelgrass, and raises the elevation of tide and mudflats (Smith and Wenger 2001, p. 83). However, according to the U.S. Fish and Wildlife Service (USFWS 2011, p. 4-2), efforts led by federal, state, and county agencies, and the cooperation of the oyster industry and private landowners, have eradicated *Spartina* from nearly all areas of Willapa Bay.

Vast beds of eelgrass (*Zostera* spp.) occur at the lower levels of the intertidal zone and are a staple food for several varieties of waterfowl (USFWS 2011, p. 4-26). Roots and stems of eelgrass stabilize mudflats, and leaf blades are grazed and support the growth of diatoms and small invertebrates. Eelgrass beds provide habitat for numerous species of mollusk and crustacean, and serve as a nursery ground for juvenile, resident, and migrating fish. Non-native Japanese eelgrass is also present and expanding (USFWS 2011, p. 4-26).

<u>Marine Forage Fish</u>

Forage fish resources include herring, anchovies, and smelt, all of which are important to other fish and wildlife of the bay (USFWS 2011, p. 4-35). Pacific herring use Willapa Bay as a spawning and nursery ground. The eggs are adhesive and can be found on rocks, piling, seaweed, and eelgrass during January and February. Immature herring are found in the bay during the spring, summer, and fall months. Northern anchovies (*Engraulis mordax*) are also plentiful in the bay during summer months. Longfin smelt (*Spirinchus thaleichthys*) and eulachon (*Thaleichthys pacificus*) use both the deeper channels of the bay and the lower reaches of tributary rivers and streams (USFWS 2011, p. 4-35).

Stick and Lindquist (2009) prepared the 2008 Washington State Herring Stock Status Report, and reported the following regarding the condition of coastal stocks (p. 71):

- "Spawning populations of Pacific herring are documented in the coastal embayments of Willapa Bay and Grays Harbor. Initial documentation of spawning activity for Grays Harbor occurred in 1998 and has been observed intermittently since that time. Herring stock assessment by WDFW has traditionally been focused on presumed larger Puget Sound stocks and limited assessment of coastal herring stocks currently takes place."

- "Herring spawning activity has been observed in February and March in Willapa Bay and February through March in Grays Harbor. Most of the spawn deposition in Grays Harbor appears to occur in the South Bay/Elk River estuary area of south Grays Harbor with some also documented in the Ocean Shores/Point Damon area."

- "Little is known about the [current status of the] coastal herring populations. However, due to the geographical separation of their spawning grounds, the Willapa Bay and Grays Harbor spawning populations are considered to be discrete. Herring spawned in coastal locations are likely components of large summer herring aggregations that concentrate in coastal offshore areas including the western end of the Strait of Juan de Fuca and the west coast of Vancouver Island."

- "The limited information available and current sampling effort for the coastal herring populations does not provide adequate basis for evaluation of the status of these stocks. Abundance of these stocks is considered relatively small compared to Puget Sound herring stocks. The cumulative spawning biomass estimate for these areas has ranged from 0 to 694 tons annually."

- "Reported fishery landings of seven tons or less have occurred since 1999 for bait herring caught in Grays Harbor, with no reported landings from Willapa Bay in recent years. No directed herring fishery harvest is allowed in Washington's coastal waters."

- "Limited survey effort suggests a decrease in spawning biomass for the Willapa Bay herring stock since 2004. Documented spawning grounds are limited to the southern portion of the bay. Little is known about this stock's life history, although it is likely that these fish spend significant time in ocean waters" (Stick and Lindquist 2009, p. 74).

Figures 17 and 18 report all of the available data to describe the annual spawning biomass for Grays Harbor and Willapa Bay herring stocks (Stick and Lindquist 2009, pp. 73, 75).

More recently, Stick, Lindquist, and Lowry (2014, Executive Summary) reported: "This is the fifth edition of the … Pacific herring stock status report. Unlike previous editions, the scope of this report is limited to Puget Sound due to a lack of assessment of coastal herring stocks since the last stock status report published in 2009."

In 2009, the Service reported that surveys are incomplete and there appear to be few or no data to describe the status of coastal surf smelt and Pacific sand lance stocks (USFWS 2009a, pp. 99, 100). It appears that is still the case in 2015.

Figures 19 and 20 identify shellfish activities located in the Willapa Bay sub-area, and their proximity to documented eelgrass beds and marine forage fish spawning habitats.

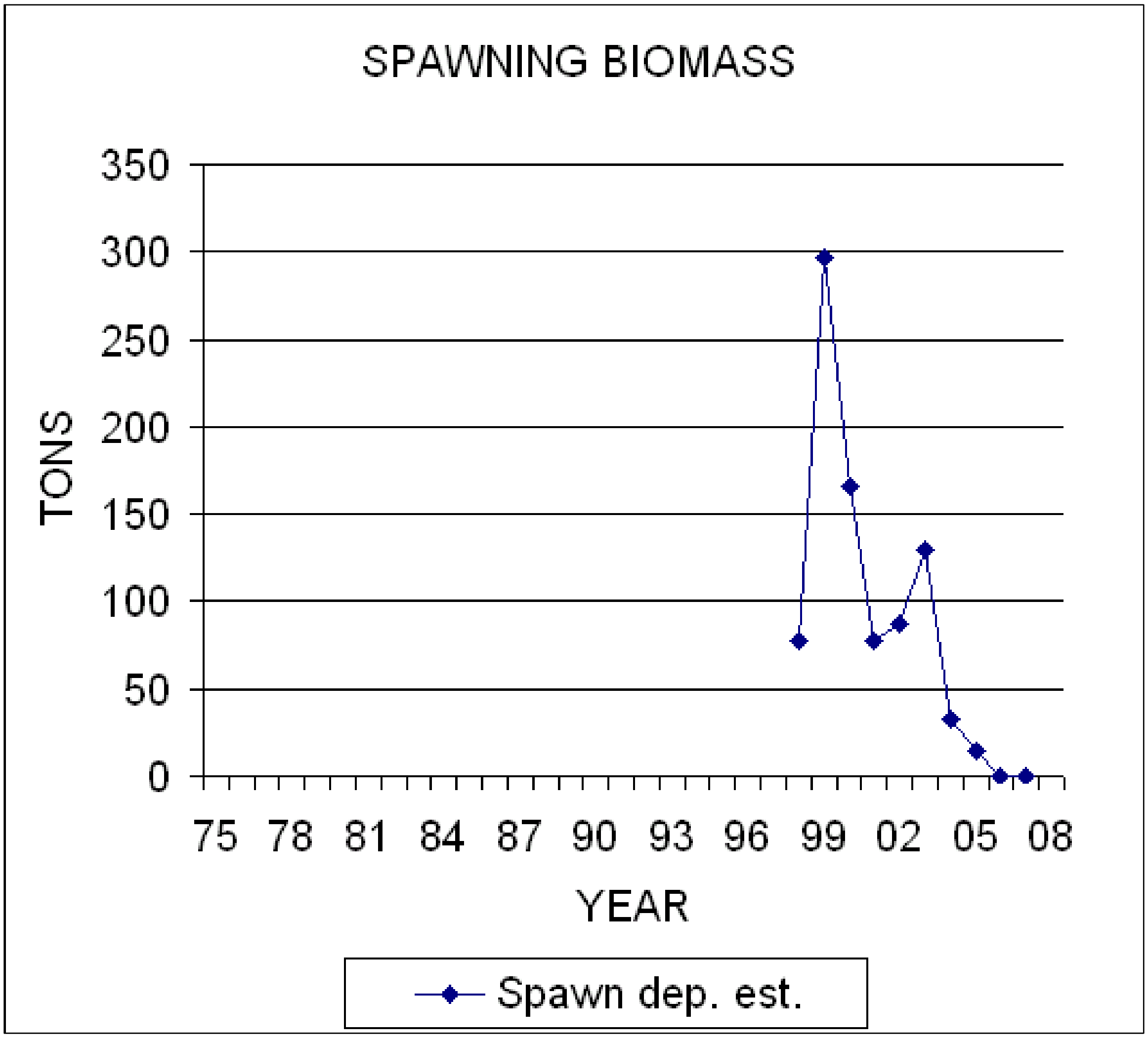

Figure 17. Annual spawning biomass for Grays Harbor herring stocks
(Stick and Lindquist 2009, pp. 73, 75)

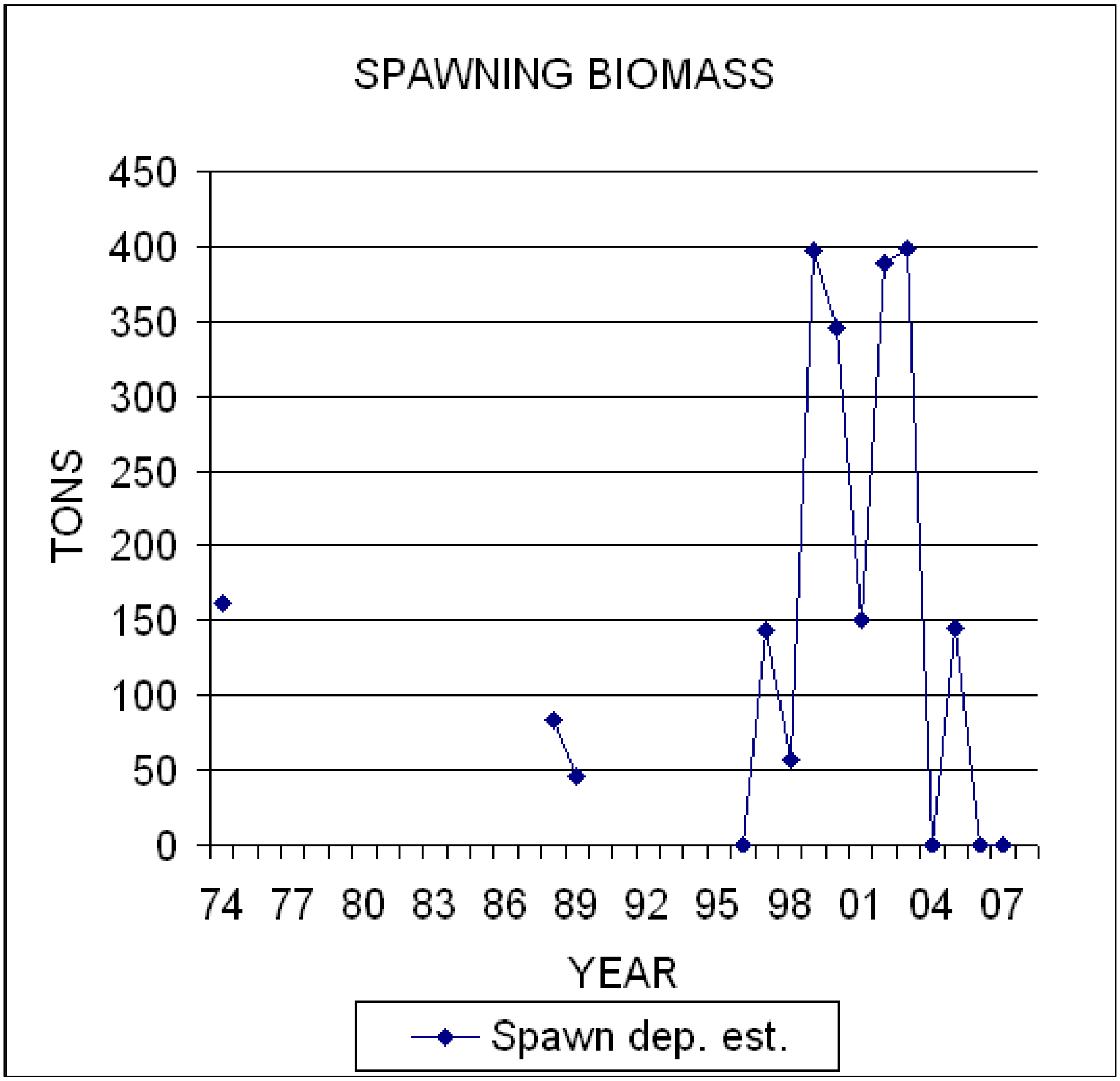

Figure 18. Annual spawning biomass for Willapa Bay herring stocks
(Stick and Lindquist 2009, pp. 73, 75)

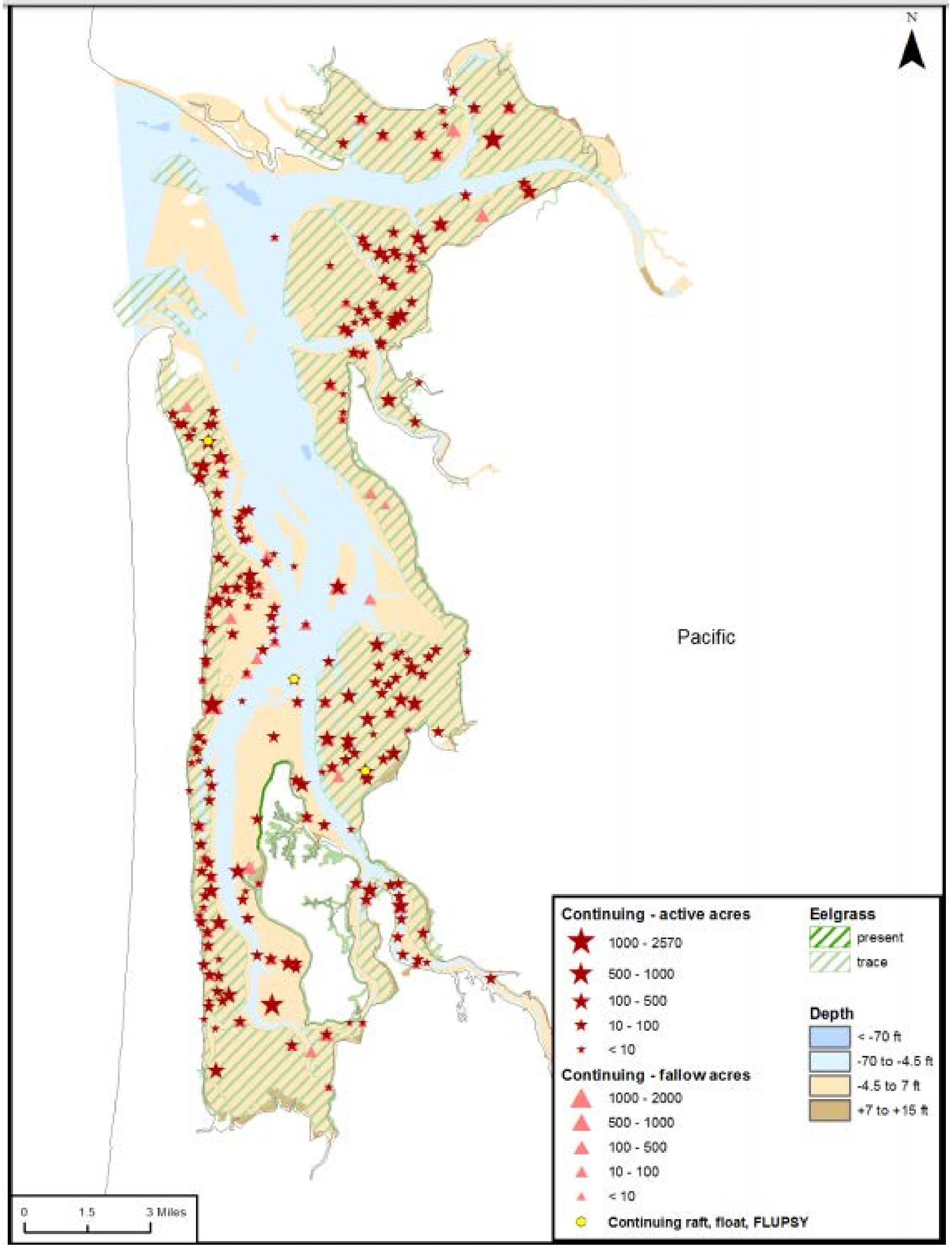

Figure 19. Shellfish operations and eelgrass in Willapa Bay
(Corps 2015, Appendix D)

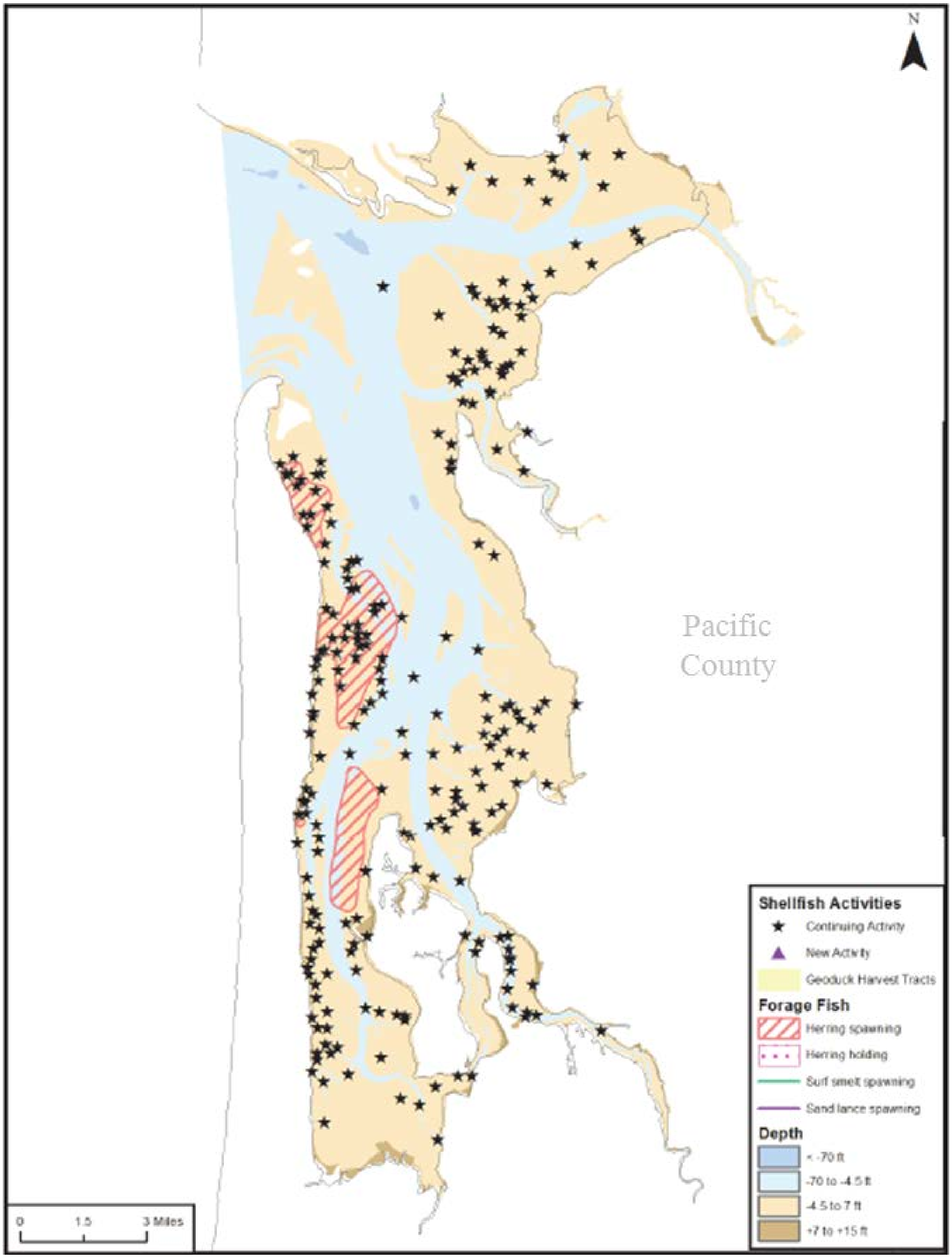

Figure 20. Shellfish operations and forage fish in Willapa Bay
(Corps 2015, Appendix E)

Grays Harbor

Grays Harbor is a medium-sized estuarine bay, approximately 17 miles long and 12 miles wide, covering at high tide approximately 97 square miles (Smith and Wenger 2001, p. 91). Orientation is roughly east-west, with a 2 mile-wide western channel opening to the Pacific Ocean. The Chehalis River, which enters at the easternmost extent of Grays Harbor, is the second largest river basin in Washington State. Grays Harbor's other major tributary is the Humptulips River. The Hoquiam River, Johns River, and several other direct tributaries have far smaller drainage basins (Smith and Wenger 2001, p. 91). All of Grays Harbor's direct tributaries, and several additional small- and medium-sized tributaries to the lower Chehalis River (e.g., the Wishkah and Wynoochee Rivers), are tidally-influenced along their lower reaches.

The estuarine habitats in Grays Harbor are more intact than many other similar systems in Washington State. Historical losses (as a result of diking, fill, etc.) are estimated at 30 percent (Smith and Wenger 2001, p. 16). However, while some portions are relatively undeveloped (e.g., North Bay), the inner harbor and vicinity of the Cities of Hoquiam and Aberdeen are heavily industrialized (Smith and Wenger 2001, p. 91).

The Chehalis River is more than 115 miles in length and drains an area of approximately 2,200 square miles, making it the second largest river basin in Washington State. Along its tidally-influenced lower 11 miles, side-channel, riparian, and floodplain habitats along the Chehalis River are in good to excellent condition, and are considered a high priority for conservation (Smith and Wenger 2001, p. 18).

The greater Grays Harbor-Chehalis watershed supports large and comparatively healthy populations of Chinook, chum, and coho salmon, steelhead and cutthroat trout. The lower Chehalis River and Grays Harbor estuary are vital to the health of these populations, as they provide important migratory and transitional habitat for outmigrating juvenile and returning adult salmonids.

Water and sediment quality are identified as limiting factors in some portions of the basin. The basin includes more than 100 impaired river segments, for which Ecology has established seven Total Maximum Daily Loads (TMDLs) (Ecology 2004, p. 1). Historical marine and industrial uses focused around the inner harbor, including pulp and paper mills, have been the cause for water quality concerns (and related fish kills) dating as far back as 1928 (Smith and Wenger 2001, p. 92). However, modernized practices and operations appear now to have controlled and greatly reduced commercial and industrial inputs. Sediment evaluations point to localized metal and synthetic organic contaminant concentrations, but it appears that an active sediment transport regime and good flushing prevent widespread chemical contamination (Ecology 1999, p. iii).

Excess sediment delivery is another important limiting factor for the basin (Smith and Wenger 2001, p. 17). The Chehalis River basin delivers immense quantities of sediment to Grays Harbor, and maintenance of the lower Chehalis River-Grays Harbor navigational channel requires dredging and in-water disposal of more than 2.5 million cubic yards of sediment annually (Smith and Wenger 2001, p. 94). While the system exhibits naturally high levels of turbidity and sedimentation at some times of year (Ecology 1993; 1994), dredging and channel maintenance produce turbidity, and the potential for resuspension of contaminated sediments, with potential consequences for juvenile fish and eelgrass habitat in particular (Smith and Wenger 2001, p. 94). Sand bars, spits, and islands, beaches, and large areas of exposed sand- and mudflat may be found throughout large portions of Grays Harbor.

Grays Harbor's estuarine habitats lack large woody material and, at some locations, have been further degraded by the introduction of invasive, non-native vegetation such as *Spartina* (Smith and Wenger 2001, pp. 92, 98). Both trends have the effect of reducing available cover and forage habitat for young salmonids, with potential consequences for survival rates and growth.

Marine Forage Fish

The status of marine forage fish is specifically described here because of their importance to the bull trout and marbled murrelet, and their link to the sensitive habitats that are affected by shellfish activities. Forage fish play a key role in the food web of the marine environment and make up a significant proportion of the diets for bull trout and marbled murrelets.

"In Grays Harbor … the primary [Pacific] herring spawning habitat is the outer edges of native salt-marsh beds, where a turf of rockweed (*Fucus*), sea-lettuce (*Ulva*), pickleweed (*Salicornia*) and salt-grass (*Distichlis*) in the uppermost intertidal zone serves as spawn deposition substrate … Spawning [Pacific] herring also use salt-marsh vegetation, along with beds of over-wintering cordgrass (*Spartina*) stubble and native eelgrass beds, in Willapa Bay (WDFW unpub. data) … [Pacific] herring spawning has been observed on dock pilings in Puget Sound and coastal bays (WDFW unpub. data)" (Penttila 2007, p. 6).

Stick and Lindquist (2009) prepared the 2008 Washington State Herring Stock Status Report, including a report on the status of coastal stocks (see *Environmental Baseline*, *Willapa Bay*). Figures 17 and 18 (pp. 48, 49) report all of the available data to describe the annual spawning biomass for Grays Harbor and Willapa Bay herring stocks (Stick and Lindquist 2009, pp. 73, 75).

Figures 21 and 22 identify shellfish activities located in the Grays Harbor sub-area, and their proximity to documented eelgrass beds and marine forage fish spawning habitats.

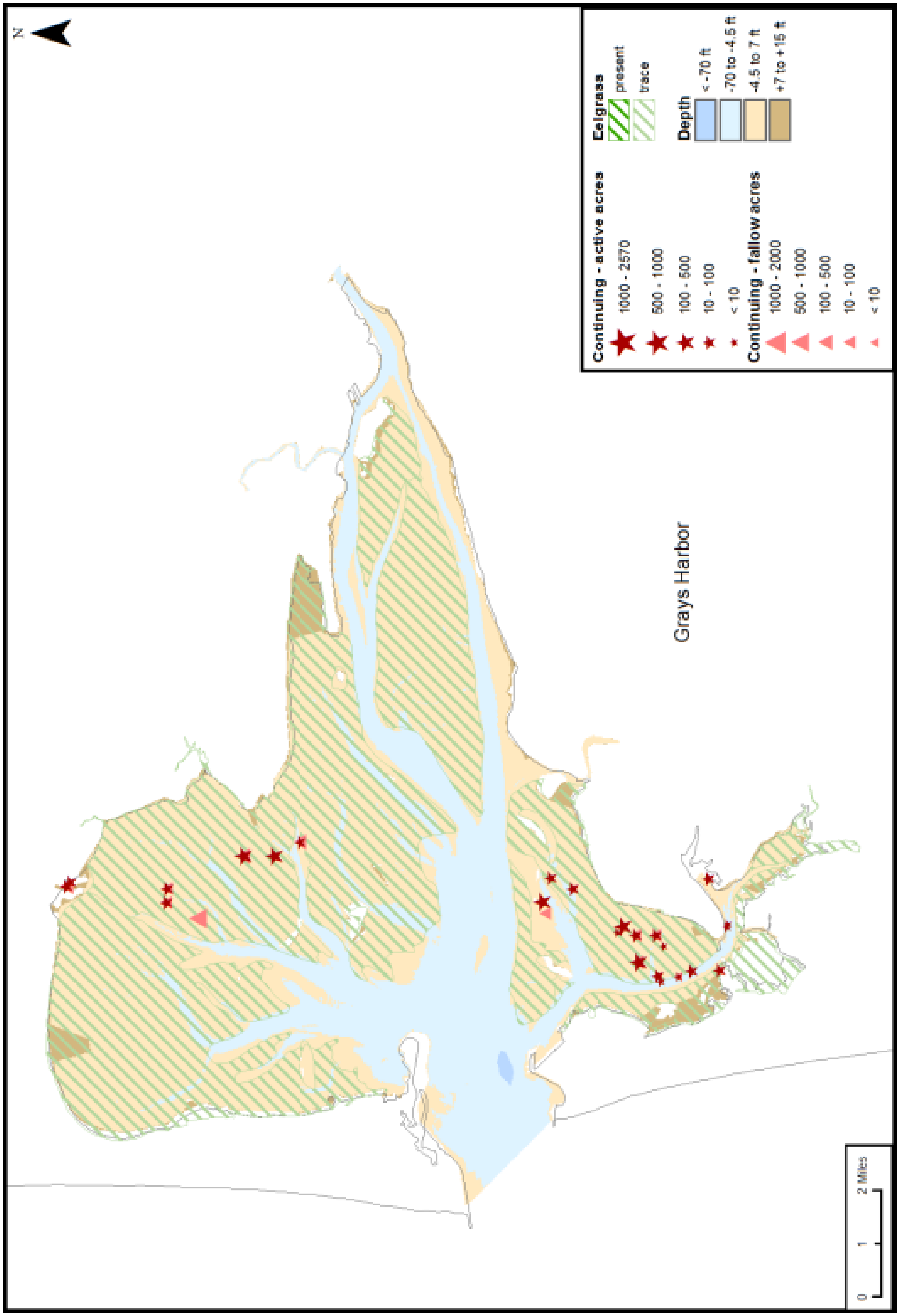

Figure 21. Shellfish operations and eelgrass in Grays Harbor
(Corps 2015, Appendix D)

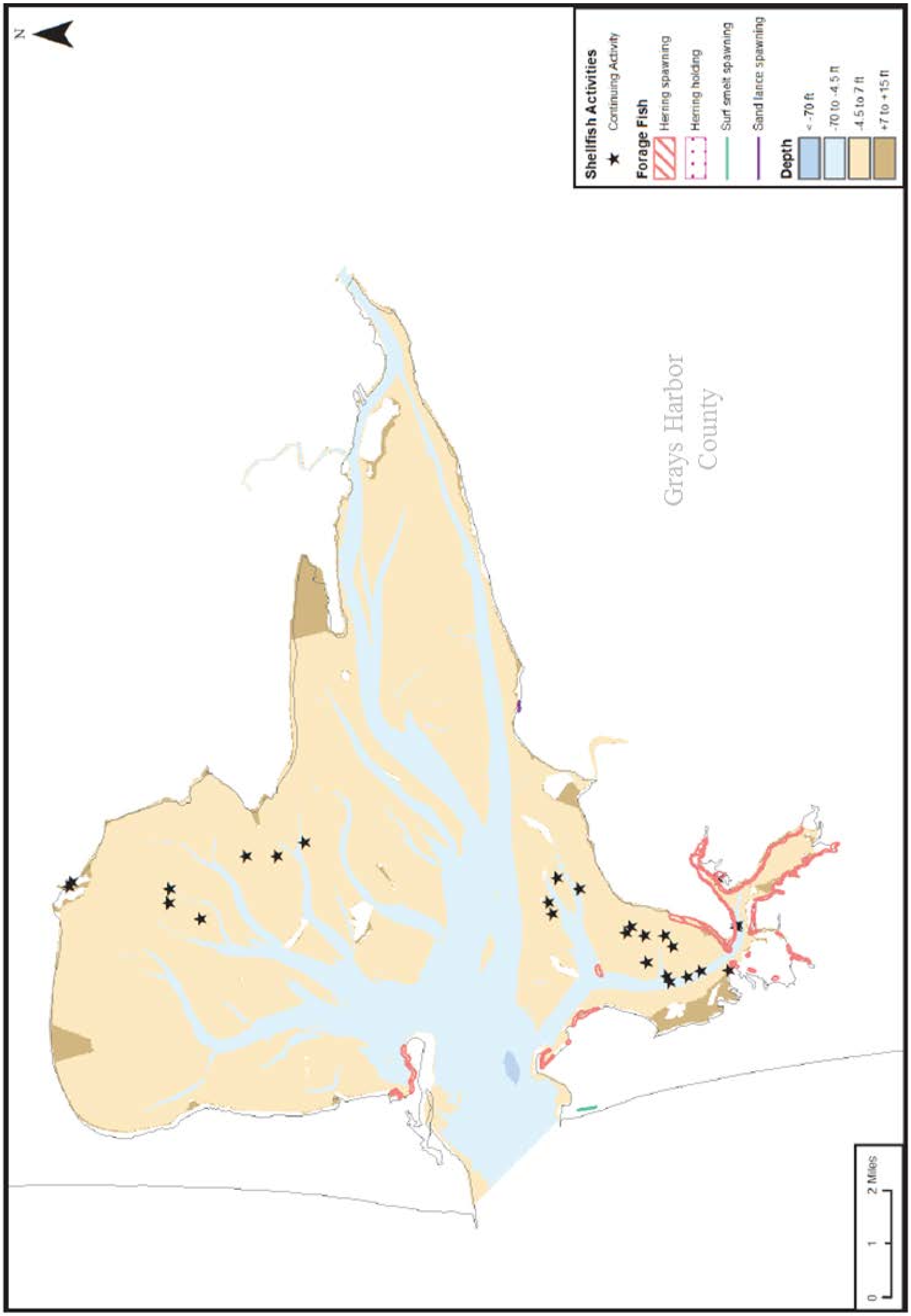

Figure 22. Shellfish operations and forage fish in Grays Harbor
(Corps 2015, Appendix E)

Puget Sound and Hood Canal

This sub-section discusses the north Puget Sound, south Puget Sound, and Hood Canal sub-areas. This geography and portion of the action area presents a huge variety of physical, chemical, and biological conditions. Describing the environmental baseline for the variety of physical and biological settings where shellfish activities are conducted is not a simple task, and therefore the Service has used and incorporates here by reference the excellent summary prepared by the DNR in support of their Aquatic Lands HCP (DNR 2014a). The DNR's Aquatic Lands HCP planning document, which was produced in part with funding provided by the Service, includes a lengthy discussion of physical, chemical, and biological characteristics, existing conditions, and, land uses and development. Appendix D includes excerpts from the DNR Aquatic Lands HCP planning document (DNR 2014a); those summaries are incorporated here by reference.

<u>Existing Conditions for Native Eelgrass</u>

The 2009 Puget Sound Ambient Monitoring Program (PSAMP) Submerged Vegetation Monitoring Project Report reached the following conclusions (Gaeckle *et al*. 2011, Executive Summary):

> "(1) The results in 2009 continue to indicate a pattern of *Z. marina* decline throughout Puget Sound. This result is supported by three main findings:
>
> a. There have been twice as many sites with long-term declining trends in *Z. marina* area than increasing trends since 2004.
>
> b. More year-to-year significant declines than increases in *Z. marina* area were evident in eight out of nine sampling intervals since 2000.
>
> c. The multiple parameter assessment identified the Hood Canal, San Juan-Straits, and the Central Puget Sound Regions with evidence of *Z. marina* decline and the Hood Canal Region having the highest level of concern for *Z. marina* loss. The assessment found no current concern for *Z. marina* loss in the Saratoga-Whidbey and North Puget Sound Region."
>
> "(2) The 2009 *Z. marina* area estimate in Puget Sound is 22,000 ± 3,600 hectares [± 95 percent Confidence Interval (CI)]. The decadal weighted mean over 2000-2009 is 21,500 ± 1,400 ha (± 95 percent CI). The patterns *of Z. marina* decline observed at the site level are not reflected in the soundwide areal estimate. A long-term, weighted linear regression analysis showed a marginally significant increasing trend in *Z. marina* area at the soundwide scale."
>
> "Although there is a marginally significant increasing trend in *Z. marina* area, the pattern of site level decline throughout Puget Sound suggests losses are prevalent at individual sites. There is consistently greater prevalence of year-to-year and long-term declines in *Z. marina* area and depth distribution throughout the study area. There is also strong evidence of *Z. marina* decline in the Hood Canal region. The occurrence and soundwide

> distribution of sites with significant declines is of concern for habitat connectivity and ecological functions. The effect of loss in areas that are considered critical nursery, forage, and migration habitat for ecologically and economically important species could affect ecosystem processes and the overall health of these areas and Puget Sound" (Gaeckle *et al*. 2011, Executive Summary).

The 2010-2013 PSAMP Submerged Vegetation Monitoring Project Report reached the following conclusions (Gaeckle *et al*. 2015, Executive Summary):

> "(1) Soundwide native seagrass area has been stable over the monitoring record [2003-2013]. There is no significant long-term linear trend in soundwide native seagrass area (permutation test, p=0.63). It is possible that small variations in soundwide native seagrass area occurred below the detection limits of the program, but seagrass in Puget Sound has not experienced a major decline."
>
> "(2) Current native seagrass conditions have not yet met the Puget Sound Partnership's target for a 20 percent increase in area by 2020. Statistical tests show that current soundwide native seagrass area is less than the target defined by the Puget Sound Partnership. It is too early to tell if the trend in seagrass area is on a trajectory to meet the target by 2020. Test results are equivocal on whether current conditions have progressed from the baseline conditions."
>
> "(3) Most of the 347 individual sites that were analyzed for change were stable throughout the entire monitoring record. Twenty-five sites decreased in native seagrass area, 17 sites increased in native seagrass area, 209 sites experienced no detectable change, and 60 sites did not have seagrass beds present. Thirty-six sites had insufficient data for trend analysis (sampled only 1 year). Many of the sites with long-term decreases in native seagrass area were located near Hood Canal, Southern Puget Sound, and the San Juan Islands ([Figure 23])."
>
> "(4) Seagrass conditions improved in the recent 2-3 years. Analysis of individual site data in recent years (n=156) shows that there are more sites with increasing (n=25) than decreasing (n=5) native seagrass area between 2010 and 2013. The reason is unknown; it could be a short-term anomaly or part of a longer-term pattern ([Figure 24])."
>
> "(5) Native seagrass area increased at two river deltas following major restoration projects: the Skokomish River delta in lower Hood Canal and the Nisqually River delta in southern Puget Sound" (Gaeckle *et al*. 2015, Executive Summary).

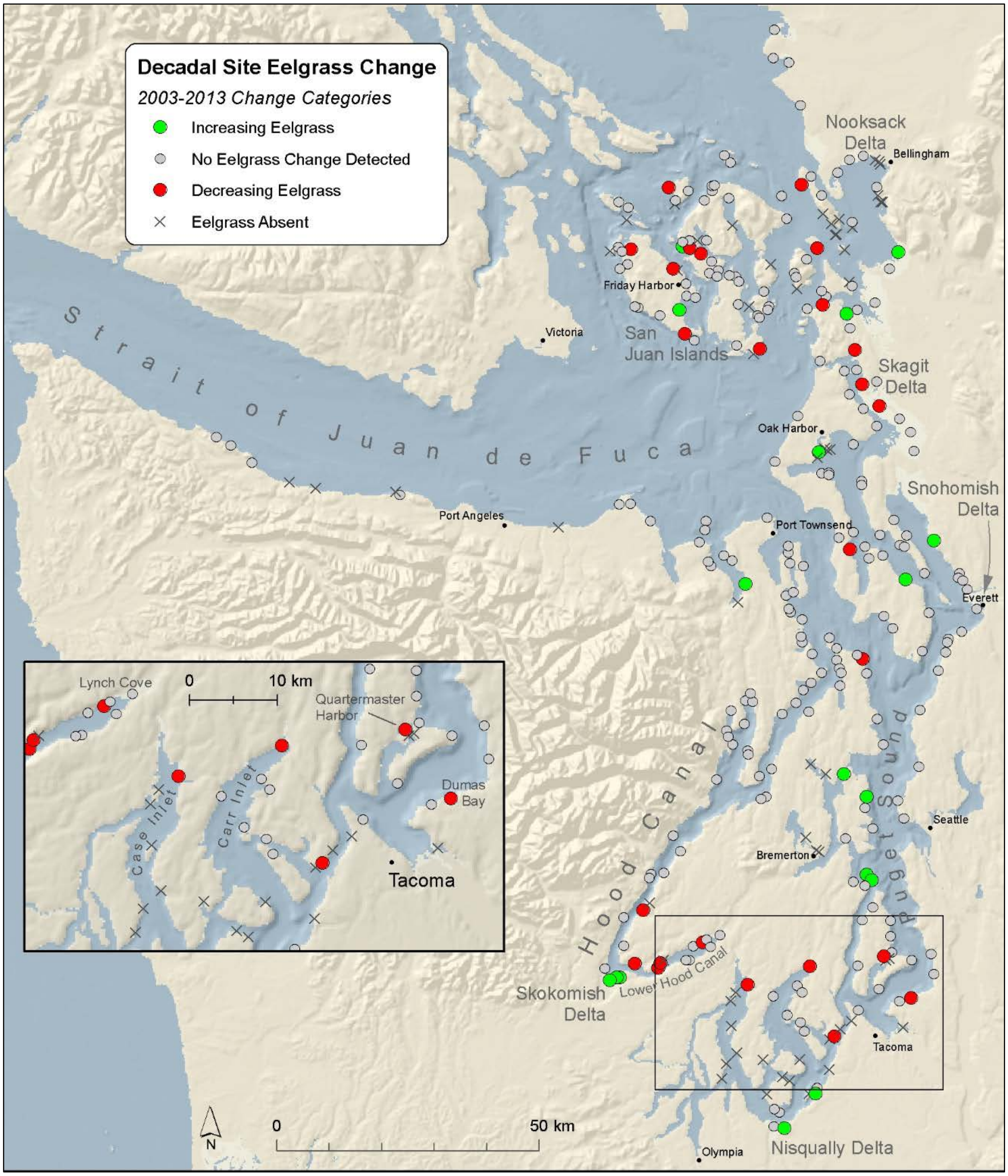

Figure 23. Increases and decreases in native seagrass area based on all available data for each site (2003-2013)
(Gaeckle *et al*. 2015, Executive Summary)

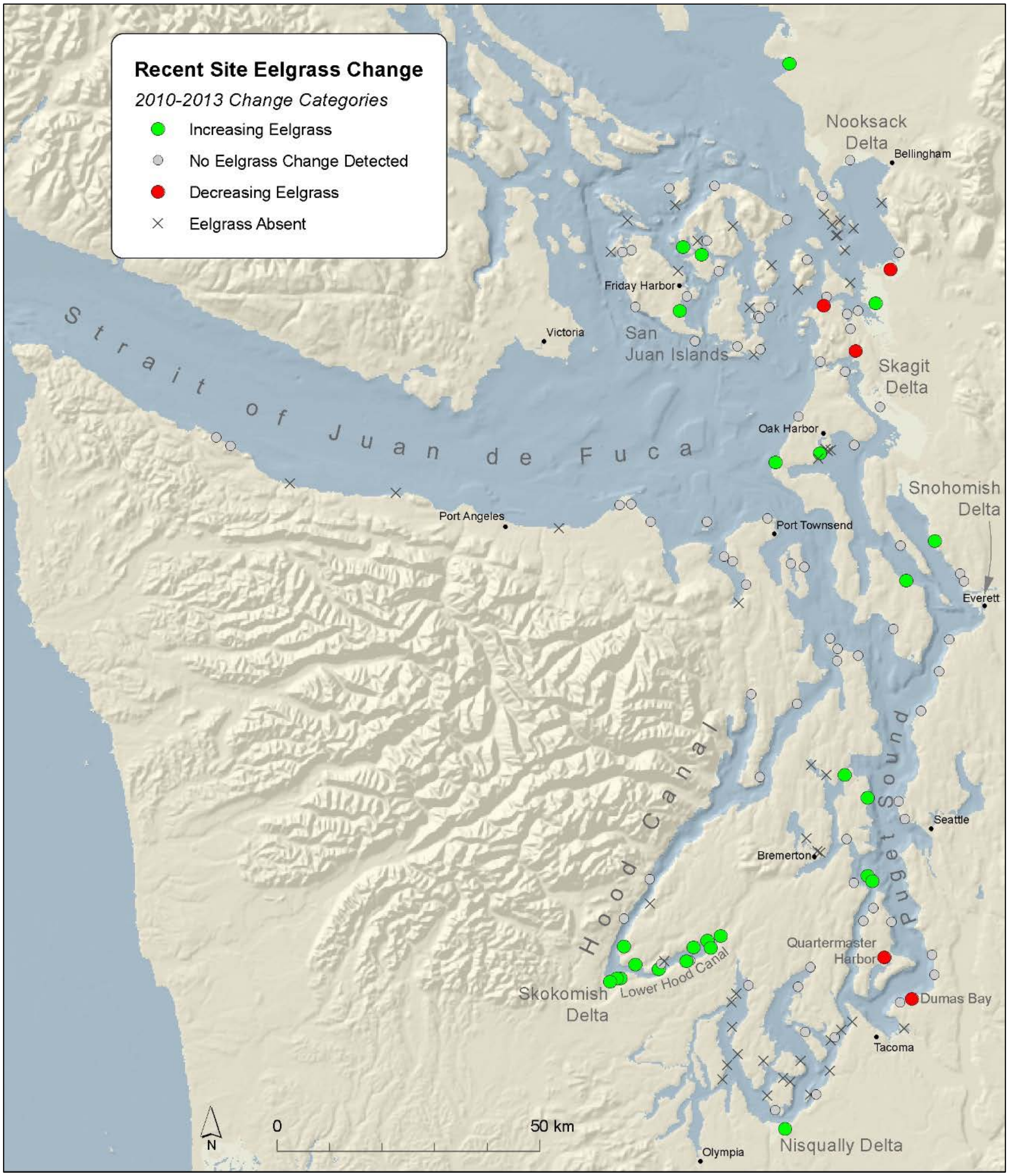

Figure 24. Increases and decreases in native seagrass area based on all available data for each site (2010-2013)
(Gaeckle *et al*. 2015, Executive Summary)

Existing Conditions for Marine Forage Fish

"Forage fishes in general, and [Pacific] herring specifically, are vital components of the marine ecosystem and are a valuable indicator of the overall health of the marine environment. Many species of sea birds, marine mammals, and finfish … depend on herring as an important prey item (DFO 2001, Fresh et al. 1981). Significant predation occurs at each stage of the herring life cycle, starting with predation on deposited spawn by invertebrates, gulls, and diving ducks. Reflecting the importance of herring in the Puget Sound ecosystem, the spawning biomass of Puget Sound herring was selected as a vital sign indicator of the health of Puget Sound by the Puget Sound Partnership" (Stick, Lindquist, and Lowry 2014, p.1).

Forage fish are loosely defined as small, schooling fishes that form critical links between the marine zooplankton community and larger predatory fish, seabirds, and marine mammals in the marine food web (Penttila 2007, Executive Summary; PSAT 2007). The three most common marine forage fish species in Puget Sound are Pacific herring, surf smelt, and Pacific sand lance. These species and their spawning habitats all commonly occur on Puget Sound beaches and in the intertidal zone, and all three use adjacent nearshore habitats as nursery grounds. "Within the Puget Sound Basin, where their spawning areas have been most completely mapped, each species appears to use approximately 10 percent of the shoreline spawning habitat during the year" (Penttila 2007, Executive Summary). Other marine forage fish species include northern anchovy, eulachon or Columbia River smelt, and longfin smelt. These species do not spawn in Puget Sound but do contribute to the total biomass of marine forage fish in Puget Sound (Penttila 2007, Executive Summary).

Some months before the onset of spawning activity, ripening Pacific herring begin to assemble adjacent to spawning sites in pre-spawning holding areas (Penttila 2007, pp. 6-8). They spawn by depositing their eggs on eelgrass, algae, hard substrates, man-made structures (such as pilings), and occasionally polychaete tubes. Figure 25 identifies most of the documented spawning areas in Puget Sound; two spawning locations only recently documented, Elliot Bay and Purdy (Stick, Lindquist, and Lowry 2014, p. 5), are not depicted. Most egg deposition occurs from 0 to -10 ft MLLW (Bargmann 1998), but in some areas spawning can occur as deep as - 32 ft (-10 m)(Penttila 2007, pp. 6-8). The eggs incubate for 10 to 14 days prior to hatching. Following hatching, the larvae drift in the currents. Following metamorphosis, young herring spend their first year in Puget Sound; some then spend their entire lives within Puget Sound, while others migrate to the open ocean to mature. After reaching sexual maturity (2 to 4 years), Pacific herring migrate back to spawning grounds. Most spawning occurs between mid-January and March.

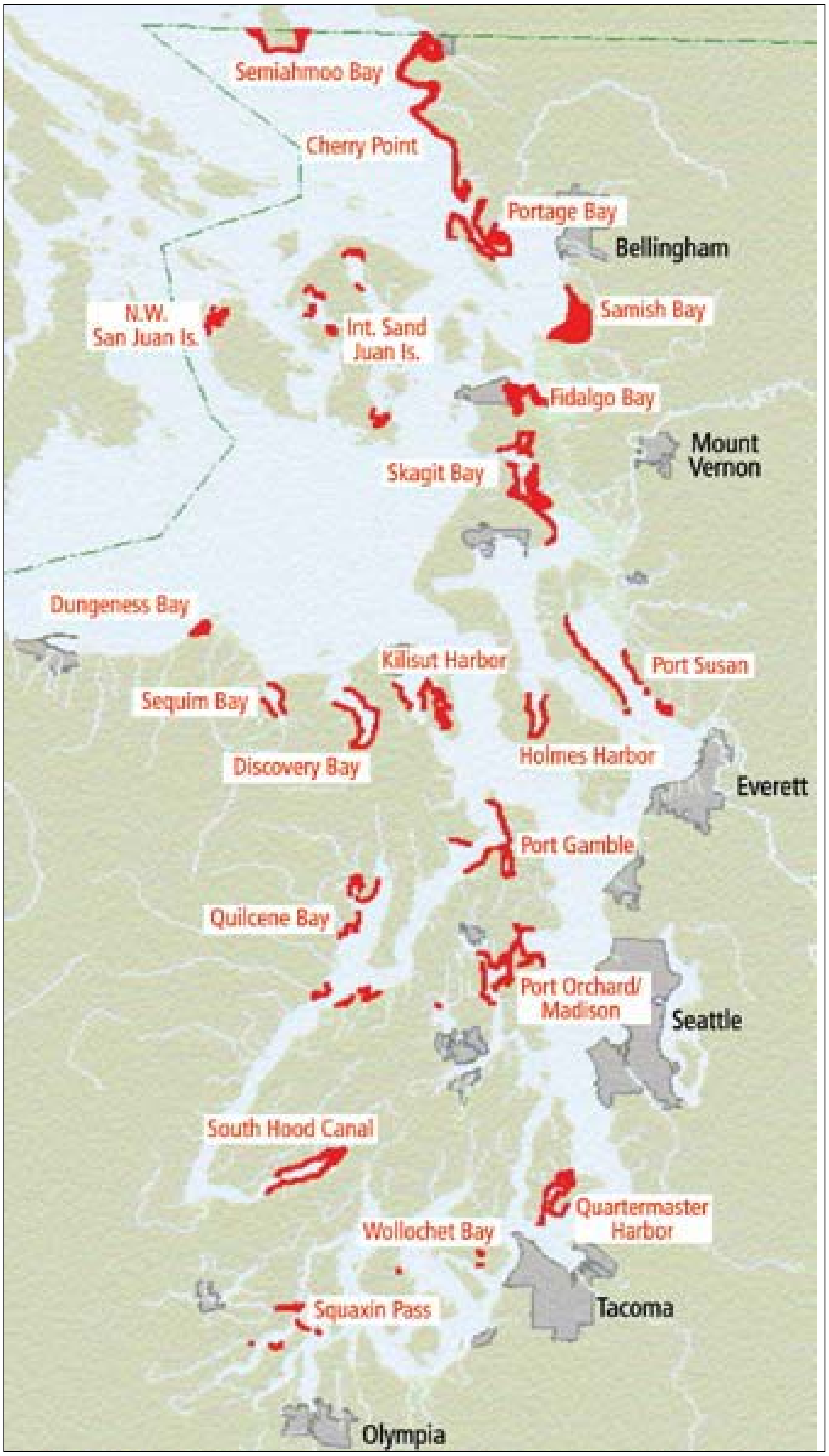

Figure 25. Documented Pacific herring spawning areas in Puget Sound
(Penttila 2007, p. 3)

Pacific herring are visual feeders. They forage on planktonic macro-zooplankton that may be found anywhere across the width of Puget Sound. They undergo diurnal depth migrations, i.e., deep during the day and shallow at night, often concentrating at depths of 180 to 240 ft where prey are abundant. During the daytime, some (commonly juveniles) may reside at midwater or surface water depths. Juvenile Pacific herring commonly rear at shallow depths (a few ft), even in the daytime.

Surf smelt are common, year-round residents in the nearshore areas of Puget Sound. They are a short-lived fish with most spawning populations comprised of 1- and 2-year old fish. Spawning occurs on mixed-sand and gravel substrates in the upper intertidal zone, generally higher than +7 ft MLLW (Penttila 2007, pp. 3, 8-10). Eggs incubate for two to six weeks. It appears that surf smelt spawn year-round in portions of Puget Sound.

Surf smelt feed on macrozooplankton and are closely associated with the shoreline, spending their entire lives shoreward of the 10-fathom contour (-60 ft). There is no information on movement patterns and no evidence of seasonal migration out the Strait of Juan de Fuca. Their home ranges are unknown and there has been no region wide assessment of stock status (Penttila 2007, pp. 3, 8-10). The WDFW has documented spawning habitat on approximately 200 lineal miles of Puget Sound shoreline. However, the surveys are incomplete (Bargmann 1998).

Pacific sand lance (or candlefish) are common, year-round residents in the nearshore areas of Puget Sound. They feed on macrozooplankton. During spring and summer months, Pacific sand lance are considered epibenthic, schooling pelagically during the day to forage, and burrowing in the benthic substrate at night (Penttila 2007, pp. 3, 4, 10, 11). Their home ranges are unknown and there has been no region-wide assessment of stock status. Juveniles may be more closely associated with shorelines and protected bays, often found in mixed schools with Pacific herring and surf smelt of similar age and size. There is no information on movement patterns and no evidence of seasonal migration out the Strait of Juan de Fuca.

The WDFW has documented Pacific sand lance spawning habitat on approximately 130 lineal miles of shoreline; however, the surveys are incomplete (Bargmann 1998). Several spawnings may occur at any given site during the November to February spawning season. Pacific sand lance frequently use the same stretches of beach used by surf smelt, and sometimes at the same time of year (Bargmann 1998). Spawning is confined to the upper intertidal zone, generally higher than + 5 ft MLLW. Eggs incubate for approximately 30 days (Penttila 2007, pp. 3, 4, 10, 11).

In 2009, the Service reported the following regarding the status of marine forage fish in Puget Sound (USFWS 2009a, pp. 62, 63, 98, 99):

- "Many fish populations have been depleted due to overfishing, reduction in the amount or quality of spawning habitat, and pollution. As of 2004, only 50 percent of the Puget Sound herring stocks were classified as healthy or moderately healthy, with north Puget Sound's stock being considered depressed and the Strait of Juan de Fuca's stocks being classified as critical (McShane *et al*. 2004a)."

- “Natural mortality in some of these stocks has increased; e.g., the mean estimated annual natural mortality rate for sampled stocks from 1987 through 2003 averaged 71 percent, up from 20 to 40 percent in the late 1970s (WDFW 2005a).”

- “There is currently only one commercial herring fishery which operates primarily in south and central Puget Sound (WDFW 2005c) where herring stocks are healthier.”

- “While there are commercial and recreational fisheries for surf smelt, the amount of harvest does not appear to be impacting the surf smelt stocks. There are no directed commercial fisheries for sand lance (Bargmann 1998). Anchovies are taken commercially within coastal and estuarine waters of Washington. While the current harvest level doesn’t appear to be impacting anchovy stocks, there is no current abundance information (Bargmann 1998).”

- “WDFW recognizes 19 stocks of herring in Puget Sound, based on the timing and location of spawning activity (Stick 2005; PSAT 2007). The grounds are well defined and the timing of spawning is very specific, seldom varying more than seven days from year to year (Bargmann 1998). Puget Sound herring are thought to be a mix of ‘resident’ and ‘migratory’ stocks, with the migratory populations cycling between winter spawning grounds in the inside waters and summer on the continental shelf off the mouth of the Strait of Juan de Fuca (Penttila 2007). However, which fish or stocks are migratory and which are resident is unknown. It appears as though neither post-spawning adult herring nor pre-recruit herring persist in numbers in the immediate vicinity of any spawning ground during non-spawning times of year (Penttila 2007).”

- “For the period of 2003 to 2004 only 50 percent of all Puget Sound herring stocks were classified as ‘healthy’ or ‘moderately healthy,’ whereas 71 percent and 83 percent of stocks were considered healthy or moderately healthy in 2000 and 2002, respectively. One stock was added to the critical list in 2004. South and central Puget Sound stocks have maintained a healthy stock status since 1994, while north Puget Sound’s combined stocks have declined from a healthy status in 1994 to [a] depressed [status] since 1998. The Strait of Juan de Fuca’s status has been consistently classified as ‘critical’ since 1994” (USFWS 2009a, pp. 62, 63, 98, 99).

In 2009, the Service reported that surveys are incomplete and there appear to be few or no data to describe the status of Puget Sound surf smelt and Pacific sand lance stocks (USFWS 2009a, pp. 99, 100). It appears that is still the case in 2015.

Stick, Lindquist, and Lowry (2014) have reported findings from the 2012 Washington State Herring Stock Status Report. Important trends and conclusions include the following:

- Fewer stocks may be classified as ‘healthy’ or ‘moderately healthy’.

- The Cherry Point stock shows no signs of recovery from its critically low level of abundance, and the Strait of Juan de Fuca regional spawning biomass continues to be at a low level of abundance.

- Estimated spawning biomass for the Skagit Bay stock has dropped by over 50 percent since 2009.

- The Fidalgo Bay stock has decreased substantially in recent years. Compared to the previous 25 year mean spawning biomass, the 2012 status is very depressed.

- Two stocks, N.W. San Juan Island and Kilisut Harbor, have not had detectable spawning activity since 2008 and have a 'disappearance' classification.

- If Puget Sound herring stocks interact as a metapopulation, observed 'disappearance' and/or dramatic decreases in abundance of individual stocks may not be cause for major concern.

Appendix D includes excerpts from Stick, Lindquist, and Lowry (2014); those fuller excerpts are incorporated here by reference.

Selleck *et al*. (2015) recently published the first synthesis of historical sand lance capture records for the inland waters of Washington State. They report the following:

- "Despite a number of studies characterizing their distribution and habitat use in Alaska and British Columbia, surprisingly little is known about population attributes in the Salish Sea [which includes Puget Sound]. We compiled and analyzed 15,192 records collected from 1,630 sites, primarily by beach seine or tow net in nearshore shallow areas between 1970 and 2009, to determine sand lance spatial and seasonal distribution in the inland waters of Washington State" (p. 185).

- "Studies have shown that at nearshore sites in the region, juvenile Chinook salmon … feed largely on larval and juvenile sand lance (Duffy and others 2010). Sand Lance also are the most numerically abundant prey in the diet of lingcod (*Ophiodon elongates*), a recreationally important species (Beaudreau and Essington 2007) … Additionally, they are one of the two most important prey for common murres (*Uria aalge*) and rhinoceros auklets (*Cerorhinca monocerata*; Lance and Thompson 2005), and can comprise up to 67 percent of the diet of marbled murrelets … in regional populations (Norris and others 2007)" (p. 185).

- "Commercial exploitation of this species is prohibited by the Washington Department of Fish and Wildlife (Bargmann 1998). Consequently, unlike other forage fishes such as Pacific herring … and surf smelt … stock structure and population assessments have not been conducted (Mitchell 2006; Stick and Lindquist 2009)" (p. 186).

- "Sampling effort was not uniform spatially or temporally … No data were available from Hood Canal. [The] Whidbey basin had the highest sampling effort … [and] the Strait of Juan de Fuca basin had the lowest sampling effort … Of Puget Sound's estimated 3,970 km of shoreline, approximately 13 percent was sampled for sand lance … which were present along 78 percent of the shoreline sampled" (p. 187).

- “The largest catches … occurred between May and August, with peak catches estimated at 16,000 and 50,000 fish recorded in the San Juan Archipelago in June 1976 and 2005, respectively. Work conducted in Alaska also showed increased total beach seine catch … in summer (Johnson and others 2008). Seasonal abundance has important biological implications … Abundance of sand lance in marbled murrelet diet varies seasonally, with fewer sand lance in the winter diet (Burkett 1995). Reduced occurrence in winter could reflect an absolute reduction in … availability in winter, fewer large schools of fish, or an increase in the relative abundance or distribution of another more preferred prey fish” (pp. 192, 193).

- “Lacking a better understanding of the basic biology of this species, it is impossible to gauge the potential anthropogenic or natural impacts on regional food webs. This study demonstrates that sand lance are present throughout the inland waters of Washington, which is consistent with the hypothesis that they are important drivers of local marine food webs … [However,] numerous knowledge gaps exist about this ecologically important fish in the inland waters of Washington, including basic knowledge about the status of populations and subpopulations” (Selleck *et al*. 2015, p. 193).

Figures 26 through 33 identify shellfish activities located in the north Puget Sound, south Puget Sound, and Hood Canal sub-areas, and their proximity to documented eelgrass beds and marine forage fish spawning habitats.

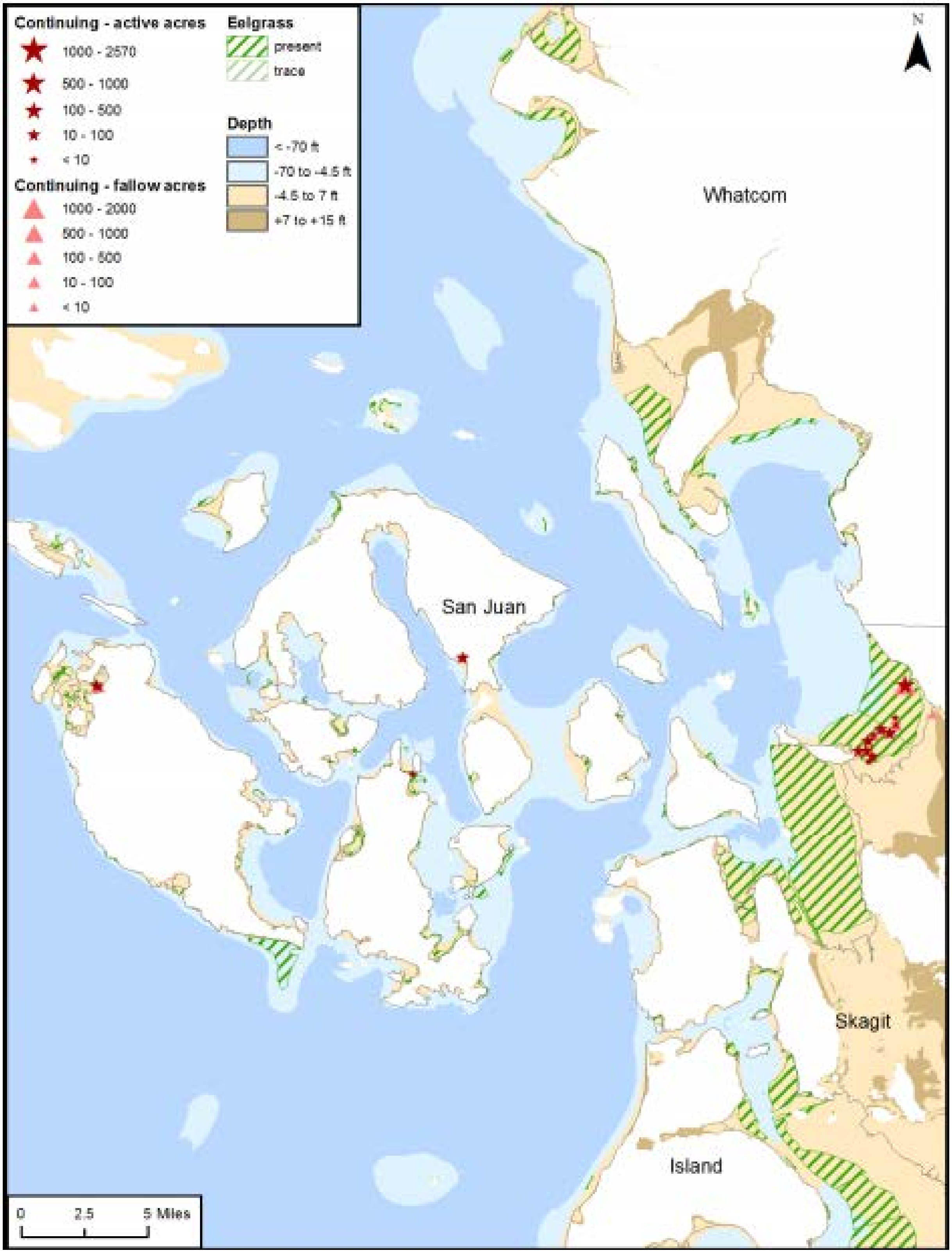

Figure 26. Shellfish operations and eelgrass in north Puget Sound
(Corps 2015, Appendix D)

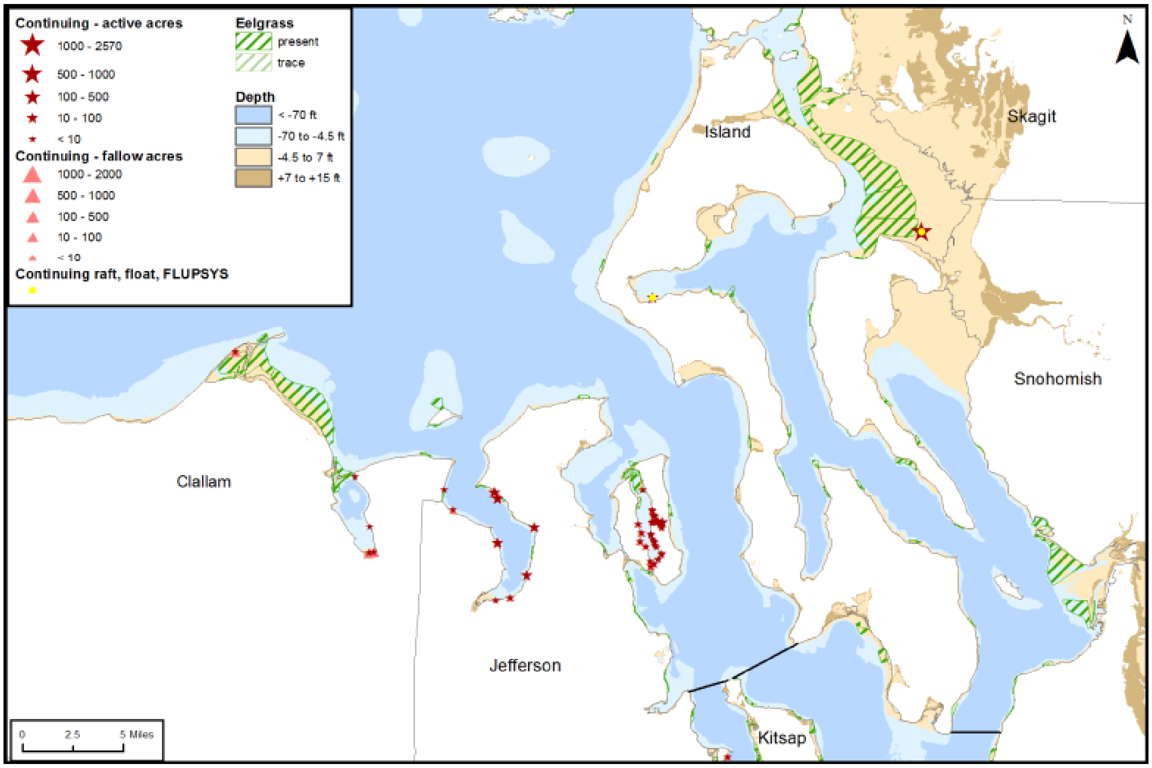

Figure 27. Shellfish operations and eelgrass in north Puget Sound
(Corps 2015, Appendix D)

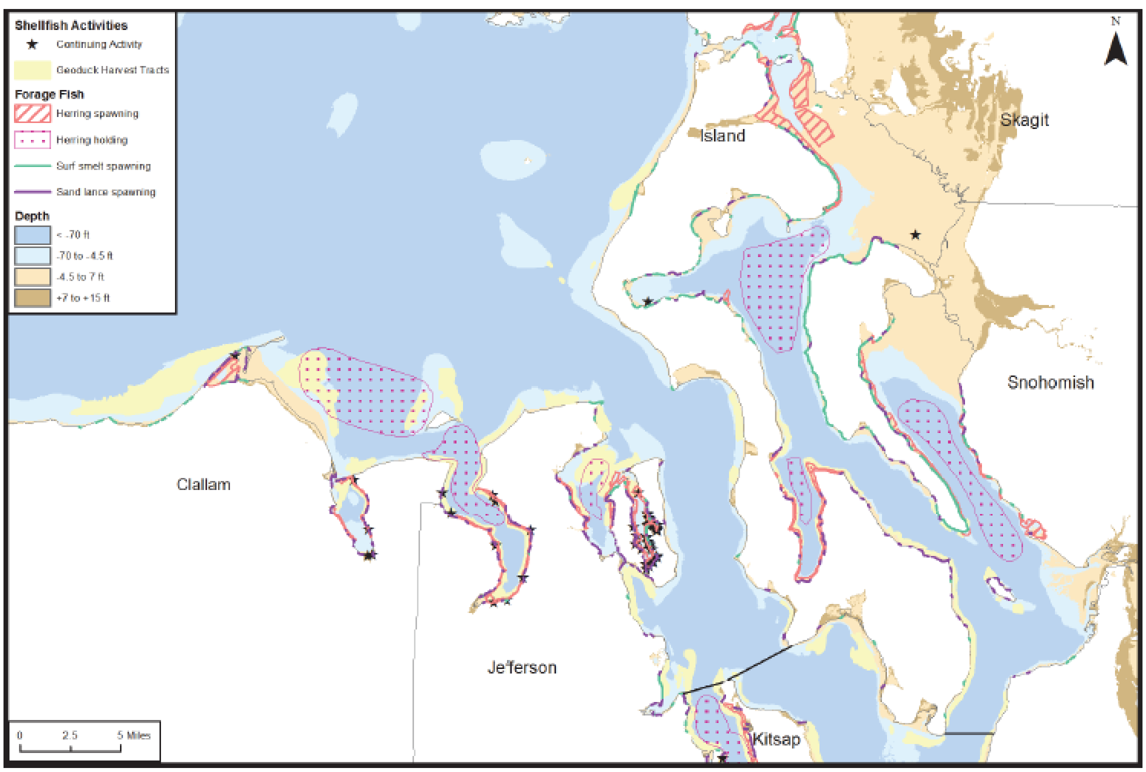

Figure 28. Shellfish operations and forage fish in north Puget Sound
(Corps 2015, Appendix E)

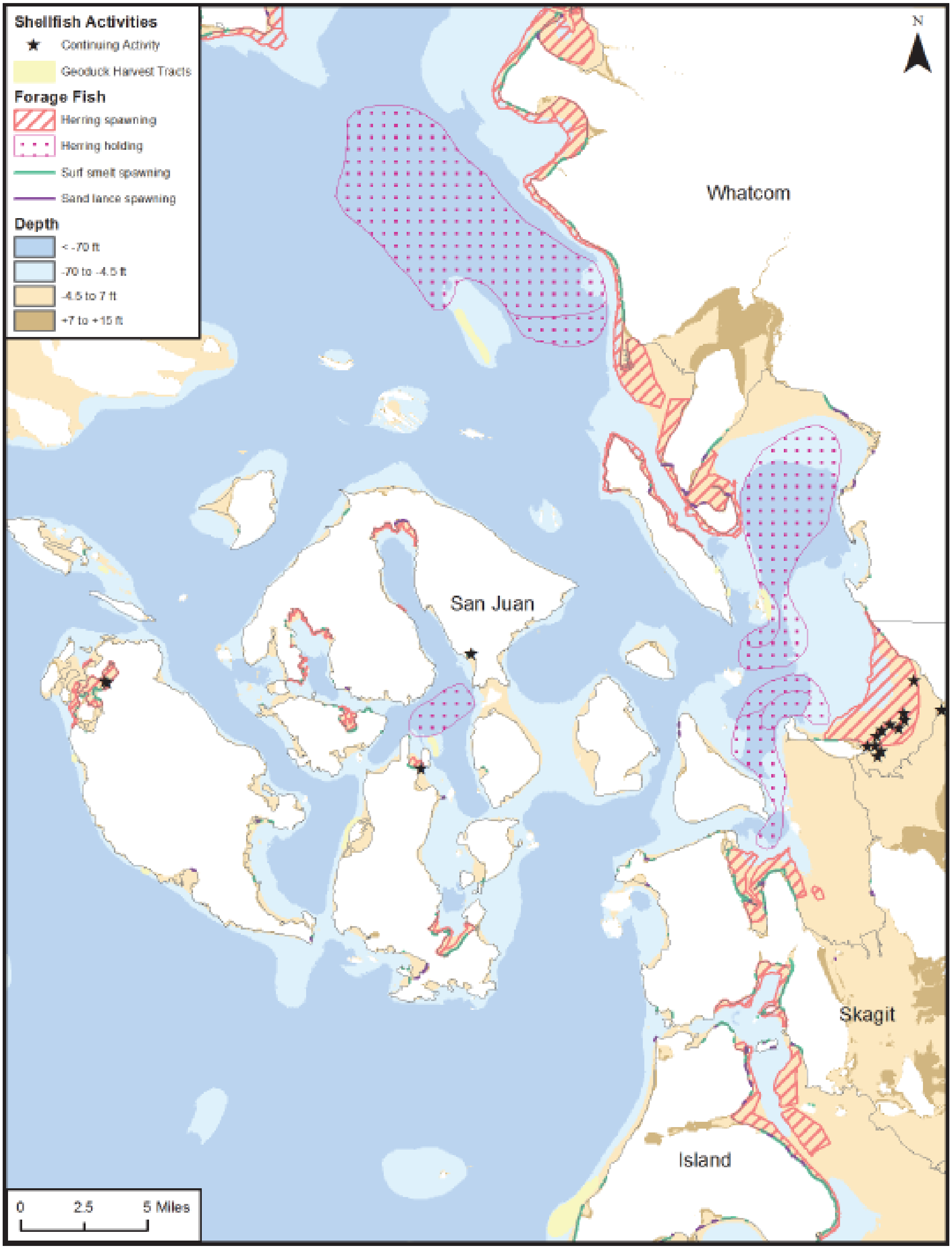

Figure 29. Shellfish operations and forage fish in north Puget Sound (Corps 2015, Appendix E).

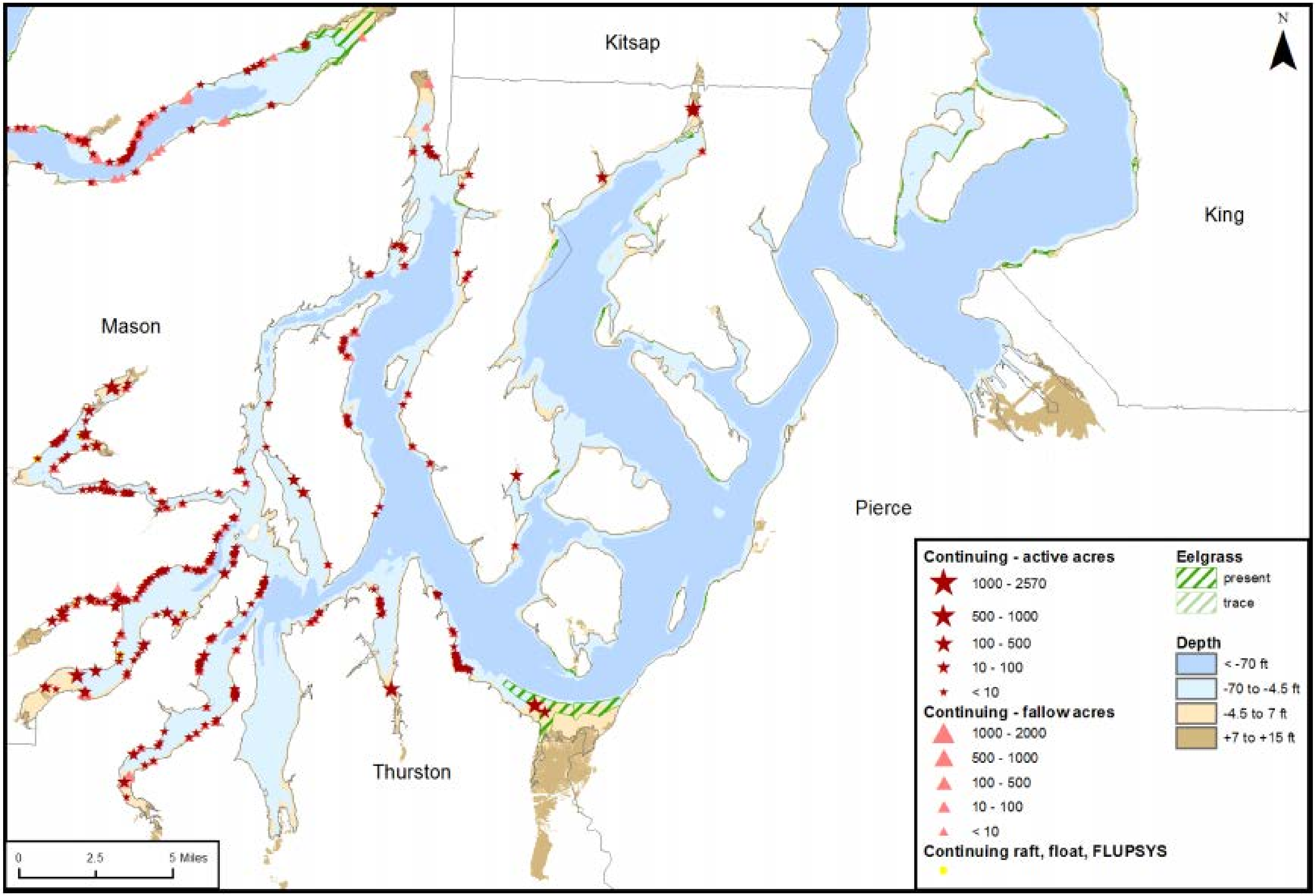

Figure 30. Shellfish operations and eelgrass in south Puget Sound
(Corps 2015, Appendix D)

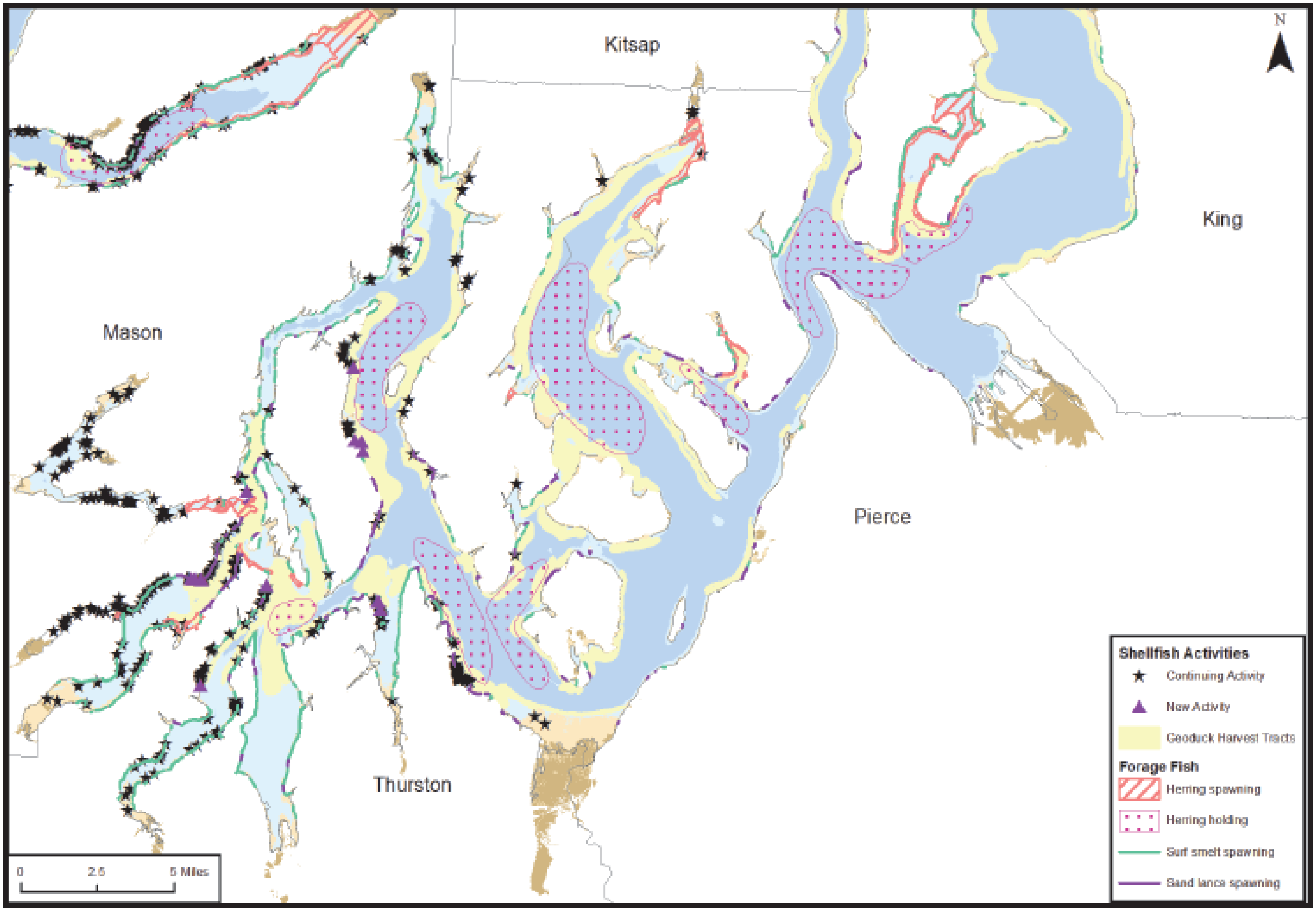

Figure 31. Shellfish operations and forage fish in south Puget Sound
(Corps 2015, Appendix E)

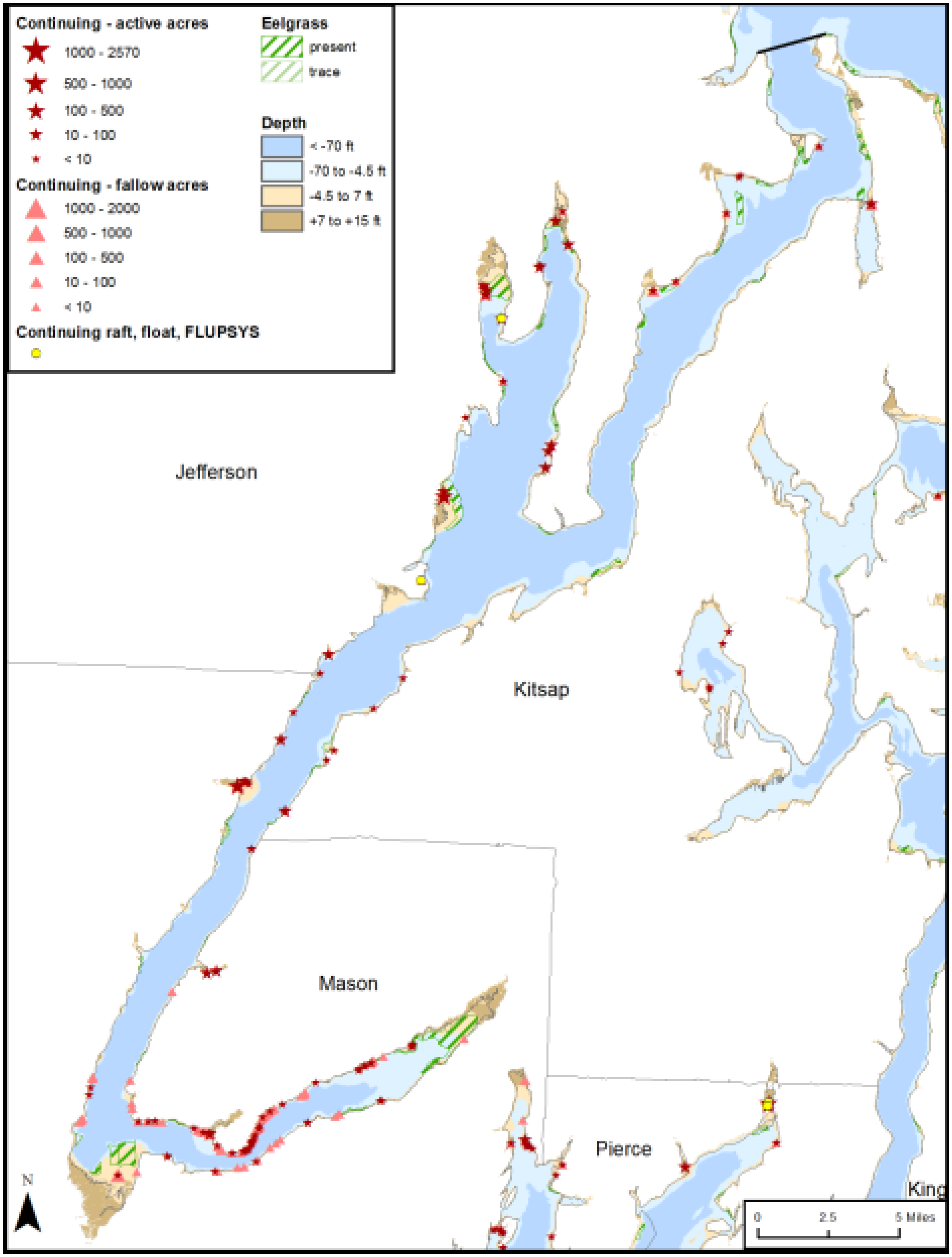

Figure 32. Shellfish operations and eelgrass in Hood Canal
(Corps 2015, Appendix D)

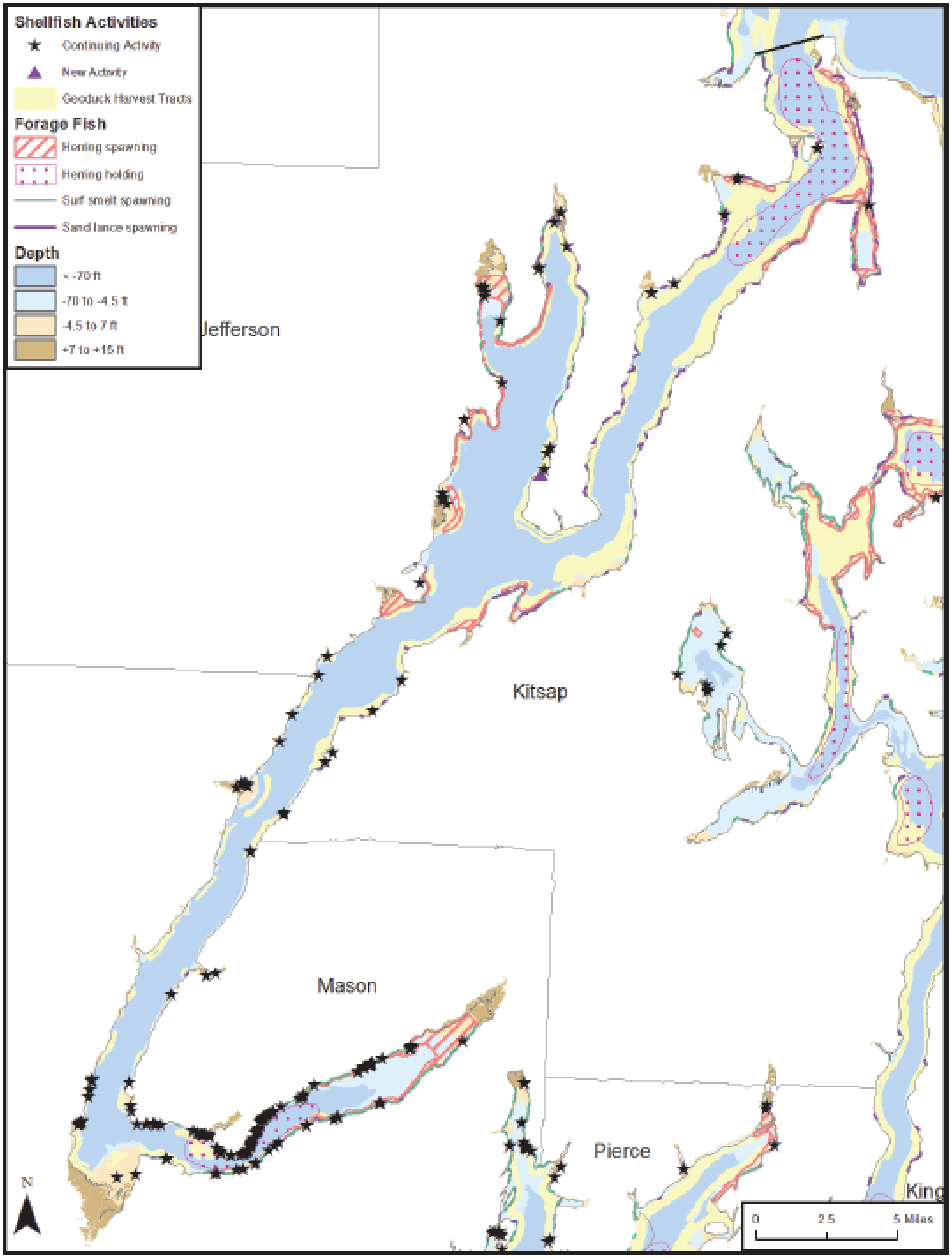

Figure 33. Shellfish operations and forage fish in Hood Canal
(Corps 2015, Appendix E)

Current Condition in the Action Area (Bull Trout and Critical Habitat)

The action area includes all of the tidelands and nearshore marine waters associated with continuing and new (projected future) shellfish activities, encompassing an area of approximately 38,716 acres (Corps 2015, pp. 40-49, 77-82). Where cultured tidelands extend with only occasional interruption, interspersed uncultured areas may experience direct or indirect effects, and are therefore considered part of the action area. At all locations, the action area extends a minimum of 2,000 ft from the farm footprint (active and fallow). Factoring and incorporating these other considerations, we estimate conservatively that regulated shellfish activities in Washington State, specifically those for which this Opinion provides programmatic coverage, are likely to directly or indirectly affect more than 45,000 acres of nearshore marine habitat (45,000 to 50,000 acres in total; Willapa Bay: approx. 30,000 acres; Grays Harbor: approx. 4,000 acres; north Puget Sound: approx. 5,000 acres; south Puget Sound: approx. 5,000 acres; and, Hood Canal: approx. 3,000 acres).

Anadromous bull trout forage and migrate along the nearshore (generally in water less than 10 meters deep) and are opportunistic foragers, often traveling to access and take advantage of seasonally abundant food resources. Anadromous bull trout feed primarily on marine forage fish and juvenile salmonids when in the marine environment. Eelgrass meadows and other complex nearshore marine and estuarine habitats are a focal point for their foraging activities and provide essential prey resources.

Hayes *et al*. (2011) used acoustic transmitter tags, habitat class preferences, and compositional analysis of selection to describe bull trout movements, position, and marine habitat use in and around the Skagit River delta:

- “Summaries of fish positions and habitat descriptions were based on our best estimate of a fish’s position during each ‘event’ … Detections separated by at least 2 hours were considered separate ‘events’.” (pp. 398, 399)

- “Habitat descriptions included shoreline, substrate, and vegetation classes (McBride *et al*. 2006) … These data were available for the majority of bay perimeter and shallow water habitat, but not for the Swinomish Channel … Substrate and vegetation data were available only within the intertidal zone.” (p. 399)

- “We ranked habitat class preferences (Aebischer *et al*. 1993) by using a compositional analysis of selection (Leban 1999) to compare habitat use with habitat availability.” (p. 399)

- "Habitat class data and compositional analysis … suggested that bull trout use of habitats was not random … Coastal deposits, low bank, and sediment bluff accounted for nearly 76 percent (by length) of natural shoreline classes … Modified and unmodified shoreline classes were used in proportion to their availability … common modifications included concrete bulkhead and riprap … Green algae, eelgrass (*Zostera* sp.), and unvegetated were frequent vegetation classes; combined, they made up more than 70 percent of the area used by bull trout … Use of spit-berm, salt marsh habitats, and green algae vegetation classes was greater than expected, based on availability, while the unvegetated class ranked low." (p. 400)

- "One behavior that was common among bull trout in marine waters was the use of shallow, nearshore habitats … In general, fish positions were within 400 m of the shoreline and shallower than 4 m … Although some bull trout probably crossed sections of Skagit Bay with water depths greater than 10 m to reach the east shore of Whidbey Island, our detections never indicated that fish maintained positions in these deeper areas … The general pattern suggested that individual bull trout moved from the river to a discrete section of bay shoreline or the Swinomish Channel, stayed there for much of their marine residency, and then returned to the river … We found no evidence of consistently nomadic behavior for any fish." (pp. 403, 404)

- "Our descriptions of substrate, vegetation, and shoreline classes in bull trout habitats are the first of this type and thus are valuable despite incomplete mapping … However, habitat preference data should be considered preliminary because the number of detections of some fish was small, our fish location data were imprecise, and preference may be related to other factors … More detailed data are required to determine bull trout selection and intensity of use for specific habitats." (Hayes *et al*. 2011, p. 404)

Appendix D includes excerpts from Hayes *et al*. (2011); those fuller excerpts are incorporated here by reference.

Willapa Bay and Grays Harbor: Several coastal drainages to the north, including the Quinault, Queets, and Hoh Rivers, support local populations and spawning of anadromous bull trout. Bull trout occur regularly in Grays Harbor and its lower tributaries. They have been documented in Willapa Bay and its tributaries, though infrequently and in low numbers. These represent the southernmost populations of anadromous bull trout found anywhere in North America.

The action area provides nearshore marine, foraging, migrating, and overwintering (FMO) habitat for adult and subadult bull trout originating from coastal Washington core areas and local populations to the north (the Quinault, Queets, and Hoh River bull trout core areas). The best available, current information indicates that the major tributaries to Grays Harbor and Willapa Bay do not support bull trout spawning and rearing, or local populations.

The Quinault, Queets, and Hoh River bull trout core areas support small and moderately sized local bull trout populations. These local populations appear to be relatively stable, with some year-to-year variation in the measured indices for abundance and reproduction.

North Puget Sound: All of the north Puget Sound's larger drainages support local populations and spawning of anadromous bull trout. The Elwha and Dungeness Rivers, which both drain to the Strait of Juan de Fuca, also support local populations. Bull trout occur regularly and in significant numbers throughout the nearshore marine areas of the north Puget Sound.

The action area provides nearshore marine FMO habitat for adult and subadult bull trout originating from several core areas (e.g., the Nooksack, Skagit, Stillaguamish, and Snohomish-Skykomish River bull trout core areas), and numerous local populations. These bull trout core areas support large and moderately sized local bull trout populations, including the largest anadromous bull trout populations found anywhere in Washington State (and the entire range of the species). Most of these local populations appear to be relatively stable, with some year-to-year variation in the measured indices for abundance and reproduction. The best available, current information indicates that the Dungeness River continues to support a small population of anadromous bull trout, but few (if any) anadromous bull trout remain in the Elwha River system (due to prolonged isolation above the dams, which have recently been removed).

South Puget Sound: The Puyallup River bull trout core area supports anadromous, fluvial, and resident life history forms. The core area is believed to support the Puget Sound's southernmost anadromous bull trout populations. Data available for the Puyallup River core area are incomplete and do not allow for an accurate estimation of adult abundance or reproduction. However, trap counts at the Buckley Diversion Dam, and other available sources, suggest that the Puyallup River core area supports only low to very low numbers of anadromous bull trout.

The action area provides nearshore marine FMO habitat for adult and subadult bull trout originating from the Puyallup River core area. However, the best available, current information indicates that tributaries to the Puget Sound located south of Tacoma (including the Nisqually River) do not support bull trout spawning and rearing, or local populations.

The Puyallup River bull trout core area supports moderately sized local bull trout populations, including a small population of anadromous bull trout. Most of these local populations appear to be relatively stable or increasing, with some year-to-year variation in the measured indices for abundance and reproduction. Bull trout populations in the White River have been increasing since 2009, possibly due to a significant increase in the populations of pink and coho salmon.

Hood Canal: The nearshore marine waters of Hood Canal provide FMO habitat for anadromous bull trout. Bull trout originating from the Dungeness or other, north Puget Sound core areas may occasionally occur within northern portions of Hood Canal.

There are at least two local populations of bull trout in the Skokomish River. One is an adfluvial population that inhabits Lake Cushman and the North Fork Skokomish River above the lake. Another population, found in the South Fork Skokomish River, is a depressed but stable fluvial population. Anadromy has not been documented in the Skokomish River populations and no bull trout have been captured in the nearshore marine areas of the estuary. However, historic reports of bull trout in rivers such as the Duckabush, Dosewallips, Hamma Hamma, and

Quilcene Rivers suggest that a few individuals may be present in the nearshore marine waters of Hood Canal. The local populations of the Skokomish River are depressed but relatively stable, with some year-to-year variation in the measured indices for abundance and reproduction.

Factors Responsible for the Condition of the Species

The factors responsible for the condition of the species (bull trout) in the action area are described elsewhere (see *Status of the Species*, *Status of Critical Habitat*, and *Environmental Baseline*).

Factors Responsible for the Condition of Critical Habitat

In nearshore marine areas, the inshore extent of critical habitat is the MHHW line, including the uppermost reach of the saltwater wedge within tidally influenced, freshwater heads of estuaries. Critical habitat extends offshore to a depth of 10 meters (33 ft) relative to the MLLW line (75 FR 63935; October 18, 2010).

The action area includes approximately 12,000 acres of designated bull trout critical habitat, mostly located in Grays Harbor (approximately 4,000 acres), the north Puget Sound (approximately 5,000 acres), and Hood Canal (approximately 3,000 acres)(Corps 2015 Appendix H, Figures H-1 through H-8)(Table 4). South of Tacoma, designated bull trout critical habitat only extends as far as the Nisqually River delta. No portion of Willapa Bay has been designated as critical habitat for the bull trout.

Within the action area, the current condition of designated bull trout critical habitat varies considerably. Current conditions reflect natural variability, patterns of disturbance and recovery from both natural and man-made events, and the effects of earlier and concurrent, unrelated activities occurring in the same nearshore environments and watersheds.

As working tidelands, where shellfish activities have for many years and will continue to affect habitat conditions (i.e., water quality, substrate conditions, physical habitat structure and function, benthic/epibenthic community structure and composition, and predator-prey dynamics), most of the action area cannot be regarded as pristine in its current state. Also, at many locations this habitat exhibits the pervasive effects of shoreline development and alteration. Armored and hardened shorelines, diking and filling of marine and estuarine areas, and overwater structures are all characteristic of the action area. At many locations these features impair important natural processes that create and maintain functional nearshore marine habitat.

Water and sediment quality conditions are generally suitable and adequately functioning, though some sub-basins and embayments fail to consistently maintain the State's surface water quality criteria (Ecology 2016). Portions of Sequim Bay, Discovery Bay, and lower Hood Canal are listed on the State's 303(d) list of impaired water bodies for failing to meet criteria for dissolved oxygen. However, most shellfish activities are conducted on intertidal sites, which "…are substantially or completely flushed on every tidal cycle" (Forrest *et al*. 2009, p. 5). Water temperatures are generally suitable and adequately functioning throughout the action area.

Natural nearshore habitat complexity is either mildly or moderately impaired throughout much of the action area. The same can be said for the condition of the bull trout prey base. At some locations either or both of these functions may be severely impaired.

Table 4. Designated bull trout critical habitat within the action area; co-location with mapped eelgrass and marine forage fish habitat.

GEOGRAPHY	Affected Nearshore Acres in Designated Critical Habitat (Action Area)	Continuing Shellfish Activities (Acres)		
		Total	Co-Located with Mapped Eelgrass	Co-Located with Mapped Forage Fish
Grays Harbor	4,000	2,965	1,918 (65%)	73 (2%)
Hood Canal	3,000	1,356	685 (51%)	663 (49%)
North Puget Sound	5,000	3,687	3,370 (91%)	2,865 (78%)
Total	Approx. 12,000	Approx. 8,000	Approx. 6,000	Approx. 3,600

The action area includes nearshore marine environments providing five of the nine PCEs of designated bull trout critical habitat (50 FR 63898; October 18, 2010):

(2) *Migration habitats with minimal physical, biological, or water quality impediments between spawning, rearing, overwintering, and freshwater and marine foraging habitats, including but not limited to permanent, partial, intermittent, or seasonal barriers*.

Within the action area this PCE is impaired but still functions. At some locations, where armored and hardened shorelines, marine and estuarine fill, and overwater structures are more pervasive, this PCE is moderately or severely impaired. There are currently no barriers to migration along the marine shorelines in the action area.

(3) *An abundant food base, including terrestrial organisms of riparian origin, aquatic macroinvertebrates, and forage fish.*

Within the action area this PCE is either mildly or moderately impaired. Most of the nearshore marine areas in the action area provide important spawning habitat for forage fish species such as Pacific herring, Pacific sand lance, and surf smelt. Across most portions of the action area, both salmonid and marine forage fish prey resources are well below historic, long-term peaks of production. However, year-to-year and geographic variability is significant and not easy to generalize with recognizable trends.

(4) *Complex river, stream, lake, reservoir, and marine shoreline aquatic environments, and processes that establish and maintain these aquatic environments, with features such as large wood, side channels, pools, undercut banks and unembedded substrates, to provide a variety of depths, gradients, velocities, and structure.*

Within the action area this PCE is moderately impaired, but still functions. At some locations, where armored and hardened shorelines, fill, and overwater structures are more pervasive, and where important natural processes that create and maintain functional nearshore marine habitat are impeded, this PCE is severely impaired.

(5) *Water temperatures ranging from 2 to 15 °C (36 to 59 °F), with adequate thermal refugia available for temperatures that exceed the upper end of this range. Specific temperatures within this range will depend on bull trout life-history stage and form; geography; elevation; diurnal and seasonal variation; shading, such as that provided by riparian habitat; stream flow; and local groundwater influence.*

Though some shallow embayments experience seasonally elevated temperatures (i.e., during summer months), those conditions are usually of limited duration. Water temperatures in the nearshore marine areas of Puget Sound and the coastal bays are generally not degraded. Within the action area this PCE is fully functioning, with little or no significant impairment.

(8) *Sufficient water quality and quantity such that normal reproduction, growth, and survival are not inhibited.*

Water and sediment quality conditions are generally suitable and adequately functioning, though some portions of the action area exhibit mild or moderate impairment.

Conservation Role of the Action Area (Bull Trout)

On September 28, 2015, the Service announced the availability of a Recovery Plan for the Coterminous U.S. Population of Bull Trout (USFWS 2015a). The bull trout is listed as threatened in the lower 48 states, where it occurs in Montana, Idaho, Washington, Oregon, and Nevada. The Recovery Plan updates the recovery criteria proposed in the 2002 and 2004 draft recovery plans, to focus on effective management of threats, and de-emphasize the achievement of targeted population numbers (i.e., numbers of adult bull trout in specific areas)(USFWS 2015b).

Between 2002 and 2004, three separate bull trout recovery plans were drafted, including a plan for the Coastal-Puget Sound in western Washington (2004). The previous 2002 and 2004 bull trout recovery plans required that all recovery criteria be achieved in each of 27 recovery units. Although these previous draft recovery plans have served to identify recovery actions and provide the framework for implementing numerous recovery actions, they were never finalized (USFWS 2015c).

The final Recovery Plan is based on new information regarding bull trout life history, ecology, distribution, and persistence, including the benefits of various conservation actions implemented on behalf of the bull trout, along with an improved understanding of the various threat factors. The Recovery Plan is intended to promote and support cooperative work with our partners, and serves to focus and implement effective conservation actions in those areas that offer the greatest long-term benefit and where recovery can be achieved (USFWS 2015c).

The previous 2002 and 2004 draft bull trout recovery plans proposed adult abundance levels (demographics) as recovery targets for each identified bull trout core area, considering theoretical estimates of effective population size, historic census information, and the professional judgment of recovery unit team members. In developing the final Recovery Plan, the Service recognizes that bull trout continue to be found in suitable habitats and generally remain geographically widespread across 110 core areas in five states. The Recovery Plan identifies conservation needs for bull trout in each of the 110 core areas. However, the Service acknowledges, that despite the best conservation efforts, it is likely that bull trout will become locally extirpated from some core areas within the foreseeable future. Factors responsible for declining populations and/or local extirpations include impacts of stochastic events on existing small populations, climate change, and isolation (35 of 110 extant core areas comprise a single local population). Moreover, the availability of survey data for accurate population estimates is problematic, and in certain core areas the geographic limitations on available habitat may inherently constrain the ability of bull trout populations to achieve the earlier demographic targets (USFWS 2015c).

The strategy set forth in the Recovery Plan has five key elements (USFWS 2015c):

- Conserve bull trout so that they are geographically widespread across representative habitats and demographically stable in six recovery units (Figure 34);
- Effectively manage and ameliorate the primary threats in each of six recovery units at the core area scale so that bull trout are not likely to become endangered in the foreseeable future;
- Build upon the numerous and ongoing conservation actions implemented on behalf of bull trout, and improve our understanding of how various threat factors potentially affect the species;
- Use that information to work with partners to design, fund, prioritize, and implement effective conservation actions in those areas that offer the greatest long-term benefit to sustain bull trout, and where recovery can be achieved; and

- Apply adaptive management principles to implementing the bull trout recovery program to account for new information.

The final Recovery Plan includes individual Recovery Unit Implementation Plans (RUIPs) for each recovery unit. The RUIPs were developed through collaboration with federal, Tribal, State, private, and other partners prior to completion of the plan (USFWS 2015b).

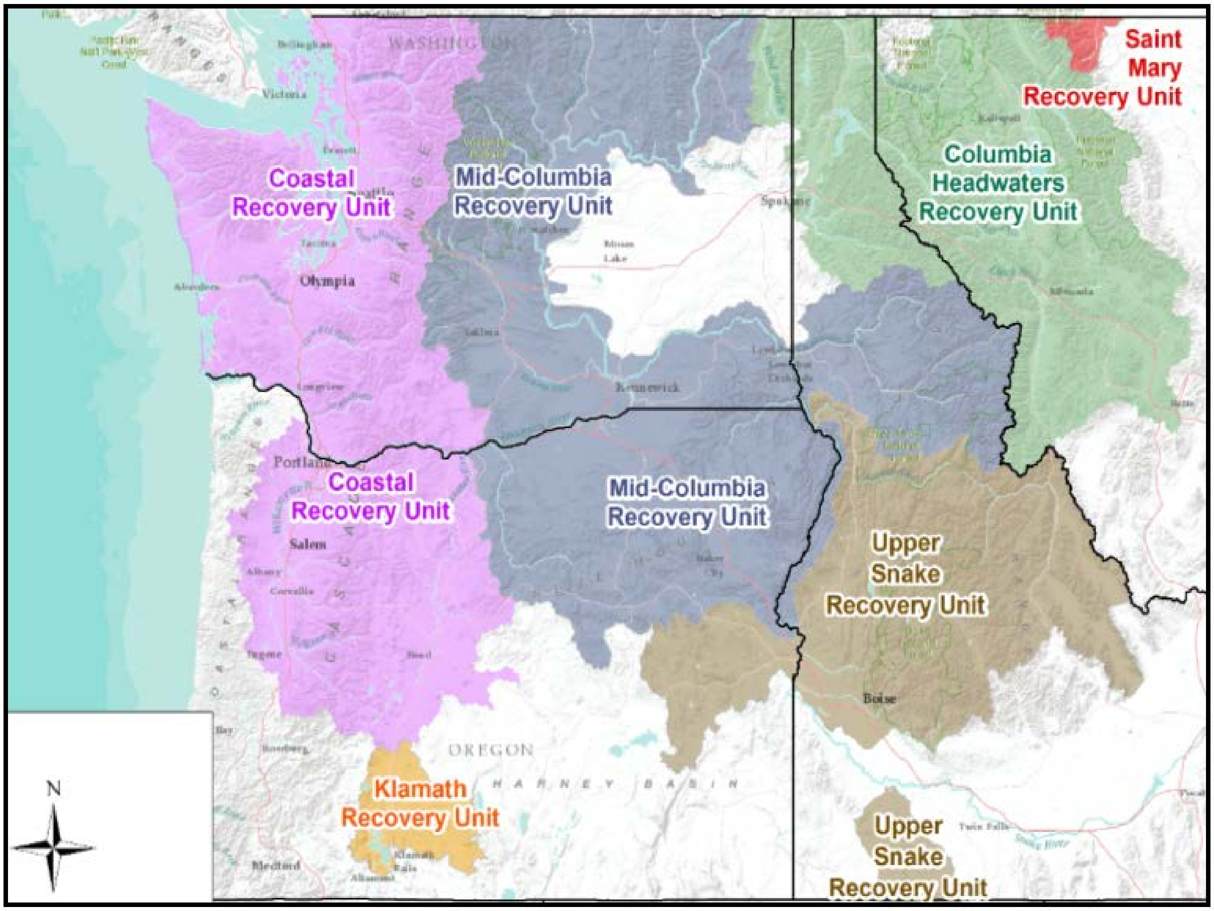

Figure 34. Bull trout recovery units
(USFWS 2015d)

The Service does not expect, plan, or intend to fully recover all bull trout populations in each of the currently occupied core areas identified by the final Recovery Plan. We recognize that accomplishing recovery at the scale of the recovery units will require that we improve the status of bull trout local populations, and their habitats, in some core areas relative to the time of listing. However, in other core areas it may only be necessary to maintain bull trout local populations and their habitats, more or less in their current condition, into the foreseeable future.

If the threats described in the final Recovery Plan are effectively managed, the Service expects that bull trout populations in each recovery unit will respond accordingly, reflecting the biodiversity principles of resiliency, redundancy, and representativeness. Specifically, achieving the proposed recovery criteria in each recovery unit would result in geographically widespread and demographically stable local bull trout populations, and would protect their essential cold water habitats to allow all diverse life history forms to persist into the foreseeable future (USFWS 2015a, p. viii).

Connectivity between spawning and rearing habitat and downstream FMO habitat sufficient for bull trout to move freely and with minimal risk is necessary for the expression of migratory life history patterns. In core areas where multiple local populations exist, interaction among local populations through movement of migratory individuals is critical to maintaining genetic diversity and recolonizing local populations that become extirpated. Thus, when connectivity with FMO habitat is impaired or blocked, bull trout populations tend to become restricted to isolated local populations, which may have low genetic diversity, are vulnerable to extirpation, and cannot be readily recolonized. Barriers to connectivity may consist of natural physical features such as waterfalls; river reaches that create mortality risks or prevent movement of adult fish because of entrainment, excessively warm water, or poor water quality; instream structures such as culverts or weirs; or dams (USFWS 2015a, p. 27).

Lack of suitable FMO habitat, including shared FMO habitats in mainstem, estuarine, and nearshore areas, can increase mortality of migratory individuals or discourage movement through these areas, resulting in reduced connectivity among local populations or core areas. Therefore, impaired FMO areas should be identified within core areas and in shared FMO habitats, and habitat improvement measures should be implemented where feasible. In estuarine and nearshore habitats, projects may include improving nearshore habitat conditions for forage fish; removing or modifying structures such as shoreline armoring, bulkheads, dikes, and tide gates; contaminant remediation; or, restoring eelgrass or kelp beds (USFWS 2015a, p. 28).

With our revised designation of bull trout critical habitat (75 FR 63935; October 18, 2010) the Service identified a number of marine or mainstem river habitats outside of bull trout core areas that provide primary constituent elements of critical habitat. These areas do not provide spawning and rearing habitat, but do provide FMO habitat that is typically shared by bull trout originating from multiple core areas. These shared FMO areas support the viability of bull trout populations by contributing to successful overwintering survival and dispersal among core areas (USFWS 2015a, p. 35).

Bull trout are opportunistic feeders, with food habits primarily a function of size and life history strategy (USFWS 2015a). Resident and juvenile migratory bull trout prey on terrestrial and aquatic insects, macro-zooplankton, and small fish. Adult migratory bull trout feed primarily on a wide variety of resident and anadromous fish species. In coastal areas of western Washington, bull trout feed on forage fish species such as Pacific herring, Pacific sand lance, and surf smelt, in nearshore marine areas and the Pacific Ocean (USFWS 2015a).

The Coastal Recovery Unit is located within western Oregon and Washington. Major drainages include the Olympic Peninsula, Puget Sound, and Lower Columbia River basins, Upper Willamette River, Hood River, Lower Deschutes River, Odell Lake, and the Lower Mainstem Columbia River. In the Coastal Recovery Unit, the Service identified 21 existing bull trout core areas, including the Clackamas River core area where bull trout had been extirpated and were recently reintroduced, and 4 historically occupied core areas that could be reestablished (Figure

35). Core areas within the recovery unit are distributed among three geographic regions: Puget Sound, Olympic Peninsula, and Lower Columbia River. Ten shared FMO habitats are also identified outside of core areas (Table 5). The only core areas in the coterminous states that currently support anadromous local populations of bull trout are located within the Puget Sound and Olympic Peninsula geographic regions (USFWS 2015a, pp. 38, 79).

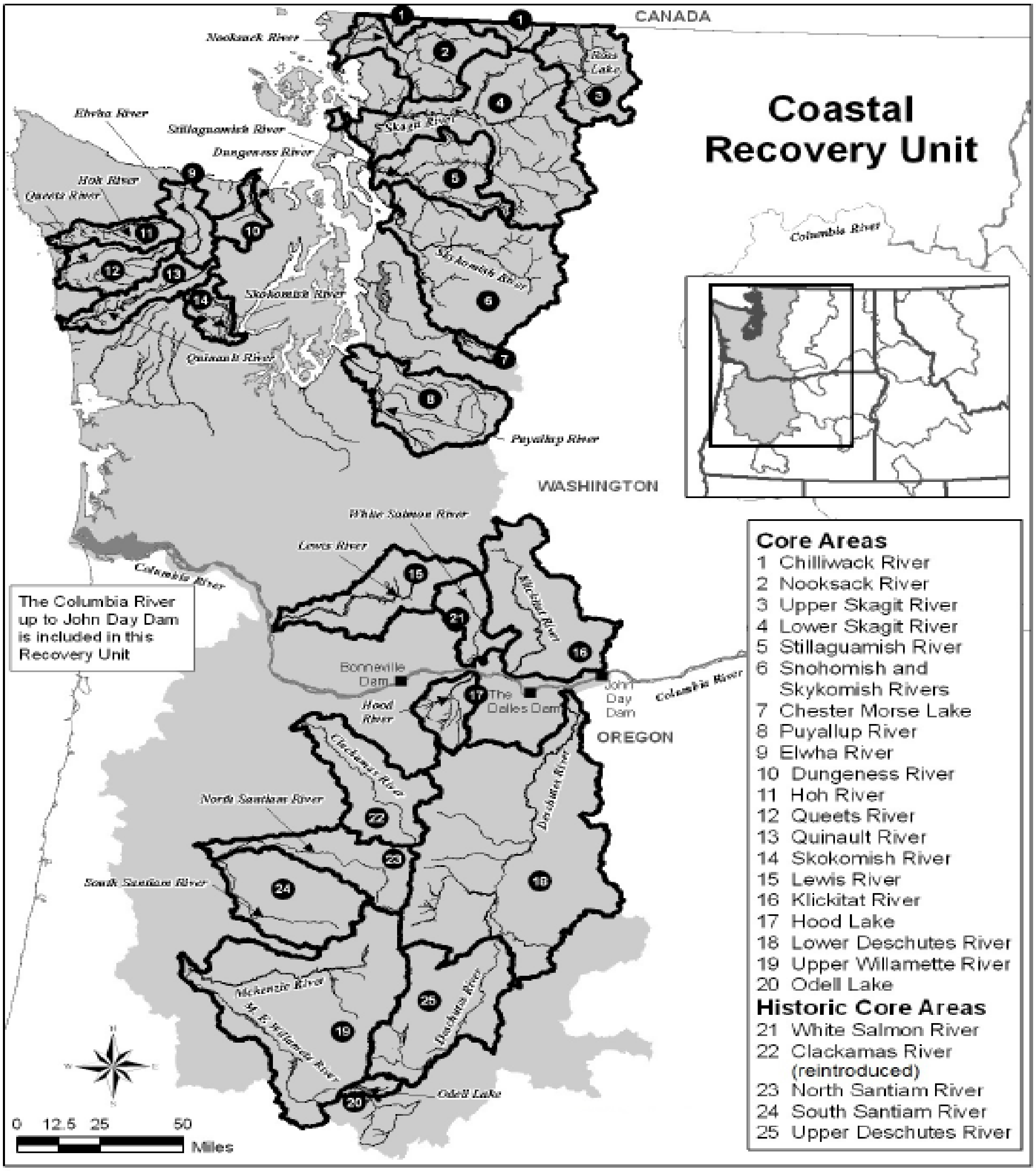

Figure 35. Map of the Coastal Recovery Unit and core areas (USFWS 2015a, p. 78).

Table 5. Shared FMO habitat in the Coastal Recovery Unit (USFWS 2015a, p. 79).

Shared FMO Habitat Areas	**Recovery Unit**	**Area Description**
Lower Columbia River FMO	Coastal	Mainstem Columbia River from the mouth to John Day Dam
Puget Sound FMO	Coastal	Nearshore marine habitat on eastern edge of Puget Sound from Nisqually River north to Canadian border
Lower Nisqually River FMO	Coastal	Mainstem lower Nisqually River
Lower Green River FMO	Coastal	Mainstem lower Green River and Sunday Creek
Lake Washington FMO	Coastal	Salmon Bay, Lake Union, and Lake Washington
Samish River FMO	Coastal	Mainstem Samish River
Hood Canal Marine FMO	Coastal	Mainstem Dosewallips River, and nearshore marine habitat in Hood Canal extending from Dabob Bay and the mouth of Union River outward to Hazel Point
Strait of Juan de Fuca FMO	Coastal	Nearshore marine habitat from Pillar Point to Cape George
Pacific Coast FMO	Coastal	Nearshore marine habitat from Grays Harbor to Ozette Lake vicinity, and mainstem riverine habitat Copalis River, Raft River, and Goodman Creek
Grays Harbor/Chehalis River FMO	Coastal	Nearshore marine habitat in Grays Harbor, and mainstem riverine habitat in Humptulips, Chehalis, Wishkah, Wynoochee, Satsop, and

There are five core areas within the Coastal Recovery Unit that have been identified as current population strongholds. These are the Lower Skagit and Upper Skagit core areas in the Puget Sound region, the Quinault River core area in the Olympic Peninsula region, and the Lewis River and Lower Deschutes River core areas in the Lower Columbia River region. These are the most stable and abundant bull trout populations in the recovery unit (USFWS 2015a, p. 79).

The Recovery Plan identifies the following recovery actions (USFWS 2015a, pp. 51, 52):

1. Protect, restore, and maintain suitable habitat conditions for bull trout.

2. Minimize demographic threats to bull trout by restoring connectivity or populations where appropriate to promote diverse life history strategies and conserve genetic diversity.

3. Prevent and reduce negative effects of non-native fishes and other non-native taxa on bull trout.

4. Work with partners to conduct research and monitoring to implement and evaluate bull trout recovery activities, consistent with an adaptive management approach using feedback from implemented, site-specific recovery actions, and considering the effects of climate change.

Promoting and restoring connectivity, both within core areas and with riverine or coastal FMO habitat, should encourage the full expression of known migratory life history strategies (fluvial, adfluvial, anadromous, amphidromous), and allow appropriate genetic interaction and demographic exchanges among core areas (USFWS 2015a, p. 51).

Future climate change impacts on bull trout will require development of a decision framework to help inform where climate change effects are most likely to impact bull trout. The identification of core areas and watersheds that are most likely to maintain habitats suitable for bull trout over the foreseeable future, and under probable climate change scenarios, will help guide the allocation of bull trout conservation resources to improve the likelihood of recovery (USFWS 2015a, p. 53).

The Recovery Plan summarizes our current knowledge of potential future climate change scenarios, and their significance for bull trout recovery (USFWS 2015a, pp. 17-19, 30, 31). Bull trout are vulnerable to the effects of warming climates and changing precipitation and hydrologic regimes. Climate change in the Pacific Northwest will include rising air temperatures, changes in the timing and volume of streamflow, increases in extreme precipitation events, and other changes that are likely to degrade bull trout habitat and increase competition with non-native warmwater fish (Mote *et al*. 2014).

Several climate change assessments or studies have been published (Rieman *et al*. 2007; Porter and Nelitz. 2009; Rieman and Isaak 2010; Isaak *et al*. 2010, 2011; Wenger *et al*. 2011; Eby *et al*. 2014) or are currently underway assessing the possible effects of climate change on bull trout. The results of these efforts will allow us to better understand how climate change may influence bull trout, and help to identify suitable conservation actions to improve the status of bull trout throughout their range. Issues include: the effects of rising air temperatures and lower summer flows on range contractions; changing stream temperatures, influenced by stream characteristics (e.g., amount of groundwater base flow contribution to the stream, stream geomorphology, etc.) affecting suitable bull trout spawning and rearing habitat; threats to redds and juvenile habitat from stream scouring caused by increased winter precipitation extreme events and increased rain in lower elevations; and lower summer flows inhibiting movement between populations, and from spawning and rearing habitat to foraging habitat (USFWS 2015a, p. 18).

A study of changing stream temperatures over a 13-year period in the Boise River basin estimated an 11 to 20 percent loss of suitable coldwater bull trout spawning and early juvenile rearing habitats (Isaak *et al*. 2010). These results suggest that a warming climate is already affecting suitable bull trout instream habitats. This is consistent with the conclusions of Rieman *et al*. (2007) and Wenger *et al*. (2011) that bull trout distribution is strongly influenced by climate, and predicted warming effects could result in substantial loss of suitable bull trout habitats over the next several decades. Wenger *et al*. (2011) also noted that bull trout already seem to inhabit the coldest available streams in some study areas, and in several watersheds bull trout do not have the potential to shift upstream with warming stream temperatures at lower elevations (USFWS 2015a, p. 18).

Sensitivity of stream temperature to changes in air temperature is complex and is influenced by geological and vegetational factors such as topography, groundwater recharge, glaciation history, and riparian vegetation (Isaak *et al*. 2010; Isaak and Rieman 2013). A new stream temperature data collection, modeling and mapping project, NorWeST, provides a much improved foundation for assessing bull trout cold water habitat (USFS 2014). Stream temperature data have been compiled from dozens of resource agencies at more than 15,000 unique stream sites. These temperature data are being used with spatial statistical stream network models to develop an accurate and consistent set of climate scenarios for all streams (USFWS 2015a, p. 19).

Fine-scale assessments of the current and projected future geographic distribution of coldwater streams and suitable bull trout habitat have been recently developed through the NorWeST (Isaak *et al*. 2015) and Bull Trout Vulnerability Assessment (Dunham 2015) processes. These assessments model probability of presence using the NorWeST stream temperature data and models, and map suitable habitat "patches" using fish presence, local threats, migratory connectivity, and climate sensitivity. The climate sensitivity parameters and data that will be linked to patches include flow variability (e.g., percent high frequency of winter floods), thermal variability (percent very cold), fire history (percent severely burned relative to patch area), and snowpack (snow cover frequency). Other factors include composite indicators of human impacts and non-native presence. Connectivity parameters include data among patches (stream/lake/sea distance to nearest occupied patch), migratory connectivity (distance to lake/sea), local barriers (culverts, diversions), and natural geomorphic features (USFWS 2015a, p. 19).

Climate change is an independent threat to bull trout, but also one that exacerbates many of the other threats. The Service expects the threat to increase in severity over coming decades. Increasing air temperatures and other changes to hydrology, modified by local habitat conditions, will tend to result in increased water temperatures, and reduce the amount of habitat with suitable cold water conditions. Warm dry conditions are also likely to increase the frequency and extent of forest fires, with a potential to increase sedimentation and eliminate riparian shading. Projected lower instream flows and warmer water in FMO habitats will exacerbate the lack of connectivity within and between bull trout core areas. And, we expect that increased water temperatures will alter competitive interactions between bull trout and other fish species that are better adapted to warm conditions. Climatic warming will change seasonality of streamflow, and increased spring runoff from rain-on-snow events will increase scouring of spawning gravels. Glacial retreat and reduction of summer snowpack will reduce cold water flows during summer months. Sea level rise will result in the loss of, and changes to, nearshore and estuarine habitat. Although addressing the root causes of greenhouse gas emissions and climate change is not within our jurisdiction, management planning should account for these increased threats and proactively protect those habitats that we expect will best maintain cold water conditions suitable for bull trout (USFWS 2015a, pp. 30, 31).

The RUIP for the Coastal Recovery Unit includes the following specifics regarding bull trout recovery actions for shared Puget Sound FMO, the coastal Washington core areas, and shared Olympic Penninsula FMO (USFWS 2015e, pp. A-57 through A-59, A-63 through A-67, A-71, A-72):

- Implement protection activities in nearshore marine and estuarine habitats. Past and current impacts from residential development and urbanization along shorelines have significantly degraded nearshore habitats essential to anadromous bull trout and their marine prey base. Efforts should prioritize the protection of intact shorelines, key habitats, and natural shoreline processes (eelgrass beds, forage fish spawning and holding areas, feeder bluffs), particularly those in close proximity to core areas or shared freshwater FMO habitats. Use project prioritization identified in the Puget Sound Partnership's most current near term action agenda.

- Implement restoration activities in nearshore marine and estuarine habitats. Past and current impacts from residential development and urbanization along shorelines have significantly degraded nearshore habitats essential to anadromous bull trout and their marine prey base. Efforts should target the restoration or enhancement of natural shoreline features, shoreline processes, or key habitats that are currently degraded, particularly those in close proximity to core areas or shared freshwater foraging, migration, and overwintering habitats. Use project prioritization identified in the Puget Sound Partnership's most current near term action agenda.

- Assess impacts of contaminants to anadromous bull trout. Increasing residential development and urbanization exacerbates the ongoing transfer of contaminants into nearshore habitats of Puget Sound. Additional evaluation of the impacts to anadromous bull trout and to their key prey base (salmon and marine forage fish) is required to develop and implement any necessary and appropriate mitigation strategies.

- Assess importance of small independent streams to anadromous bull trout. Small independent streams play an important overwintering role for anadromous bull trout in the Olympic Peninsula region (Brenkman *et al*. 2007 *In* USFWS 2015e), but their role for Puget Sound populations is less clear due to the environmental setting. Additional evaluation of the locations and level of use by anadromous bull trout is required to develop and implement any necessary protection and restoration strategies.

- Ensure fisheries do not impede recovery. Direct and incidental catch of bull trout from commercial gill net and popular recreational angling fisheries on the coast (Brenkman *et al*. 2007; Kerr *et al*. 2013; E. Harvey, NPS, in litt. 2014 *In* USFWS 2015e) can have significant selective pressure on older and larger bull trout (Brenkman *et al*. 2007 *In* USFWS 2015e). Develop and implement strategies to reduce incidental mortality of larger spawners caught in fisheries.

- Monitor and evaluate fisheries impacts. Develop and implement appropriate level of monitoring to ensure fisheries do not significantly impact bull trout recovery, and periodically review harvest management and make recommendations for change as needed.

- Implement restoration activities in nearshore marine and estuarine habitats. Efforts should target the restoration or enhancement of natural shoreline features, processes, or key habitats that are currently degraded, particularly those in close proximity to Dungeness River core area or shared freshwater FMO habitats. Use project prioritization identified in the Puget Sound Partnership's most current near term action agenda.

- Implement restoration actions in small, independent, coastal marine tributaries. Although these small independent streams have been identified as either medium or low priority watersheds for salmon compared to larger natal watersheds (QIN 2011 *In* USFWS 2015e), these are key shared FMO habitats for anadromous bull trout (Brenkman *et al*. 2007; USFWS 2010 *In* USFWS 2015e). Many of these small streams, whose estuaries and lower reaches are used by anadromous bull trout, have been heavily impacted by past forest practices (QIN 2011 *In* USFWS 2015e). Implement appropriate protection and restoration actions.

- In the Chehalis River/Grays Harbor watershed, assess potential for "re-establishing" a natal population of bull trout to the Satsop River.

<u>Summary</u>

The action area includes more than 45,000 acres of nearshore marine habitat, including approximately 12,000 acres of designated bull trout critical habitat (45,000 to 50,000 acres in total; Willapa Bay: approx. 30,000 acres; Grays Harbor: approx. 4,000 acres; north Puget Sound: approx. 5,000 acres; south Puget Sound: approx. 5,000 acres; and, Hood Canal: approx. 3,000 acres). Bull trout occur in these nearshore marine waters, and the anadromous (or amphidromous) bull trout that these waters support are unique to the Coastal Recovery Unit and rangewide distribution of the species. These nearshore marine waters support the complex migratory behaviors and requirements of the anadromous form of bull trout, provide foraging opportunities, allow for enhanced individual growth, and support the connectivity of bull trout core areas over time (with genetic exchange). As such, these nearshore marine waters are essential to the persistence of the anadromous bull trout life history form.

Data collected in Puget Sound indicate that the majority of anadromous bull trout tend to migrate into marine waters in the spring, and return to rivers in the summer and fall. Although much less common, tagged bull trout have been detected in Puget Sound nearshore marine waters during December and January, which indicates that some fish may remain in or return to marine waters during the winter.

Marine FMO habitat located in Puget Sound, Hood Canal, the Pacific Coast, and Grays Harbor is considered essential for maintaining the anadromous life history form of bull trout. Recovery plans assign no specific conservation role to Willapa Bay, because bull trout are thought to occur there infrequently and in low or very low numbers.

Current Condition in the Action Area (Marbled Murrelet)

The action area includes all of the tidelands and nearshore marine waters associated with continuing and new (projected future) shellfish activities, encompassing an area of approximately 38,716 acres (Corps 2015, pp. 40-49, 77-82). Where cultured tidelands extend with only occasional interruption, interspersed uncultured areas may experience direct or indirect effects, and are therefore considered part of the action area. At all locations, the action area extends a minimum of 2,000 ft from the farm footprint (active and fallow). Factoring and incorporating these other considerations, we estimate conservatively that regulated shellfish activities in Washington State, specifically those for which this Opinion provides programmatic coverage, are likely to directly or indirectly affect more than 45,000 acres of nearshore marine habitat (45,000 to 50,000 acres in total; Willapa Bay: approx. 30,000 acres; Grays Harbor: approx. 4,000 acres; north Puget Sound: approx. 5,000 acres; south Puget Sound: approx. 5,000 acres; and, Hood Canal: approx. 3,000 acres).

The Recovery Plan for the Threatened Marbled Murrelet in Washington, Oregon, and California (USFWS 1997, p. 115) identifies six Conservation Zones throughout the listed range of the species. Conservation Zone 1 (Puget Sound) includes all the waters of Puget Sound and most waters of the Strait of Juan de Fuca south of the U.S.-Canadian border. Conservation Zone 2 (Western Washington Coast Range) includes marine waters within 1.2 miles (2 km) off the Pacific Ocean shoreline, with the northern terminus immediately south of the U.S.-Canadian border near Cape Flattery along the midpoint of the Olympic Peninsula, and extending to the southern border of Washington (the Columbia River)(USFWS 1997, p. 126).

<u>Offshore Area Subunit/Conservation Zone 2</u>

During the breeding season (April through September), marbled murrelet density in the Offshore Area Subunit is lower than in the nearshore coastal and inland waters. During the summer, it is assumed that 5 percent of marbled murrelets detected during Northwest Forest Plan Effectiveness Monitoring Program (NWFPEM) are offshore (the NWFPEM effort detects approximately 95 percent of the population, and the remaining 5 percent are assumed to be offshore), but not beyond the continental shelf (37 km, or 20 nm). Table 6 shows the density estimates for marbled murrelets detected by NWFPEM in Conservation Zone 2.

Table 6. Marbled murrelet population estimates and densities in Conservation Zone 2 from 2001 to 2015

Year	**Conservation Zone 2** – Stratum					
	All		1		2	
	Density (birds/km^2)	Population Estimate	Density (birds/km^2)	Population Estimate	Density (birds/km^2)	Population Estimate
2001	0.90	1,518	1.43	1,040	0.50	478
2002	1.23	2,031	2.45	1,774	0.28	258
2003	2.41	3,972	2.64	1,912	2-23	2,061
2004	1.82	3,009	3.37	2,444	0.61	565
2005	1.56	2,576	2.79	2,018	0.60	558
2006	1.46	2,381	2.26	1,638	0.80	743
2007	1.54	2,535	2.85	2,065	0.51	470
2008	1.17	1,929	2.58	1,872	0.06	57
2009	0.77	1,263	1.61	1,166	0.11	97
2010	0.78	1,286	1.34	968	0.34	318
2011	0.72	1,189	1.31	952	0.26	237
2012	0.72	1,186	1.18	853	0.36	333
2013	0.77	1,271	1.61	1,163	0.12	108
2014	1.32	2,176	2.88	2,086	0.10	90
2015	1.94	3,204	2.85	2,064	1.23	1,140

(Lynch *et al*. 2016, pp. 10-13)

Inland Waters Subunit/Conservation Zone 1

The Inland Water Subunit within Conservation Zone 1 encompasses all of Puget Sound and the Strait of Juan de Fuca. Within the Inland Water Subunit, marbled murrelets tend to forage in well-defined areas during the breeding season. They are found in the highest densities in the nearshore waters of the San Juan Islands, Rosario Strait, the Strait of Juan de Fuca, Admiralty Inlet, and Hood Canal. They are more sparsely distributed elsewhere in Puget Sound, with smaller numbers observed during different seasons within the Nisqually Reach, Possession Sound, Skagit Bay, Bellingham Bay, and along the eastern shores of Georgia Strait. In the most southern end of Puget Sound, they occur in extremely low numbers. During the non-breeding season, they typically disperse and are found farther from shore (Strachan *et al*. 1995).

It appears that marbled murrelets from Vancouver Island, British Columbia move into more sheltered waters in Puget Sound and the Strait of Georgia, which contributes to increased numbers of murrelets in Puget Sound in fall and winter (Burger 1995a). Surveys along the southern shore of the Strait of Juan de Fuca conducted by the Washington Department of Fish and Wildlife from 1996-1997 (Thompson 1997) showed an increase in the number and group size of marbled murrelets in August in the eastern Strait of Juan de Fuca, although numbers declined in the western portion of the Strait of Juan de Fuca. Surveys in the near-shore waters of the San Juan Islands (Evans and Associates 1999; Ralph *et al*. 1995) showed a similar increase in abundance in August and September. Increases in abundance have been detected as well in September and October during surveys of Admiralty Inlet, Hood Canal, Saratoga Passage, and

Possession Sound (Merizon *et al*. 1997). A breeding marbled murrelet, banded in Desolation Sound in summer, was recovered near Orcas Island in September, and then recovered in Desolation Sound the following year (Beauchamp *et al*. 1999).

Marbled murrelet presence in the Inland Water Subunit is documented by several sources. The most accurate information comes from the consistent sampling method used to estimate population size and trends under the NWFPEM (Raphael *et al*. 2007). Since 2000, the estimated population size for Conservation Zone 1 has ranged from a low of 2,822 marbled murrelets in 2014 to a high of 9,758 in 2002 (Table 7) (Lynch *et al*. 2016, pp. 10-13). The most recent (2015) estimated population for Conservation Zone 1 is 4,290 marbled murrelets (2,783-6,492, the upper and lower 95 percent confidence intervals; see Lynch *et al*. 2016) (Lance and Pearson 2016, p. 4; Lynch *et al*. 2016, p. 13). Since 2001, the estimated marbled murrelet density in Conservation Zone 1 has ranged from 0.81 to 2.79 marbled murrelets per km^2, with the most recent (2015) density of 1.23 birds per km^2 (Lynch *et al*. 2016, p. 13).

<u>Food and Habitat Preferences</u>

Burkett (1995) reviewed marbled murrelet food habits and prey ecology, including the works of Sealy (1975c), Krasnow and Sanger (1982), Sanger (1983, 1987b), Carter (1984), Vermeer (1992), and others. Speich and Wahl (1995) described the marbled murrelet's habitat preferences and variability of occurrence in the inland marine waters of Washington State. Appendix D includes excerpts from Burkett (1995) and Speich and Wahl (1995); those excerpts are incorporated here by reference.

<u>Factors Responsible for the Condition of the Species</u>

Some of the factors responsible for the condition of the species (marbled murrelet) in the action area are described elsewhere (see *Status of the Species* and *Environmental Baseline*).

As part of the Service's 5-year review of the current status of the marbled murrelet, we identified new threats and stressors across the listed range of the species, including several environmental factors affecting marbled murrelets in the marine environment:

- Habitat destruction, modification, or curtailment of the marine environmental conditions necessary to support marbled murrelets due to: elevated levels of polychlorinated biphenyls in murrelet prey species; changes in prey abundance and availability; changes in prey quality; harmful algal blooms that produce biotoxins leading to domoic acid and paralytic shellfish poisoning; and climate change in the Pacific Northwest.

- Manmade factors that affect the continued existence of the species include: derelict fishing gear leading to mortality from entanglement; energy development projects (wave, tidal, and on-shore wind energy projects) leading to mortality; and disturbance in the marine environment (e.g., sound pressures caused by pile-driving and underwater detonations, vessel traffic).

Table 7. Marbled murrelet population estimates and densities in Conservation Zone 1 from 2001 to 2015.

Year	**Conservation Zone 1** - Stratum							
	All		1		2		3	
	Density (birds/km^2)	Population Estimate	Density (birds/km^2)	Population Estimate	Density (birds/km^2)	Population Estimate	Density (birds/km^2)	Population Estimate
2001	2.55	8,936	4.51	3,809	1.76	2,111	2.07	3,016
2002	2.79	9,758	7.21	6,092	1.88	2,248	0.97	1,419
2003	2.43	8,495	6.64	5,617	1.44	1,721	0.79	1,156
2004	1.56	5,465	3.83	3,241	1.51	1,807	0.29	417
2005	2.28	7,956	2.50	2,114	2.43	2,895	2.02	2,947
2006	1.69	5,899	2.76	2,333	1.42	1,693	1.28	1,873
2007	2.00	6,985	3.45	2,912	1.22	1,453	1.80	2,620
2008	1.34	4,699	3.57	3,019	0.90	1,073	0.42	607
2009	1.61	5,623	3.81	3,221	0.69	822	1.08	1,580
2010	1.26	4,393	2.00	1,694	1.78	2,128	0.39	571
2011	2.06	7,187	5.58	4,717	1.24	1,484	0.68	986
2012	2.41	8,442	7.17	6,056	1.51	1,799	0.40	587
2013	1.26	4,395	2.38	2,010	0.66	784	1.10	1,600
2014	0.81	2,822	1.26	1,063	1.27	1,521	0.16	238
2015	1.23	4,290	2.22	1,875	1.95	2,321	0.06	94

Sources: (Lance and Pearson 2016, p. 4; Lynch *et al*. 2016, pp. 10-13)

Prey Resources and Foraging Conditions

Therriault, Hay, and Schweigert (2009) have reported recent marine forage fish trends in the Salish Sea and their potential significance for seabirds. Cury *et al*. (2011) considered global trends in seabird response to forage fish depletion. Vilchis *et al*. (2014) recently published work using winter count data collected in the Salish Sea over the period 1994 to 2010, and epidemiological theory and data processing techniques, to evaluate common drivers for declines witnessed in marine avian predators. Appendix D includes excerpts from Therriault, Hay, and Schweigert (2009), Cury *et al*. (2011), and Vilchis *et al*. (2014); those excerpts are incorporated here by reference.

Net Entanglement and Bycatch

Rodway *et al*. (1992, pp. 30, 31) reported, "Mariculture developments have proliferated in recent years throughout nearshore feeding areas for murrelets in southern British Columbia (Booth and Rueggeberg 1988) … Entanglement of alcids was reported at one of 68 salmon farms surveyed (Rueggeberg and Booth 1989) … displacement from traditional foraging areas, contamination of food supplies by antifoulants and antibiotics, and alteration of local food supplies from decomposition of fish food and fish excretion are potential problems for marbled murrelets (Vermeer and Morgan)." Laist (1997) compiled a comprehensive list of species with marine debris entanglement and ingestion records. Carter, McAllister, and Isleib (1995) describe accidental capture and mortality in commercial gill nets as one of the major threats to marbled murrelet populations. Good *et al*. (2010) has reported on the progress made removing derelict gear in Puget Sound and the Northwest Straits, and the pattern of remaining threats. Zydelis, Small, and French (2013) have considered recent bycatch trends in Washington State and British Columbia. Appendix D includes excerpts from Laist (1997); Carter, McAllister, and Isleib (1995); Good *et al*. (2010); and, Zydelis, Small, and French (2013); those excerpts are incorporated here by reference.

Conservation Role of the Action Area (Marbled Murrelet)

The action area is critically important to the marbled murrelet populations in Conservation Zones 1 and 2 (Puget Sound and Western Washington Coast Range, respectively), and by extension, is also critically important to the rangewide conservation and recovery of the species. The action area provides prey resources that are essential to the health and productivity of marbled murrelet populations in Conservation Zones 1 and 2. However, the action area also supports individuals from other conservation zones and/or British Columbia that seasonally forage and migrate in Washington's inland marine waters or the coastal bays, and therefore supports additional marbled murrelet populations from both the south and north. Many of the marbled murrelets that breed on Vancouver Island, British Columbia, appear to move into more sheltered waters (Puget Sound and the Strait of Georgia) after the breeding season, where numbers increase in fall and winter (Burger 1995a,b). The Service's recovery plan identifies all of Puget Sound, including the waters of the San Juan Islands, the Strait of Juan de Fuca, and the nearshore waters along the Pacific Coast from Cape Flattery to Willapa Bay (within 1.2 miles of the shore), including rivers mouths, as essential for marbled murrelet foraging and loafing (USFWS 1997, p. 135).

The marine environment will play an essential role in the recovery of the marbled murrelet. Protecting the quality of the marine environment is identified in the recovery plan as an integral part of the recovery effort (USFWS 1997, p. 120). Marbled murrelets spend the majority of their lives in marine areas, usually within five kilometers of the shoreline, where forage fish and other marine prey resources are most abundant (USFWS 1997, p. 120). If marine areas are degraded and do not provide sufficient prey resources, individual fitness and reproductive success may be reduced.

There are threats in the action area that must be addressed to reverse rangewide marbled murrelet population trends, and to maintain self-sustaining and self-regulating populations. A marbled murrelet Recovery Implementation Team, convened and led by the Service, found that sustained low recruitment is the most likely cause for the observed, continuing population declines, and identified five major mechanisms that contribute to this decline (USFWS 2012, cover letter, pp. 10, 11, 22):

- Changes in marine forage conditions, affecting the abundance, distribution, and quality of prey, is identified as one of the five mechanisms. Depletion of the marine forage fish resource, degraded spawning and rearing habitats for these fish (often attributable to shoreline development and alteration), and other losses or degradation of estuarine and nearshore marine habitat functions are emphasized (pp. 10, 13, 19, 22). Also, "… [marine] food webs are sensitive to climate variability … [and] there is uncertainty about how future changes will impact these [food] webs" (p. 10). For all geographic areas across the range of the listed species, degraded marine forage conditions, and the uncertain future effects of climate variability on marine forage conditions, are identified as one of the top three causes for low recruitment and the observed, continuing population declines (USFWS 2012, p. 19).

- Post-fledging mortality is another of the five mechanisms. Entanglement in nets and "other marine gear" remains one of the significant, identified causes for this mortality (USFWS 2012, pp. 11, 13).

- Cumulative and interactive effects are a top five mechanism, including the "…disconnect between [high] quality marine and terrestrial habitats…", or the lack of adequate marine and terrestrial habitat "coupling" (USFWS 2012, pp. 11, 13). "Longer commuting times between nesting and foraging habitats can increase both the energetic costs of reproduction and exposure to predators … the cumulative effect of [these] factors … may limit reproductive success."

- In Puget Sound and the San Juan Islands, most of the remaining, functional nesting habitat is located far from marine waters. In this portion of the marbled murrelet's range, where there is a "…significant distance between marine areas and remaining nesting habitat … [the] energetic costs of the commute [are] probably highest" (USFWS 2012, p. 13).

- In north Puget Sound and the Strait of Juan de Fuca, herring "…stocks are not doing well" (USFWS 2012, p. 14).

- On the coast, south of Grays Harbor, the "…disconnect between high quality terrestrial and marine habitats … [is] of more concern … due to very limited terrestrial [nesting] habitat" (USFWS 2012, p. 16).

Increasing human populations often result in increased shoreline development, and will likely further degrade nearshore marine habitat and marine prey resources. Urban and suburban sprawl, logging, and habitat fragmentation in the uplands have already greatly reduced the available, suitable nesting habitat, and have increased the distances that marbled murrelets must travel between high quality nesting and foraging habitats. New information regarding the status of marine forage fish resources in the action area, and regarding seabird responses to reduced prey availability, suggest that marbled murrelet populations may be experiencing declines that are at least partially attributable to a lack of adequate forage resources. These threats, combined with the other unaddressed rangewide threats, could affect the long-term trajectory for survival and recovery of the marbled murrelet.

Climate Change

Climate change has already begun to affect conditions throughout the action area. This sub-section discusses three related subjects: ocean acidification; "other" marine and estuarine impacts associated with or caused by climate change; and, invasive species. The impacts of ongoing and future climate change are an important aspect of the environmental baseline. Climate change will have significance for the health and function of the action area's nearshore marine habitats, which are essential to the recovery of both anadromous bull trout and the marbled murrelet.

<u>Ocean Acidification</u>

Over the past two centuries, atmospheric carbon dioxide (CO_2) concentrations have increased from approximately 280 parts per million (ppm), to approximately 380 ppm; and, over the same period, the Earth's oceans absorbed an estimated 550 billion tons of CO_2 (Le Quere *et al*. 2009 and Canadell *et al*. 2007 *in* Feely *et al*. 2012, pp. 442). Decades of observations now show that CO_2 absorbed by the oceans is changing the chemistry of seawater, in a process called ocean acidification. "When anthropogenic CO_2 is absorbed by seawater, chemical reactions occur that reduce seawater pH, concentration of carbonate ion, and the saturation states of the biominerals aragonite and calcite … When carbonate saturation states … drop below saturation … whether … due to ocean acidification or other natural processes, carbonate biominerals in shells and skeletons may begin to dissolve, and we describe the water as corrosive" (Feely *et al*. 2012, pp. 442, 443).

Since pre-industrial times, "…the pH of average open-ocean surface waters has decreased by about 0.1, equivalent to an overall increase in the hydrogen ion concentration or 'acidity' of about 30 percent" (Feely *et al*. 2012, p. 443), and "…there has been an overall decrease of about 16 percent in the aragonite saturation state of North and South Pacific surface and intermediate waters … and a decrease of about 0.34 [percent per year] over the last two decades" (Feely *et al*. 2012, pp. 11, 12). These changes to the chemistry of seawater have caused "upward migrations of the aragonite and calcite saturation horizons" (i.e., the depths at which these biominerals may be found at sufficient concentration), as well as related regional changes in circulation and biogeochemical processes (Feely *et al*. 2012, p. 1).

However, available information suggests that "…large-scale changes in circulation can be as important as, or in some cases, more important than, the direct effects of anthropogenic CO_2 … More detailed information on the temporal variability of the physical and chemical properties of the California Current is required before we can accurately predict how these long-term changes will affect our coastal ecosystems" (Feely *et al*. 2012, p. 11).

"Coastal waters, which are the source for the marine waters in the Puget Sound system, [already] carry an anthropogenic CO_2 burden, and a corresponding pH decrease associated with ocean acidification … A reasonable estimate of the range of the present-day pH decrease in the Puget Sound region due to ocean acidification is between 0.05 and 0.15" (Feely *et al*. 2012, p. 446). "The calculations … suggest that in pre-industrial times the waters flowing into Puget Sound … were above saturation with respect to aragonite, whereas today they are undersaturated … While the deep waters of Hood Canal were likely [naturally] undersaturated during the pre-industrial era, the degree of undersaturation is greater today than it would have been then" (Feely *et al*. 2012, p. 447).

"Laboratory and mesocosm experiments suggest that pH and saturation state values of the observed magnitude may impair overall calcification rates for many species of marine calcifiers, including cold water corals, coccolithophorids, foraminifera, sea urchins and pteropods (Spero *et al*. 1997; Riebesell *et al*. 2000; Engel *et al*. 2005; Orr *et al*. 2005; Guinotte *et al*. 2006; Kleypas *et al*. 2006; Fabry *et al*. 2008; Guinotte and Fabry 2008; Doney *et al*. 2009; Ries *et al*. 2009) … Similar decreases in calcification rates would be expected for edible mussels, clams, and oysters (Green *et al*. 2004; Gazeau *et al*. 2007; Hettinger *et al*. 2010)" (Feely *et al*. 2012, p. 447). Numerous authors have emphasized the pervasive nature of these changes and their fundamental importance to the productivity and resiliency of coastal and estuarine ecosystems.

Feely *et al*. (2012, pp. 446-448) have discussed current and future patterns of ocean acidification, and how they are likely to interact with and alter the natural chemistry and biology of the Puget Sound:

- "Naturally low carbonate saturation and pH levels in the North Pacific predispose the Pacific Northwest coast in general, and Puget Sound in particular, to the development of corrosive, hypoxic marine conditions."

- "As CO_2 continues to rise in the atmosphere, the ... contribution of anthropogenic CO_2 to the development of corrosive conditions in the deep waters of Puget Sound will likely increase with time."

- Ocean acidification is likely to play a role, "…exacerbating local or regional hotspots of corrosive conditions where the impacts of multiple stressors converge."

- "Stressful conditions may be exacerbated by [the] combined impacts of global, regional, and local anthropogenic processes including ocean acidification, land-use change, and nutrient enrichment. The additional pH, [altered aragonite saturation state], and CO_2 decreases associated with these anthropogenic stressors may cross critical thresholds for organisms living near the edge of their physiological tolerances."

- "The rapid decline of the large mussel populations at Tatoosh Island and the mass mortalities of oyster larvae in Pacific Northwest oyster hatcheries may be early indications of the kind of ecosystem changes caused by the combined effects of multiple processes and stressors interacting in a high-CO_2 world."

- "By the end of this century, ocean acidification may become the dominant process reducing the pH and saturation state of this large, economically important estuary" (Feely *et al*. 2012, pp. 446-448).

Greene *et al*. (2012, p. 16) found that 92 percent of Hood Canal sites (12 of 13) had minimum DO concentrations surpassing stressful conditions, and depressed DO concentrations were typically associated with highly stratified water columns. They report, "One striking bivariate relationship was observed across all temporal and spatial scales … pH and dissolved oxygen (DO). DO concentrations were positively correlated with pH across basins and months at the surface, at 6 meters deep, and at the maximum depth of the water column profiles … DO and pH may be tightly linked."

<u>Other Marine/Estuarine Impacts Associated with Climate Change</u>

As described by the Independent Scientific Advisory Board (ISAB 2007), the effects of climate change are likely to include increased ocean temperatures, increased stratification of the water column, and changes in the intensity and timing of coastal upwelling. These effects have already begun to alter, and are likely to continue altering primary and secondary productivity and the structure of marine communities.

For some large estuaries, the effects of climate change may have additional consequences (ISAB 2007): higher winter freshwater flows, and higher sea level elevations, 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 prey and predators; and, the increased temperature of freshwater inflows may extend the range of warm-adapted non-indigenous species. However, in all of these cases, the likely effects of these changes to the abundance, productivity, spatial distribution, and diversity of native biota are poorly understood (ISAB 2007).

"Growing human pressures, including climate change, are having profound and diverse consequences for marine ecosystems. Rising atmospheric … CO_2 is one of the most critical problems because its effects are globally pervasive and irreversible on ecological timescales (Natl. Res. Counc. 2011). The primary direct consequences are increasing ocean temperatures (Bindoff *et al*. 2007) and acidity (Doney *et al*. 2009) … [But] Direct effects … [to] ocean temperature and chemistry may … lead to shifts in the size structure, spatial range, and seasonal abundance of populations. These shifts, in turn, lead to altered species interactions and trophic pathways as change cascades from primary producers to upper-trophic-level fish, seabirds, and marine mammals, with climate signals thereby propagating through ecosystems in both bottom-up and top-down directions … Investigating the responses of individual species to single forcing factors, although essential, provides an incomplete story and highlights the need for more comprehensive, multispecies- to ecosystem-level analyses" (Doney *et al*. 2012, p. 12).

"Mid-latitude upwelling systems, like the California Current, exhibit strong linkages between climate and species distributions, phenology, and demography… Population-level shifts … [may be] occurring because of physiological intolerance to new environments, altered dispersal patterns, and changes in species interactions" (Doney *et al*. 2012, p. 11). Figure 36 illustrates some of the observed climate-dependent changes in the California Current ecosystem.

"Zooplankton biomass has declined dramatically over the past 60 years in concert with increases in ocean temperature (Roemmich and McGowan 1995), a trend that continues to this day … Because a shift toward less abundant, smaller, and lipid-poor subtropical copepods accompanied the transition into a warm phase of the [Pacific Decadal Oscillation] (Peterson and Schwing 2003), continued warming of the California Current is predicted to translate up the food chain to reduce juvenile survivorship in salmonid fishes" (Doney *et al*. 2012, p. 25).

The Earth's oceans are warming, with considerable interannual and interdecadal variability superimposed on the long-term trend (Bindoff *et al*. 2007). Historically, warm periods in the coastal Pacific Ocean have coincided with relatively low abundances of salmonids and other cold water-dependent fish species, while cooler ocean periods have coincided with relatively high abundances (Scheuerell and Williams 2005; Zabel *et al*. 2006). "Effects … [to native eelgrass] from global climate change include rising seawater temperatures and changes in depth from increased sea levels. High temperatures may cause loss of eelgrass in embayments already experiencing near-lethal temperatures" (Mumford 2007, p. 14).

<u>Invasive Species</u>

Among the key findings from a report published during 2007, the Puget Sound Action Team (PSAT 2007) found that more than 50 non-native species are documented in Puget Sound, a large number of these probably introduced via ship ballast. The European green crab (*Carcinus maenas*), Chinese mitten crab (*Eriocheir sinensis*), and zebra mussel (*Dreissena polymorpha*) are non-native species that could arrive at any time and threaten the Puget Sound.

"Another highly invasive kelp species, *Undaria pinnatifida* … is not yet in Puget Sound, but has been found in California and many other temperate areas, and will likely invade here in time (Silva *et al*. 2002)" (Mumford 2007, p. 4).

"Introduction of non-native species is an important management issue, particularly when they become invasive … Aquaculture and other vectors for marine invasions have been reviewed elsewhere (Gruet *et al*. 1976; Carlton and Mann 1996; McKindsey *et al*. 2007; Minchin 2007) … Regulations and practices have changed to reduce the role of aquaculture imports in homogenizing biota (e.g. ICES Code of Practice on the Introductions and Transfers of Marine Organisms, ICES 2005)" (Dumbauld, Ruesink, and Rumrill 2009, p. 201).

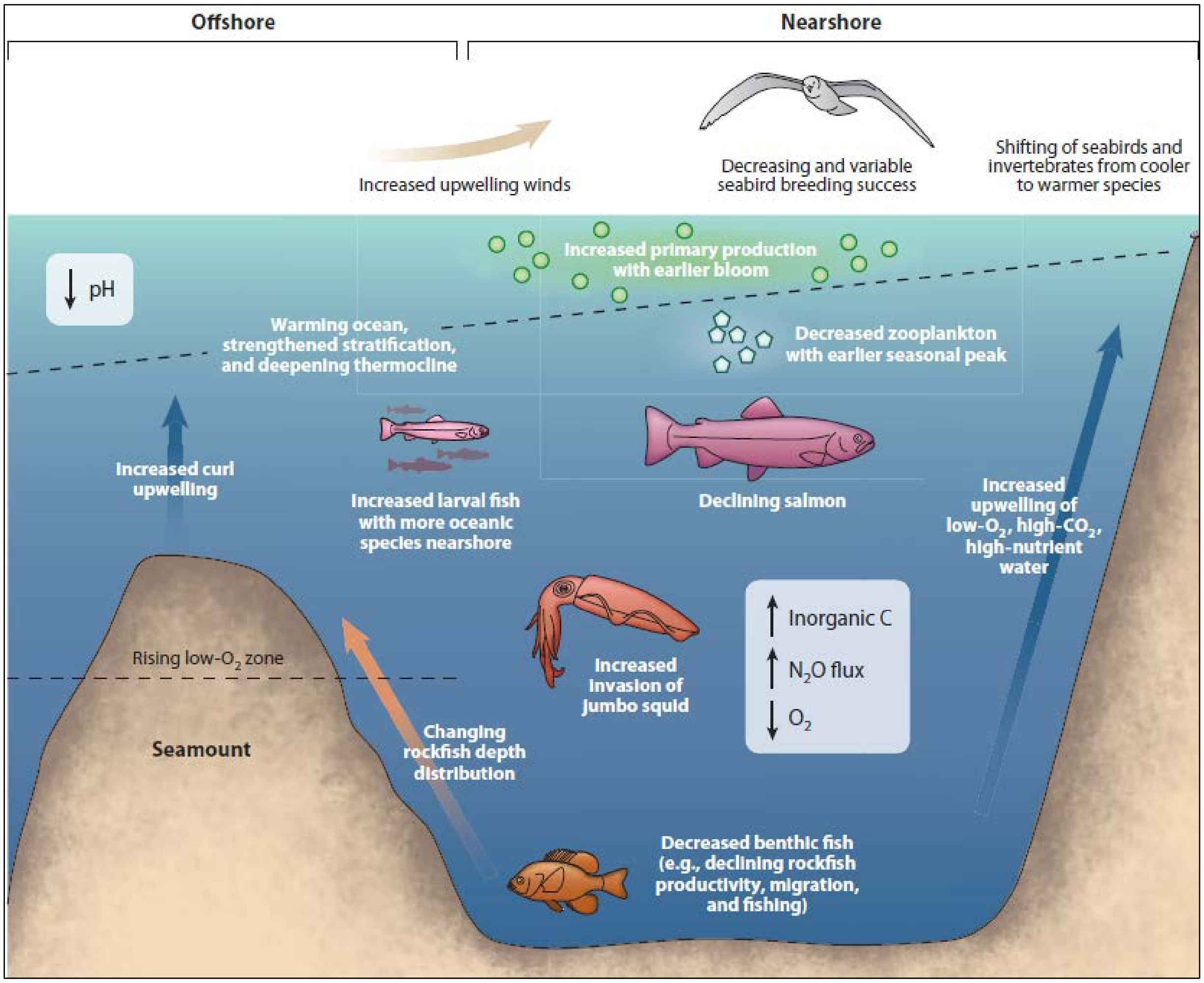

Figure 36. Climate-dependent changes in the California Current
(Doney *et al*. 2012, p. 27)

However, Forrest *et al*. (2009, p. 10) have argued that "…the role of elevated oyster culture in the spread of pest organisms … [is] particularly significant … Inadvertent pest introduction is one of the more significant issues associated with aquaculture in estuaries (DeFur and Rader 1995) … The reason is that, by comparison with all other issues, the spread of pest organisms … can occur at regional scales (e.g. as a result of seed-stock transfer) potentially leading to ecologically significant and irreversible changes to coastal ecosystems (Elliot 2003) … Although management approaches may be developed to minimize any pest risks that are considered unacceptable (e.g. treatment of seed-stock before regional transfer), there are few examples where such strategies have been completely effective (Piola *et al*. 2009)."

Bendell (2014) has reported that "…several lines of evidence suggest that the [cultured non-native] Manila [clam] is replacing the native littleneck [clam]" on intensively farmed British Columbia tidelands. "Prior to the introduction of the Manila clam, the native littleneck … and the butter clam (*Saxidomus gigantea*) were the dominant species harvested (Whiteley 2005)" (p. 369). "Within Baynes Sound, either seed spillover or natural spawning by the Manila is occurring, making it the dominant bivalve within the region" (p. 375). "The Manila, through the anthropogenic enhancement of its reproductive effort, is able to outcompete the indigenous species and overcome its predation disadvantage by occurring in greater numbers" (Bendell 2014, p. 379).

There is also a potentially significant ongoing and likely greater future interaction between marine species invasions and climate change: "Multiple factors beyond climate change influence changes in marine community composition and trophic structure, and synergistic effects may arise among climate, exploitation, and the introduction of invasive species. A survey of four well-studied marine regions found that invasions are shifting food webs toward domination by suspension and deposit feeders low in the food chain, presumably reflecting the widespread transport of small fouling organisms and the decline of large fishes caused by human harvesting (Byrnes *et al*. 2007) … Evidence from the Atlantic (Stachowicz *et al*. 2002) and Pacific (Sorte *et al*. 2010) coasts of North America indicates that nonnative species in fouling invertebrate communities are favored over native species in warmer waters. In this way, warming may tend to homogenize the composition of marine communities … Climate-mediated shifts in species distributions are creating novel or emerging no-analog ecosystems consisting of species with little or no shared evolutionary history (Hobbs *et al*. 2006; Williams and Jackson 2007) … There is growing evidence that the climate-mediated invasions mentioned above are biased taxonomically or by functional traits such as life history and trophic level (Byrnes *et al*. 2007) … Other studies suggest that a warming climate aggravates the prevalence of marine diseases (Harvell *et al*. 2002) … Climate-driven impacts on keystone and foundation species may be especially important … Some critical habitat-forming marine benthic species, such as oysters and corals, appear sensitive to CO_2 and climate change both directly and through pathogens" (Doney *et al*. 2012, pp. 19, 20).

EFFECTS OF THE ACTION

Introduction

The effects of the action refers to 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.

While generally it is our practice to describe first those activities which have insignificant or discountable effects to listed species, their habitats, and prey, we have taken an alternate approach with this Opinion's discussion of potential effects. All or nearly all of the shellfish activities covered under this programmatic Opinion result in measurable and potentially significant effects to water quality, substrate condition, physical habitat structure and function, benthic/epibenthic community structure and composition, and predator-prey dynamics.

As is always our practice, this Opinion includes an analysis and discussion of temporary (episodic or transient) stressors, resulting exposures, and potential effects. However, because with this Opinion we must consider and describe potential effects on a large scale, corresponding to hundreds of farms and farm operations, and thousands of affected nearshore marine acres, we believe that resulting persistent stressors of long duration (months, years) warrant and require special attention and focus.

Shellfish culturing activities and practices alter physical, chemical, and biological conditions on temporal scales that correspond to cycles of production and harvest. Resulting conditions also reflect variable patterns and rates of recovery from disturbance. And, the discernable direct and indirect effects of shellfish activities are generally also superimposed on, and further influenced by, natural variability, patterns of disturbance and recovery from natural events, and the confounding effects of concurrent, unrelated activities occurring in the same nearshore environments and watersheds.

The Corps has stated the following (Corps 2015, p. 83):

> "The effects [of individual activities] may be relatively short-term or longer lasting … Of equal or more relevance to ESA listed species are the effects of the collective activities, their frequency, duration, timing, geographic location, and general scale across the landscape."

We agree with the Corps and believe that the best available scientific information supports this conclusion. Our Opinion finds that the most significant and biologically relevant effects are those that result in aggregate to nearshore marine habitat structure, function, and productivity. We examine potential effects to ecological processes and ecosystem services. We also consider potential indirect effects that may result from altered patterns of prey availability and productivity ("prey-mediated effects"). And, we assess potential effects to natural forms of nearshore marine habitat structure and complexity, both those that result on the scale of an individual farm, and those that result from groupings of farms on larger scales.

The portions of the Opinion that follow discuss: 1a) *temporary stressors* resulting from shellfish activities, and 1b) *resulting short-term exposures and effects* to bull trout and marbled murrelets; 2a) *persistent stressors of long duration* resulting from shellfish activities, 2b) *aggregate effects at larger scales* (e.g., groupings of farms, embayments or sub-basins), and 2c) *resulting long-term and indirect exposures and effects* to bull trout and marbled murrelets; and, 3) effects to designated bull trout critical habitat.

Temporary Stressors, Resulting Exposures, and Effects

This portion of the Opinion discusses temporary stressors resulting from shellfish activities, and resulting short-term exposures and effects to bull trout and marbled murrelets.

Physical Disturbance

The physical disturbance that results temporarily from shellfish activities generally corresponds to two principle temporal regimes: the cycle of daily high and low tides; and, cycles of shellfish production (seeding, maintenance, and harvest). Most shellfish activities are conducted on or over the exposed or partially exposed intertidal bed. These activities, and their resulting temporary effects, therefore commonly have a temporal duration measured in hours. For example, activities conducted on intertidal shellfish beds (bed preparation, seeding or planting, maintenance, and harvest) typically occur during the 3- to 6-hour periods afforded by each low tide, or each daylight low tide (Corps 2015, p. 14). Consequently, most shellfish activities associated with ground-based culturing of oysters, clams, and geoduck are conducted as bouts of intermittent activity, with each bout lasting a few hours.

Other shellfish activities, including frosting or graveling, some methods of seeding and planting, mechanical harrowing, mechanical harvest, dive-harvest, and suspended culturing techniques, are conducted during periods of tidal inundation, and/or over the submerged subtidal bed. While some of these activities may be relieved or partially relieved of strict timing constraints, many still target specific tidal elevations and therefore proceed as bouts of intermittent activity.

The Corps has reported values, presented as acres per day, describing the typical (or average) physical extent of various shellfish activities (Corps 2015, p. 91). These values are reported for some of the more physically-intrusive or disruptive activities, including: frosting or graveling (1 acre/day); mechanical harrowing (5 acres/day); mechanical dredge harvesting (0.5 acre/day); mechanical, non-dredge harvesting (0.8 acre/day); longline harvest (0.125 acre/day); and, geoduck harvest (0.01 to 0.06 acre/day).

The Corps has stated the following (Corps 2015, p. 103):

> "[Shellfish] activities result in a pattern of effects on the environment that individually have varying levels of persistence, ranging from several days (e.g., temporary increases in suspended sediment) to many years (e.g., degraded eelgrass, leveling of substrate) … The proposed action [includes] initiation of aquaculture activities, and their pattern of effects, in the continuing fallow and new [acreages]."

Some shellfish activities clearly result in pronounced and intensive physical disturbance of the substrate, benthos, and/or submerged aquatic vegetation, including in some instances native eelgrass and/or rooted kelp. We would place pre-harvest, some methods of bed preparation (including mechanical leveling and frosting or graveling), and most methods of shellfish harvest in this category. However, many of the other activities associated with seeding or planting and maintenance are far less intrusive or disruptive. And, importantly, cycles of shellfish production (seeding, maintenance, and harvest) typically dictate that these less intrusive activities span durations of many months between bed preparation and harvest. The Corps reports (Corps 2015) that mussels are typically harvested at 12 to 14 months of age (p. 14), oysters at 18 months to 4 years of age (pp. 14, 20), clams at approximately 3 years of age (p. 25), and geoduck clams at 4 to 7 years of age (p. 33). During these intervening periods ("grow-out") less physically-intrusive or disruptive maintenance activities are the norm, with possible exceptions for removal of area or cover nets and mechanical harrowing.

Disturbance and Recovery from Disturbance in Estuarine Environments

"Estuarine communities have evolved to accommodate certain levels of physicochemical stress and disturbance. Benthic and epibenthic communities, in particular, have co-evolved in highly variable regimes of salinity, temperature, and substrate" (Simenstad and Fresh 1995, p. 43). Describing the Ecology of Eelgrass Meadows in the Pacific Northwest, Phillips (1984, pp. 12, 15, 16) observed "Eelgrass colonizes sediments varying from firm sand with moderate wave action to soft mud in quiet bays (Ostenfeld 1908; Phillips 1974). Plants have been found on gravel mixed with coarse sand where growth is patchy (Tutin 1938) … Intertidal plants [are] subjected to wide fluctuations in temperature, salinity, radiation, grazing, erosion, and wave action … Subtidal plants are relatively undisturbed physically and biologically."

Sousa (1984 *In* Simenstad and Fresh 1995, p. 43) defined disturbance as "…a discrete, punctuated killing, displacement, or damaging of one or more individuals (or colonies) that directly or indirectly creates an opportunity for new individuals (or colonies) to become established." Short and Wyllie-Echeverria (1996, p. 17) defined disturbance, whether natural or human-induced, as "…any event that measurably alters resources available to … [biota] so that a … response is induced that results in degradation or loss."

"The ability of estuarine communities to accommodate disturbance at low intensities … and to rapidly recover from occasional disasters, implies that they are … resilient … Although extreme events … may devastate benthic communities over the short term, the rate of recovery can be quite rapid (e.g., within 1 year)(Wolff 1973; Boesch *et al*. 1976; de Vlas 1982) as long as the perturbing factor does not persist" (Simenstad and Fresh 1995, p. 44). "The extent to which a particular disturbance alters structure or function and thereby affects recovery time depends on the frequency and/or duration of the disturbance (den Hartog 1971), the physiological condition of the plants, and the characteristics of the particular seagrass species involved (McRoy and Lloyd 1981; Zieman and Zieman 1989; Williams 1990; Alberte *et al*. 1994) … Additionally, recovery from disturbance can vary depending on the level of damage sustained" (Short and Wyllie-Echeverria 1996, p. 18). "The effect of physical disturbance on plant communities depends on the size, frequency, and intensity of disruption, and on ecological, physiological, and life history characteristics affecting ecosystem recovery (Pickett & White 1985)" (Neckles *et al*. 2005, p. 58).

Simenstad and Fresh (1995) reviewed the scale and intensity of disturbance, and the response of intertidal communities to aquaculture activities in Pacific Northwest estuaries. "Aquaculture … may disturb benthic-epibenthic habitats beyond natural intensities or frequencies, perhaps for years or decades. When scales of human disturbance exceed that of natural regimes … effects can potentially cascade … to affect production of other estuarine, marine, and anadromous populations" (Simenstad and Fresh 1995, p. 44). With their summary conclusions the authors emphasized three related themes:

> 1) "On a community scale, responses to chronic, low intensity or infrequent, intermediate intensity disturbances tend to be within the scope of behavioral or ecological adaptability of the flora and fauna … Dispersal of most epibenthic populations is often continuous and dynamic as a function of tidal advection and resuspension … [and] meiofaunal animals tend to have high … turnover rates that facilitate rapid recolonization" (p. 62).
>
> 2) "Subtle differences in the intensity of disturbance (e.g., amount of gravel added), the natural disturbance regime (e.g., tidal or wave resuspension and resorting of sediments), and other factors important to intertidal community structure (e.g., sedimentation rate) define [site-specific and] taxon-specific responses" (p. 63).
>
> 3) "Complex physicochemical and ecological linkages among estuarine organisms and communities can be altered over the long-term by persistent disturbances that exceed natural regimes … Large-scale disturbances, such as those associated with some intensive oyster practices, may induce chronic shifts in the benthic community by removing or reducing the influence of community dominants such as eelgrass or … [by] altering the apparent … relationship between them" (Simenstad and Fresh 1995, pp. 65, 66).

Dumbauld and McCoy (2015) recently reported the findings of a multi-year study evaluating model-predicted and actual landscape patterns of eelgrass distribution in Willapa Bay. The authors describe spatial and temporal patterns of fragmentation, loss, and recovery, and comparatively evaluate how these patterns relate to oyster culturing and harvest methods. "Our results demonstrate a negative effect of oyster aquaculture on the native seagrass … at the landscape scale in Willapa Bay … but also show that this impact is small compared to the overall signature of both *Z. marina* and oyster aquaculture in this estuary" (p. 37). "Eelgrass … appears to be resilient over both short and longer temporal periods and resistant to oyster aquaculture as a disturbance in this ecosystem" (p. 42). "Our research in Willapa Bay suggests that oyster aquaculture … is generally within the scope of existing 'natural' disturbances to the system (e.g. winter storms), and eelgrass is inherently adapted to this scale of disturbance … Bivalve aquaculture has not been implicated in shifts to alternate states or reduced adaptive capacity of the larger ecological system" (Dumbauld and McCoy 2015, p. 42).

Vanblaricom *et al*. (2015) recently reported the findings of a multi-site study evaluating the effects of geoduck harvest on benthic infaunal communities in the south Puget Sound. The authors use a treatment and control experimental design to describe spatial and temporal (i.e., seasonal) patterns of abundance and diversity, and to evaluate the effects of harvest both on and adjacent to cultured farm plots. The study found, "There was scant evidence of effects on the community structure … [and] no indications of significant 'spillover' effects of harvest on uncultured habitat adjacent to cultured plots" (p. 171). The authors suggest, "…a principal reason for the apparent insensitivity of resident infauna … is accommodation of the infaunal assemblage to a significant natural disturbance regime ... natural disturbances typical of the area provide a rate of physical intervention … substantially greater than rates of significant disturbance caused by geoduck aquaculture operations in a given plot" (p. 183). The authors suggest, "…the prevailing natural disturbance climate in the region has effectively selected the infaunal assemblage toward tolerance of and resilience to the types of disturbances associated with geoduck aquaculture operations," but also warn that "…the data may not provide a sufficient basis for unequivocal extrapolation to cases when a given plot is exposed to a long series of successive geoduck aquaculture cycles" (Vanblaricom *et al*. 2015, pp. 183, 184).

Physical Disturbance Resulting from Shellfish Activities

When discussing potential impacts and effects to vegetation, the benthic community, and habitat, the Corps has consistently emphasized that the magnitude and duration of effects vary depending on culture method, individual grower or husbandry practices, and environmental conditions (Corps 2015, p. 85, 87). We agree with the Corps and believe that the best available scientific information supports this conclusion.

Pre-harvest: Pre-harvest removes marketable product and removes, or more commonly relocates, undesirable species. For a period following pre-harvest, and until the cultured species and colonizing species become re-established, most cultured farm plots exhibit a benthic community that is reduced in abundance, biomass, and diversity (Corps 2015, p. 85; Straus *et al*. 2013, p. 20; Vanblaricom *et al*. 2015, pp. 171, 178, 180).

Frosting and graveling: Frosting and graveling are used to coarsen and firm the cultured farm plot's surficial substrates, but at the rates/amounts proposed we would not expect to see wholesale conversion of the substrate type. Simenstad *et al*. (1991 *In* Simenstad and Fresh 1995, p. 52) found that these practices can alter the benthic infaunal community, especially the dominant or co-dominant taxa, but unless there is total replacement of the natural substrate, effects to the epibenthic community (crustaceans and decapod crustaceans, mobile and sessile echinoderms, mobile and sessile gastropods, bottomfish, etc.) are less pronounced and often site-specific. The authors do acknowledge that (Simenstad and Fresh 1995, p. 50), "…the Washington Department of Fisheries has investigated differences in benthic infauna composition and densities at sites that have been graveled to enhance clam production … [and] their results (Washington Department of Fisheries 1988; Thompson and Cooke 1991; Thompson, 1995; Washington Department of Fisheries and Fisheries Research Institute, University of Washington unpublished data) indicate a shift away from communities numerically dominated by glycerid, sabellid, and nereid polychaetes [bloodworms, feather duster tube worms, and rag or clam worms] to ones dominated by bivalve molluscs and nemerteans [ribbonworms]."

Mechanical leveling and harrowing: Mechanical leveling and harrowing turn over the surficial substrates and shallow subsurface. This has measurable effects on the benthic community, particle size, sediment chemistry, nutrient status, and aspects of benthic-water column dynamics (Rhoads and Germano 1986, Newell 2004, Forchino 2010, Gutierrez *et al*. 2011). Leveling and harrowing of the bed may in some instances result in measurable impacts to submerged aquatic vegetation, including native eelgrass and/or rooted kelp.

Species richness and functional group diversity are inherent to undisturbed benthic systems, including within seemingly "barren" or "plain" sand and mud flats (Rhoads and Germano 1986, pp. 293, 294; Forchino 2010, pp. 16, 17; Gutierrez *et al*. 2011, pp. 39-45). Benthic communities are not static and the functional groups that dominate at points along the course of infaunal succession (Figure 37) influence important benthic ecosystem attributes, including secondary production, nutrient cycling, and hypoxia (Rhoads and Germano 1986, pp. 291, 298-301). "Infaunal 'ecosystem engineers' affect three-dimensional structure and thus the diversity of microhabitats in marine soft sediments … When infaunal organisms recruit into soft sediment habitats, they seek refuge by entering into the sediments and – in many cases – by producing shells, tubes, or burrows (Marinelli and Woodin 2002) … All these structures generate a remarkably more diverse environment within the sediment matrix relative to the originally smooth soft sediment" (Gutierrez *et al*. 2011, pp. 44).

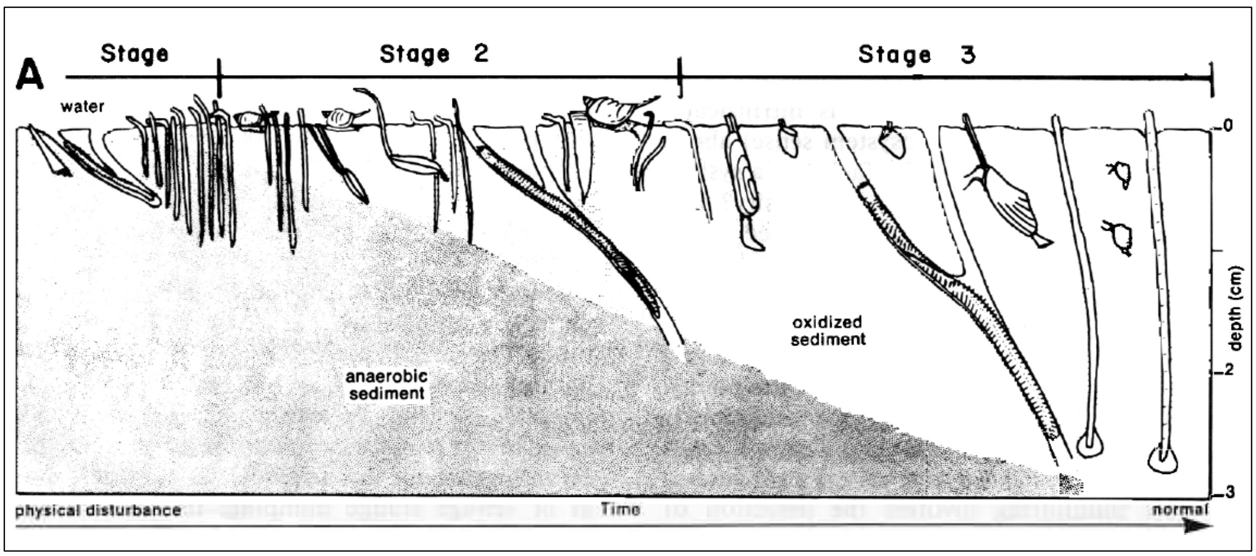

Figure 37. Development of organism-sediment relationships over time following disturbance (Rhoads and Germano 1986, p. 294)

Infaunal succession commonly requires years, and therefore benthic species assemblages and their functional relationships can be disrupted by disturbance. "[Disturbances that cause] long-term degradation … frequently involve the loss of equilibrium species … high-order seres are replaced by pioneering seres … [and] changes in organism-sediment relations and population dynamics accompany this change" (Rhoads and Germano 1986, p. 295).

Appendix D includes excerpts from Rhoads and Germano (1986), Forchino (2010), and Gutierrez *et al*. (2011); those fuller excerpts are incorporated here by reference.

Benthic microalgae, or microphytobenthos, "…are an important food source for both sessile and mobile benthic herbivorous meiofauna and macrofauna (Miller *et al*. 1996) … [these are], in turn, eaten by many carnivorous fish" (Newell 2004, p. 53). "In [the] Pacific Northwest … a number of economically-important fishes feed preferentially on specific taxa of intertidal soft-bottom meiofauna and small macrofauna. Of prime interest are juvenile chum, Chinook, and coho salmon that exhibit a high fidelity for shallow estuarine habitats. These fish feed on a restricted suite of epibenthic harpacticoid copepods, gammarid amphipods, [and] cumaceans … When feeding in estuarine habitats, particularly in eelgrass meadows and mud flats, juvenile chum salmon prey extensively on only a few taxa of harpacticoid copepods such as *Harpacticus uniremis*, *Tisbe* spp., and *Zaus* sp. (Healey 1979; Simenstad *et al*. 1982, 1988; D'Amours 1987, 1988) … A number of other species, including smelts ([Family] Osmeridae), sand lances ([Family] Ammodytidae), and sticklebacks ([Family] Gasterosteidae) also prey heavily on these same prey taxa … early in their life histories (Simenstad *et al*. 1988) … Similarly, amphipods such as *Corophium salmonis* and *C. spinicorne* and cumaceans are preyed upon extensively by juvenile Chinook salmon (Dunford 1975; Northcote *et al*. 1979; Levy and Northcote 1982; Simenstad *et al*. 1982) and by migratory waterfowl and shorebirds such as sandpipers and dunlin (*Caladris alpina*) … (Albright and Armstrong 1982; Baldwin and Lovvorn 1994)" (Simenstad and Fresh 1995, p. 63).

"Eelgrass rhizomes are buried from 3-4 cm (1.2-1.6 inches) up to 20 cm (8.0 inches) deep in sediment, depending on the sediment consistency. In firmer substrates, rhizomes may be only half as deep as in soft muddy substrates" (Phillips 1984, p. 9). "Significant injury to roots, rhizomes, and meristems is lethal to seagrass shoots" (Neckles *et al*. 2005, p. 58). "Eelgrass may … be impacted by dredging, harrowing, and leveling, all of which extensively disrupt surface sediments … destroy above-ground eelgrass shoots and leaves, and perhaps below-ground roots and rhizomes as well" (Simenstad and Fresh 1995, p. 54).

Mechanical dredge harvesting: Mechanical dredge harvesting is among the most physically-intrusive and disruptive of all the shellfish activities discussed in this Opinion. Dredge harvesting directly impacts submerged aquatic vegetation and its many important physical, chemical, biological, and habitat functions. These effects to ecological and habitat functions may persist for durations extending months or years. A later portion of this Opinion will examine the significance of these effects in greater detail (see *Persistent Stressors, Long Duration or Long-term Exposures and Effects, Effects to Nearshore Habitat Structure and Function*).

Geoduck harvest: Geoduck harvest (both dive and beach harvest) results in disturbance of the substrate and benthos. Studies conducted in the Pacific Northwest demonstrate that geoduck cultivation also results in measurable impacts to eelgrass. A 2-year experiment investigating seasonal effects of geoduck production at a site in the south Puget Sound found that the largest impacts (70 percent shoot loss) occurred during harvesting of the clams (Ruesink and Rowell 2012, p. 718).

Horwith (2013) investigated changes in eelgrass and infauna over a 5-year crop cycle in Samish Bay, located in the northern portion of Puget Sound. "Immediately following harvest … eelgrass remained patchily distributed within the farm (being present in 64 percent of quadrats), but where it was present, *Z. marina* was now 78 percent more dense in the unfarmed area ... Eelgrass was no longer present on the farm 1 year after harvest … following a period of heavy [algae] biofouling on the blanket nets" (Horwith 2013, p. 111). However, "…the first signs of recovery for eelgrass began 1 year after the removal of tubes and nets, and continued evidence for recovery appeared in the following year … Geoduck aquaculture practices do not appear to have made this site unsuitable for later recolonization by eelgrass" (Horwith 2013, p. 112). This too is a subject for a later portion of this Opinion (see *Persistent Stressors*, *Long Duration or Long-term Exposures and Effects, Effects to Nearshore Habitat Structure and Function*).

Exposures and Responses to Physical Disturbance (Bull Trout and Marbled Murrelet)

This sub-section has discussed physical disturbance with a focus on resulting potential effects to substrates, sediment size and chemistry, benthic biomass and diversity, and submerged aquatic vegetation. The effects discussed here, to physical, chemical, and biological conditions, are temporal and limited in both physical extent and duration.

Shellfish culturing and harvesting have direct and indirect effects to nearshore marine habitat structure, function, and productivity. These effects may have significance for how well these habitats support the essential behaviors and needs of listed species. However, when we consider the frequency, duration, and likely physical extent of temporary physical disturbances that result in temporary impacts on individual farms and cultured beds, it is difficult or impossible to establish that they alone are a recognizable and measurable cause for adverse effects to bull trout or marbled murrelets.

We conclude that temporary physical disturbance resulting from shellfish activities causes insignificant effects to bull trout and marbled murrelets. However, shellfish culturing activities and practices do have measurable effects to ecological and habitat functions, some of which are likely to persist for durations extending months or years. A later portion of this Opinion will examine the significance of these effects in greater detail (see *Persistent Stressors, Long Duration or Long-Term Exposures and Effects, Effects to Nearshore Habitat Structure and Function*).

<u>Water Quality</u>

The effects to water quality that result temporarily from shellfish activities generally correspond to the same two temporal regimes that were discussed above with reference to physical disturbance: the cycle of daily high and low tides; and, cycles of shellfish production (seeding, maintenance, and harvest). And, the preceding discussion of shellfish activities, their typical durations, and physical extent is the same that should inform our discussion here of effects to water quality and their significance.

Shellfish activities result in measurable, temporary impacts to water quality. While many, perhaps most, activities result in temporary effects that are localized, limited in physical extent, and low intensity, other culturing activities and practices (such as mechanical leveling, mechanical harrowing, frosting or graveling, and mechanical dredge harvesting) may have more pronounced and intensive impacts to water quality. The removal of biofouling in the field, from culturing equipment and materials, is another shellfish activity discussed here.

Activities that disturb the substrate create localized turbidity. Activities conducted at low tide, on the exposed or partially exposed intertidal bed, sometimes create turbidity when water re-floods the recently worked area (Corps 2015, p. 83). Activities conducted during periods of tidal inundation (e.g., frosting or graveling, mechanical harrowing and harvest, dive harvest) also create localized turbidity. Activities that disturb the substrate to some depth, that turn over the surficial substrates and shallow subsurface (e.g., mechanical leveling, harrowing, and harvest), have the potential to temporarily increase both turbidity and nutrients in the water column (Corps 2015, p. 83; Riemann and Hoffmann 1991, pp. 171, 176).

Where temporary impacts to water quality are concerned, our primary focus is on four biologically and behaviorally relevant water quality parameters: turbidity, DO, BOD, and nutrients (e.g., nitrogen and ammonium). Turbidity is an optical measure of water clarity, and an indirect measure or indicator of the amount of suspended material (clay, silt, sand, algae, plankton, etc.). Both DO and BOD relate to the availability of oxygen to support aerobic respiration. BOD is a measure of the dissolved oxygen necessary to break down organic materials present in a water sample. "Within the estuarine to coastal continuum, multiple nutrient limitations occur among nitrogen, phosphorus, and silicon along the salinity gradient and by season, but nitrogen is generally considered the primary limiting nutrient" (Rabalais 2002, p. 102).

Turbidity

Although few studies have specifically examined the issue as it relates to bull trout, increases in suspended sediment affect salmonids in several recognizable ways. The variety of effects may be characterized as lethal, sublethal, or behavioral (Bash *et al*. 2001, p. 10; Newcombe and MacDonald 1991, pp. 72-73; Waters 1995, pp. 81-82). Lethal effects include gill trauma and physical damage to the respiratory structures (Curry and MacNeill 2004, p. 140). Sublethal effects include reduced respiratory function and performance (Waters 1995, p. 84), increased metabolic oxygen demand (Servizi and Martens 1992), physiological stress reducing the ability of fish to perform vital functions (Cederholm and Reid 1987, pp. 388, 390), reduced feeding efficiency (Newcombe and MacDonald 1991, p. 73), and increased susceptibility to disease and other stressors (Bash *et al*. 2001, p. 6). Sublethal effects can act individually or cumulatively to reduce growth rates and survival over time. Behavioral effects include avoidance of preferred habitats, loss of territoriality, and related secondary effects to feeding rates and efficiency (Bash *et al*. 2001, p. 7). Fish may be forced to abandon preferred habitats and refugia, and may be exposed to additional hazards (including predators) when seeking to avoid elevated suspended sediment concentrations.

The marbled murrelet relies primarily on its sense of sight to visually identify, locate, and capture prey. "Marbled murrelets feed in shallow, nearshore waters (Sealy 1975b, Carter 1984), often opportunistically on locally abundant prey, mainly fish (Carter 1984) … Marbled murrelets forage within 500 m of shore in waters less than 30 m deep (Sealy 1975b) … mainly on

Euphausiids (*Thysanoessa spinifera*) during the [spring] … later Pacific sandlance (*Ammodytes hexapterus*) … along with smaller numbers of seaperch (*Cymatogaster aggregata*)" (Rodway *et al*. 1992, pp. 22, 23). "In Barkley Sound … distribution of [marbled] murrelets paralleled changes in the distribution of the principle prey, Pacific herring (*Clupea harengus*) and sandlance (Carter 1984) … Adults carried single fish, primarily sandlance, to nestlings, and less frequently herring and anchovy (*Engraulis mordax*)(Carter 1984, Carter and Sealy 1987a) … Prey selected for nestlings were larger than ingested prey" (Rodway *et al*. 1992, p. 23). While a related species, Kittlitz's murrelet (*B. brevirostris*), appears to favor and has specialized to take advantage of turbid, glacially-affected waters when foraging, the marbled murrelet does not show the same preference and may actively avoid turbid waters (Day, Prichard, and Nigo 2003, p. 680).

Dissolved Oxygen and Biochemical Oxygen Demand

Low DO levels, or hypoxia, can result in both bottom substrates and the water column when biological activity is high (including aerobic decomposition of organic litter and wastes). Some waterbodies exhibit seasonally low DO levels, which are generally attributable to excessive nutrients loads and enrichment, seasonally elevated temperatures, seasonal die-off and decomposition of organic materials, poor or incomplete flushing and mixing, or a combination of these factors. Some shellfish activities are conducted at locations and/or times of year when waterbodies already present less than ideal conditions.

The BOD created by feces, pseudofeces, and other decomposing organic materials consumes oxygen in the sediments and water column. And, as with their potential to temporarily increase turbidity and nutrients in the water column, shellfish activities that turn over the surficial substrates and shallow subsurface (e.g., mechanical leveling, harrowing, and harvest) may also expose and hasten the aerobic decomposition of litter and wastes. At least conceptually, this has the potential to increase BOD and temporarily suppress DO.

The Corps has reported that shellfish activities are noticeably concentrated in some sub-basins and embayments, including South Bay (Grays Harbor); Samish Bay; Sequim Bay; Discovery Bay and Kilisut Harbor (near Port Townsend); the Henderson, Eld, and Totten Inlets; Oakland Bay; upper Case Inlet; lower Hood Canal; Dabob Bay; and, Dyes Inlet. Some of these same sub-basins and embayments fail to consistently meet the State's surface water quality criteria (Ecology 2015). Portions of Sequim Bay, Discovery Bay, Henderson Inlet, Little Skookum Inlet (a portion of larger Totten Inlet), upper Case Inlet, Henderson Bay (upper Carr Inlet), and several portions of lower Hood Canal are listed on the State's 303(d) list of impaired water bodies for failing to consistently meet the DO criteria.

It is widely known that low or extremely low DO levels are a common cause for fish kills. However, there is less appreciation for the significant sub-lethal effects that can result from exposure to hypoxic conditions. Kramer (1987) has provided a useful summary review of fish behavioral responses to DO availability. As with exposure to high temperatures, exposure to hypoxic conditions frequently imposes a metabolic cost that results in less energy being available for locomotion and other basic functions which are important to growth and survival. DO levels indicate the "… amount of medium which must be ventilated in order to obtain a given amount of oxygen," and the increased ventilation rates that are required under hypoxic conditions place a burden on metabolic and energetic reserves (Kramer 1987, pp. 83, 85). Sustained swimming and effective escape movements also place demands on energy, and therefore predator avoidance and locomotion may be compromised under conditions of low DO availability (Kramer 1987, p. 85). Salmonids are considered "metabolic conformers," they exhibit a metabolic rate that is dependent upon environmental conditions, and therefore they are commonly understood to be less tolerant of high temperatures and/or hypoxia (Barnes *et al*. 2011, p. 397).

Exposures and Responses to Water Quality (Bull Trout and Marbled Murrelet)

This sub-section has discussed temporary impacts to water quality that result from shellfish activities. The effects discussed here, to physical, chemical, and biological conditions, are temporal and limited in both physical extent and duration.

The Corps has stated the following (Corps 2015, p. 92):

> "In the context of temporary impacts that occur with the activities, the relevance of frequency is dependent on recovery from the impact. Effects that diminish quickly such as increases in suspended sediment are minor in the context of a once per year frequency. The collective activities conducted on a particular acreage may increase this [effect or impact] to 3 or 4 times per year. Collectively the total … is still minor and on the order of days."

We agree with the Corps and believe that the best available scientific information supports this conclusion. But, before interpreting the potential significance of shellfish activities and their temporary impacts to water quality, we should acknowledge patterns of natural variability, the scale of natural events and their effects to water quality, and the confounding effects of concurrent, unrelated activities occurring in the same nearshore environments and watersheds.

It is widely acknowledged that both naturally occurring and cultured shellfish provide significant water quality improvement functions (Forrest *et al*. 2009, p. 5; Straus *et al*. 2013, pp. 16, 17). "High densities of suspension feeding bivalves can dramatically impact water quality in myriad ways (Newell 2004). Numerous studies have shown that filter-feeding bivalves can locally decrease phytoplankton abundance in both natural (Asmus and Asmus 1991, Cressman *et al*. 2003, Grizzle *et al*. 2006) and cultured settings (Strohmeier *et al*. 2005, Grizzle *et al*. 2006) … In addition to removing phytoplankton, bivalve filter feeding removes inorganic particles from the water column, reducing turbidity (Newell 2004). The reduced turbidity results in deeper light penetration, which can improve the condition for submerged aquatic vegetation, including seagrasses (Newell and Koch 2004, Straus *et al*. 2013, p. 16)." "Filter feeding also removes nitrogen and phosphorus from the water column, nutrients that may ultimately be removed from the ecosystem via the harvest of cultured bivalves … Thanks to this nutrient-removal capacity, bivalve aquaculture can improve water quality. Several authors have suggested aquaculture … to mitigate eutrophication pressure in coastal systems (Newell 2004, Lindahl *et al*. 2005, Zhou *et al*. 2006)" (Straus *et al*. 2013, p. 17).

Forrest *et al*. (2009, p. 5) have observed, "…the potential for adverse water quality-related effects … is low, which is perhaps not surprising considering that intertidal farm sites are substantially or completely flushed on every tidal cycle. Any water quality effects associated with … culture can … be minimized by appropriate site selection and farm design (e.g. ensuring … minimal retardation of flushing processes)." "For the most part … [water quality] conditions depend on interannual variability in oceanic boundary conditions, residence times in the different inlet and embayments, and the input of nitrogen into the system through [other] human activities" (ENVIRON International Corp. 2011, p. 41).

Shellfish culturing and harvesting have direct and indirect effects to nearshore marine habitat structure, function, and productivity. These effects may have significance for how well these habitats support the essential behaviors and needs of listed species. However, when we consider the temporary impacts to water quality that result from activities conducted on individual farms and cultured beds (i.e., their intensity, frequency, duration, and likely physical extent), it is difficult or impossible to establish that they alone are a recognizable and measurable cause for adverse effects to bull trout or marbled murrelets.

During 2008, the Service and NMFS approved a low-effect HCP developed in coordination with the DNR for their commercial geoduck fishery. That record of HCP approval indicates minor and small-scale effects resulting from elevated turbidity and sedimentation during harvest activities (Service Ref. No. PRT-TE187810-0). The Service stated, "…we do not expect this action to typically result in significant disruption of normal behavior patterns … disruption of the substrate … during geoduck harvest will have a temporary, negative impact on the benthic community … [but will] result in short-term effects … [and] significant disruptions to foraging bull trout are not anticipated" (USFWS 2009b, p. 133). The Service stated, "… [marbled] murrelets are mobile and will most likely avoid the harvest area … the small area of geoduck harvest [at any one time] … compared to the size of foraging areas [suggests] that murrelets will not have to move far to find food … the [Service] therefore has determined that the risk of impacts to murrelets due to harvest activities is likely to be very small or immeasurable" (USFWS 2009b, pp. 144, 145).

Taking into consideration both the geographic setting (i.e., an open water marine environment), and the intensity and duration of exposures, we conclude that temporary impacts to water quality resulting from shellfish activities are unlikely to significantly disrupt normal bull trout or marbled murrelet behaviors (i.e., the ability to successfully feed, move, and/or shelter). We conclude that temporary impacts to water quality resulting from shellfish culturing and harvest activities cause insignificant effects to bull trout and marbled murrelets. However, shellfish activities do have measurable effects to ecological and habitat functions, some of which are likely to persist for durations extending months or years. A later portion of this Opinion will examine the significance of these effects in greater detail (see *Persistent Stressors, Long Duration or Long-Term Exposures and Effects*).

Sound and Visual Disturbance

Shellfish culturing and harvest activities result in temporary elevated sound levels and visual disturbance. This disturbance corresponds to two principle temporal regimes: the cycle of daily high and low tides; and, cycles of shellfish production (seeding, maintenance, and harvest). Most shellfish activities are conducted on or over the exposed or partially exposed intertidal bed. These activities, and their resulting temporary effects, therefore commonly have a temporal duration measured in hours. For example, activities conducted on intertidal shellfish beds (bed preparation, seeding or planting, maintenance, and harvest) typically occur during the 3- to 6-hour periods afforded by each low tide, or each daylight low tide. Most shellfish activities associated with ground-based culturing of oysters, clams, and geoduck are conducted as bouts of intermittent activity, with each bout lasting a few hours. While some activities (e.g., frosting or graveling, mechanical harrowing, mechanical harvest, dive-harvest, and suspended culturing techniques) may be relieved or partially relieved of strict timing constraints, many still target specific tidal elevations and therefore proceed as bouts of intermittent activity.

In-Air and Underwater Sound

The Corps has described elevated sound levels that result temporarily from some typical shellfish activities and equipment (Corps 2015, pp. 86, 87). Small- and medium-sized work vessels and skiffs are used widely. These are generally powered with outboard motors, and produce in-air and underwater sound levels that are likely to exceed the ambient condition to a distance of a few hundred ft. Most of the other equipment used widely and extensively when conducting shellfish activities has a similar potential to elevate sound levels (e.g., gas-powered air compressors, hydraulically powered onboard equipment). Mechanical methods of bed preparation, maintenance, and harvest (e.g., mechanical dredge harvesting) typically use larger vessels and may produce more intense underwater sound levels. However, all of these sources of measurable in-air and underwater sound are non-impulsive, and even the loudest and most intense sounds resulting from shellfish activities are unlikely to exceed the ambient condition to a distance of more than 500 hundred ft.

Related or Additional Considerations for Marine Birds and Shorebirds

"Shellfish aquaculture typically occurs in shallow, nearshore waters, which also tend to harbor the greatest densities and diversity of marine birds. However, only a relatively small number of studies have evaluated the effects of shellfish aquaculture on birds" (Zydelis *et al*. 2009, p. 2). "Much of the literature to date has focused on marine waterfowl depredation of cultured bivalve stocks, which in turn sometimes leads to active disturbance or exclusion by shellfish farmers (Vermeer and Morgan 1989; Thompson and Gillis 2001; Caldow *et al*. 2004; Dionne 2004)" (Zydelis *et al*. 2009, p. 2).

"When disturbance does occur, birds compensate by moving elsewhere or by feeding at a greater rate during undisturbed periods of the day … birds move from adjacent bed … to bed … when large numbers of people occur there" (Goss-Custard and Verboven 1993, p. 64). "They can … habituate to people … though this depends critically on the extent to which the people move about … Anglers and the local … mussel pickers usually move rather little … having found a suitable place, they remain there for much of the tidal cycle … After the initial disturbance, the [birds] settle down and even feed nearby … Severe disturbance … usually arises if … pickers … give the birds little chance to settle down … The effects on most birds might be insignificant because they can adapt their foraging behavior" (Goss-Custard and Verboven 1993, p. 65).

More recently, and working with the same species (oystercatcher; *Haematopus ostralegus*), Stillman and Goss-Custard (2002, abstract, p. 358) observed the following: "We show how the response of overwintering oystercatchers … to disturbance is related to their starvation risk … As winter progresses … energy requirements increase and their feeding conditions deteriorate … they spend longer feeding and so have less time to compensate for disturbance … Their behavioral response to disturbance is less … These results have implications for studies which assume that a larger behavioral response means that a species is more vulnerable to disturbance … The opposite may be true … Studies should measure both behavioral responses and the ease with which animals are meeting their requirements."

Appendix D includes excerpts from Zydelis *et al*. (2009) and Goss-Custard and Verboven (1993); those fuller excerpts are incorporated here by reference.

Exposures and Responses to Sound and Visual Disturbance (Bull Trout and Murrelet)

This sub-section has discussed temporary impacts to the sound and visual environment that result from shellfish activities. The effects discussed here, to physical and biological conditions, are temporal and limited in both physical extent and duration.

Exposure to elevated non-impulsive sound may interfere with an organism's ability to perceive and respond to their environment, communicate, or engage in other important behaviors. For many years, the Service has used measures of sound intensity and duration to assess, describe, and interpret the significance of sound exposures and potential effects. However, in the Pacific Northwest, most of this work has focused on impulsive sound, including the sound produced by impact pile driving and underwater detonations.

Injury and mortality in fishes has been attributed to impact pile driving (Stotz and Colby 2001; John H. Stadler, NMFS, pers. comm. 2002; Fordjour 2003; Abbott *et al*. 2005; Hastings and Popper 2005). The injuries associated with exposure to these high underwater sound pressure levels (SPLs) are referred to as barotraumas, and include hemorrhage and rupture of internal organs, hemorrhaged eyes, and temporary stunning (Yelverton *et al*. 1973, p. 37; Yelverton *et al*. 1975, p. 17; Yelverton and Richmond 1981, p. 6; Turnpenny and Nedwell 1994; Hastings and Popper 2005).

Interpreting the significance of non-injurious sound exposures is more difficult. There is much uncertainty regarding the behavioral responses of fish to underwater sound. Measures of underwater sound expressed as "root mean square" (rms; root square of the energy divided by duration) are commonly used when evaluating behavioral effects. Turnpenny and others (1994) investigated the behavioral responses of brown trout (*Salmo trutta*), bass (*Micropterus*), sole (family Soleidae), and whiting (family Gadidae). An avoidance reaction was documented in brown trout when exposed to underwater SPLs above 150 dB_{rms}, and other reactions were observed at 170 to 175 dB_{rms} (e.g., a momentary startle). Turnpenny *et al*. (1994) referenced Hastings' "safe limit" recommendation of 150 dB_{rms}, and conclude that the safe limit provides a reasonable margin below the lowest levels where fish injury was observed. Feist *et al*. (1992) suggested that SPLs in this range (above 150 dB_{rms}) may disrupt the normal migratory behaviors of juvenile salmon. In a study conducted by Fewtrell (2003), responses observed in caged fish included alarm, changes to swimming speeds and group orientation, and movement toward the lower portions of the cage. Fewtrell (2003) also evaluated physiological stress responses (measures of plasma cortisol and glucose levels), but found no statistically significant changes.

Given the large amount of uncertainty, not only in extrapolating from experimental data to the field, but also between sound sources and from one species to another, the Service has generally applied thresholds analogous to the "lowest observed adverse effect level" used frequently in the field of toxicology.

The Corps has reported the source sound level for a 250-horsepower outboard motor when operating at full speed (approximately 147 dB_{rms} re 1 microPascal at 1 meter)(Wyatt 2008 *In* Corps 2015, p. 87). Wyatt (2008, pp. 59-62) has also reported source sound levels for the following: a 50-horsepower four-stroke outboard motor operating at 13 knots (approximately 166 dB_{rms} at 1 meter); a 90-horsepower outboard motor operating at idle and full speed (approximately 141 dB_{rms}, and 163 dB_{rms}, at 1 meter respectively); twin 210-horsepower inboard motors operating at idle and full speed (approximately 148 dB_{rms}, and 162 dB_{rms}, at 1 meter respectively); and a 450-horsepower motor operating at 12 knots (approximately 139 dB_{rms} at 30 meters).

Vessels and equipment used when conducting shellfish activities produce underwater sound levels that exceed 150 dB_{rms}, which has at least some potential to disrupt the normal behaviors of bull trout. However, other factors must also be considered. First, the small- and medium-sized work vessels and skiffs that are used most widely are unlikely to exceed 150 dB_{rms} when operating at low or moderate speeds. Second, larger vessels with larger motors, and small- to medium-sized work vessels operating at full speed, are unlikely to exceed 150 dB_{rms} to a distance of more than 100 ft. And third, vessels transiting to and from farms produce in-air and underwater sound levels that are transient and passing, lasting only a very short time at locations along the path of travel.

Taking into consideration both the geographic setting (i.e., an open water marine environment), and the intensity and duration of likely exposures, we conclude that underwater sound resulting from the operation of vessels, motors, and other shellfish equipment (e.g., gas-powered air compressors, hydraulically powered onboard equipment) is unlikely to significantly disrupt normal bull trout behaviors (i.e., the ability to successfully feed, move, and/or shelter). Resulting temporary impacts to the sound and visual environment are low intensity and limited in both physical extent and duration. We conclude that related exposures and effects to bull trout are insignificant.

The Service's work in the Pacific Northwest involving sound exposures and effects to marbled murrelets has focused on both underwater and in-air sound. Marbled murrelets typically forage in groups of two or more and are highly vocal on the surface when foraging (Speckman *et al*.

2003; Sanborn 2005). Conspecific vocalizations play an important role, and whether they are audible may influence foraging efficiency (SAIC 2012, p. 13). Based on field observations, it appears that the social foraging strategy employed by marbled murrelets requires adequate acoustic communication to distances up to 30 meters (98 ft)(SAIC 2012, p. 16). Hearing and hearing sensitivity are also important to predator detection and avoidance.

When hearing sensitivity is reduced, the measurable effect is referred to as threshold shift (TS). There are varying levels or degrees of TS, the amount and duration of which are correlated to the duration and intensity of sound exposures (SAIC 2012). When associated with actual injury (e.g., physical damage to the hair cells), either permanent TS or temporary TS can result. A TS ≥40 dB is generally indicative of injury (SAIC 2012). However, TS occurs whenever the auditory system processes acoustic stimuli, and some amount of TS is inconsequential because it is effectively truncated by the masking effect of ambient sound. If TS is below the ambient sound it is inconsequential; the ambient sound itself interferes with signal perception (SAIC 2012).

Masking occurs when a sound interferes with the perception of a signal of interest. Masking is assessed by considering the critical ratio, the difference (measured in dB) between a hearing threshold and the masking noise. Critical ratios are documented for a number of bird species (Dooling *et al*. 2000). In general, a signal at specific frequency must be approximately 25 dB above the ambient sound level to be detected by a bird.

The keer call of the marbled murrelet is relatively loud; the source level is approximately 95 dB_{rms}, with the majority of the energy centered at 3 kHz. The Service, working with a panel of experts (SAIC 2012), has estimated ambient in-air sound levels for industrialized and non-industrialized marine shoreline areas, and has adjusted those estimates downward to arrive at ambient in-air sound levels centered at 3 kHz. When adjusted downward, the ambient in-air sound level for non-industrialized marine shoreline areas is approximately 15 dB (SAIC 2012). Based on this work, the Service has concluded that non-injurious TS (<40 dB) occurring in the marine environment would not generally have a measurable effect on marbled murrelet behaviors; the effect of ambient sound levels on signal perception would be greater than that of TS (SAIC 2012). The Service also concluded that a TS <40 dB will not generally interfere with predator detection.

Marbled murrelets exposed to elevated underwater and in-air sound levels resulting from the operation of vessels, motors, and other shellfish equipment (e.g., gas-powered air compressors, hydraulically powered onboard equipment) will not experience TS ≥40 dB, and non-injurious TS (<40 dB) occurring in the marine environment is unlikely to significantly disrupt normal marbled murrelet behaviors (i.e., the ability to successfully feed, move, and/or shelter). In-air sound levels may mask marbled murrelet vocalizations to a distance of 100 to 200 ft. However, these exposures will be transient and passing; at a given location, they are unlikely to significantly interfere with conspecific vocalizations and social foraging, and will not interfere with predator detection and avoidance.

However, marbled murrelets are also sensitive to visual disturbance, and there is information to suggest that sound and visual disturbance experienced in the marine environment may have implications for the energetics of some individuals (Speckman, Piatt, and Springer 2004; Agness *et al*. 2008). Appendix D includes excerpts from Speckman, Piatt, and Springer (2004) and Agness *et al*. (2008); those excerpts are incorporated here by reference.

Like most other birds that utilize the nearshore marine environment, marbled murrelets are accustomed to at least low levels of human activity. Many, perhaps most, individuals are unlikely to leave, or discontinue foraging, in response to the sound and visual disturbance that results temporarily from shellfish activities. However, it is also possible that some breeding adults may incur added energetic costs associated with avoidance diving and flights, or as a result of failed prey deliveries and bouts of repeated foraging. There is information to suggest that lower vessel speeds could reduce the frequency and/or severity of adverse responses.

On balance, however, when considering the transient and low intensity nature of sound and visual disturbances resulting temporarily from shellfish activities, and in light of the fact that most shellfish activities are conducted on or over the exposed or partially exposed intertidal bed, the Service expects that the majority of foraging marbled murrelets will typically resume their activity with nothing more than a short delay. Furthermore, those shellfish activities that are conducted during periods of tidal inundation, and/or over the submerged subtidal bed (e.g., frosting or graveling, mechanical harrowing, mechanical harvest, dive-harvest, and suspended culturing techniques), are all either stationary or proceed at slow or moderately-slow vessel speeds.

Available information indicates that marbled murrelets will be exposed to temporary sound and visual disturbances resulting from shellfish activities. However, taking into consideration both the geographic setting (i.e., an open water marine environment), and the intensity and duration of likely exposures, we conclude that sound and visual disturbance resulting from shellfish activities is unlikely to significantly disrupt normal marbled murrelet behaviors (i.e., the ability to successfully feed, move, and/or shelter). Resulting temporary impacts to the sound and visual environment are low intensity and limited in both physical extent and duration. We conclude that related exposures and effects to marbled murrelets are insignificant. Exposures with the potential to cause direct injury, or measurable adverse effects to energetics, growth, fitness, or long-term survival, are extremely unlikely and therefore considered discountable.

This general conclusion regarding shellfish activities does not extend to the practice of intentionally hazing wildlife. When and where farm operators take measures to intentionally haze wildlife, those practices, resulting potential exposures, and outcomes may be quite different (see the sub-section that follows, *Intentional Hazing of Wildlife*).

<u>Intentional Hazing of Wildlife</u>

The Corps has not collected or provided information to describe practices that represent intentional hazing of wildlife. However, the Service is aware of information indicating that some growers and farm operators engage in such practices.

Content from the Pacific Coast Shellfish Growers Association's (PCSGA) Environmental Codes of Practice states the following (PCSGA 2011, pp. 60-67):

> "Pest and Predator Controls. Control methods may include benign forms of prevention such as planting at times when predation is least likely to occur … Netting and other predator exclusion devices may be used … especially during [the] most vulnerable, juvenile, stage … In extreme cases, where other methods have failed, pests and predators may be destroyed … the lowest impact control methods should be used first, graduating on to higher impact methods only as needed" (p. 60).
>
> "Netting and hand removal [or relocation] are the two most common methods utilized for control [of oyster drills, starfish, and moon snails]" (p. 61).
>
> "In some areas, predation by [waterfowl] is significant, especially Scoter ducks [(*Melanitta* sp.)] … Passive measures including … fencing … tubes and netting are the preferred methods … Hazing is also used with some degree of success" (p. 61).
>
> "Marine Mammals. Most marine mammals do not prey on cultured shellfish … The only known cases … involve sea otters [(*Enhydra lutris*)] … Interactions with marine mammals can have serious consequences for shellfish farmers. Harassment of marine mammals is not allowed by the [Marine Mammal Protection Act], effectively prohibiting a farmer … from even scaring away [marine mammals]" (p. 64).
>
> "Objective: Develop and Use an Integrated Pest Management Program. Suggested Strategies: … 4) Schedule farm activities to coincide with times when birds are most likely to be present … 5) Implement "scaring" or hazing techniques on sites prone to bird predation, prior to production of any shellfish and immediately upon arrival of early migrating birds" (PCSGA 2011, p. 67).

Gorenzel and Salmon (2008) have reviewed available techniques and strategies for hazing and dispersing birds. They present information and recommendations on the use of propane cannons, pyrotechnics, and other sound-making devices; biosonics (e.g., distress or alarm call generators); visual scaring devices (e.g., mylar tape, lasers); chemical repellants; manned patrols on-foot or vehicle; and, hunting. Key points of emphasis include the following:

> "The species present … will in part determine the types of hazing equipment that can be used. Certain hazing techniques are very effective in deterring certain species, but could be completely ineffective and sometimes counterproductive with other species" (p. 2).
>
> "The key elements in any strategy to haze birds are timing, organization, variation, and persistence … Variation, the use of a variety of hazing techniques, whether in combination or in rotation … helps prevent or delay the onset of habituation … To be successful, the hazing operation must be diligently applied [and] dynamic" (Gorenzel and Salmon 2008, p. 10).

Gorenzel, Conte, and Salmon (1994) have prepared guidance for the control of bird damage at aquaculture facilities. In addition to the auditory and visual hazing and deterrent techniques mentioned above, they provide additional guidance regarding a potential role for trapping and shooting (i.e., hunting):

> "All fish-eating birds that frequent aquaculture facilities are classified legally as migratory and thus are protected by federal, and in most cases, state laws" (p. E-10).
>
> "A permit is not needed to physically or mechanically exclude any fish-eating bird … Except for … species such as the bald eagle [(*Haliaeetus leucocephalus*), which is protected under the Bald and Golden Eagle Protection Act], a permit is not required to harass or scare fish-eating birds" (p. E-10).
>
> "In recent years more incidences of aquaculture-related bird depredation cases have been reported, and increased legal action has been directed against growers charged with wildlife violations. Because of the severe legal consequences, it is highly recommended that a grower have knowledge of all these factors and proceed through the proper permit process before taking action against depredating species" (Gorenzel, Conte, and Salmon 1994, p. E-10).

Similar guidance and suggestions have been offered more recently (Tucker and Hargreaves eds. 2008, p. 212): "When all measures to disperse birds using nonlethal techniques have been exhausted, farmers may consider … killing birds to reinforce the fear of nonlethal measures. Depredation permits are required from the USFWS, and in some states from the state wildlife agency, to kill almost any species of bird. For currently applicable laws, contact the nearest USDA Wildlife Services or USFWS office."

Appendix D includes excerpts from Gorenzel, Conte, and Salmon (1994), Gorenzel and Salmon (2008), and Tucker and Hargreaves (eds. 2008); those fuller excerpts are incorporated here by reference. Appendix D also includes related information obtained from the Service's Pacific Region Migratory Birds and Habitat Program (USFWS 2016).

Exposures and Responses to Intentional Hazing (Bull Trout and Marbled Murrelet)

It is extremely unlikely that bull trout will be exposed to stressors as a result of intentional hazing of wildlife. Exposures and resulting effects to bull trout are extremely unlikely, and therefore considered discountable.

Entranco, Inc. and Hamer Environmental (2005) have reported outcomes from a program of intentional hazing implemented in conjunction with marine construction at the Hood Canal Bridge. A program of intentional hazing was implemented in an effort to keep marbled murrelets from diving or otherwise approaching ongoing construction activities that included impact pile driving. This work was conducted in compliance with the terms and conditions of a Biological Opinion addressing the construction activitiy and program of intentional hazing. Entranco, Inc. and Hamer Environmental (2005) reported very little success at keeping marbled murrelets (and other seabirds) away from the construction activity. Intentional hazing did not prevent the majority of birds from foraging, diving, and approaching the ongoing marine construction. Appendix D includes excerpts from Entranco, Inc. and Hamer Environmental (2005); those excerpts are incorporated here by reference.

Other than this one example (Entranco, Inc. and Hamer Environmental 2005), the Service knows of no other instances where marbled murrelets have been intentionally and systematically hazed in the marine environment. However, the work reported by Speckman, Piatt, and Springer (2004) and Agness *et al*. (2008), which is discussed in the preceding sub-section (see *Sound and Visual Disturbance*), does indicate that some breeding adults could incur added energetic costs associated with avoidance diving and flights, or as a result of failed prey deliveries and bouts of repeated foraging.

Unfortunately, the Service has little information to inform an assessment of potential exposures and effects to marbled murrelets resulting from intentional hazing conducted on shellfish farms. For example, there is no information to meaningfully describe where and how often murrelets may be exposed to hazing practices, and what measurable outcomes may result for individuals.

Available information suggests that exposure of marbled murrelets to intentional hazing is likely to occur very infrequently, if at all. We conclude that exposures are not discountable ("extremely unlikely"). However, the Service is not able to demonstrate that potential exposures to hazing are reasonably certain to result in a significant disruption of normal behaviors (i.e., the ability to successfully feed, move, and/or shelter); measurable adverse effects to energetics, growth, fitness, or long-term survival; or, direct injury or mortality.

Growers and farm operators who engage in intentional wildlife hazing should educate themselves and understand their liabilities under the Migratory Bird Treaty Act, Bald and Golden Eagle Protection Act, and ESA. Non-injurious and non-lethal methods must be implemented (and documented) before the issuance of a Depredation Permit is an option. Growers and farm operators should consult with the Service and U.S. Department of Agriculture (Animal and Plant Health Inspection Service, APHIS) before engaging in any practice that may represent an enforceable violation under federal or State law.

Physical Entrapment and Stranding

The Corps has acknowledged the potential for physical entrapment or entanglement of fish and wildlife in shellfish culturing equipment (Corps 2015, pp. 86, 110). The Corps and Services developed conservation measures to address related, potential impacts, and the Corps has included the conservation measures in their proposed action (Corps 2015, pp. 49-53).

The Corps has stated (Corps 2015, p. 86):

> "Area nets used for clam and geoduck culture could potentially entrap fish, birds, or other aquatic species if they become loose or dislodged … [However,] under the proposed action … nets must be tightly secured to the substrate, maintained, and periodically inspected in accordance with the Conservation Measures. This should minimize [the Service would suggest "reduce"], but not necessarily eliminate, the number of loose or dislodged nets."

The Corps has included conservation measures addressing storage and security of culturing equipment on the tidelands (conservation measure No.s 11, 18, and 19), and addressing patrols to locate and remove debris (conservation measure No. 22)(Corps 2015, pp. 49-53). Farm plots are patrolled by crews on a regular basis. Culturing equipment, not limited to nets, bags, racks, stakes, longlines, tubes, anchors, screens, socks, ropes, and wires, are all routinely inspected to ensure that they remain secure.

Although the Corps has included a number of conservation measures addressing the security of culturing equipment (Corps 2015, pp. 49-53) and many growers and farm operators invest significant time and resources to prevent the loss of equipment, the Service is aware of information documenting instances where equipment such as nets and tubes have become dislodged and moved from farmed areas by wind and waves. For example, as recently as January 2015, the Corps and Service received information from a concerned member of the public regarding a large quantity of discarded or dislodged and freely floating geoduck tubes on Squamish Harbor, Hood Canal (P. Sanguinetti pers. comm. 2015)(Figure 38).

The Virginia Eastern Shorekeepers (Ayers 2006) looked at the distribution of lost, discarded, and abandoned clam nets on the Atlantic barrier islands, and made observations regarding their effects on substrates, vegetation, and nesting and migratory birds. They report (Ayers 2006, pp. 8, 9): "…there was a 41 percent reduction in the amount of clam net found on the barrier island beaches … from spring 2004 to autumn 2006"; "there was no evidence of clam net disrupting or disturbing any nesting birds … [and] no observed impacts on any mammals, reptiles, or amphibians … there has been an anecdotal report of diamondback terrapins [*Malaclemys terrapin*] trapped in net, but no evidence was produced to support this [claim]." Grower education and public involvement have played a constructive role (Figure 39). Appendix D includes excerpts from Ayers (2006); those excerpts are incorporated here by reference.

Figure 38. Unsecured culturing equipment; Squamish Harbor, Hood Canal
(P. Sanguinetti pers. comm. 2015)

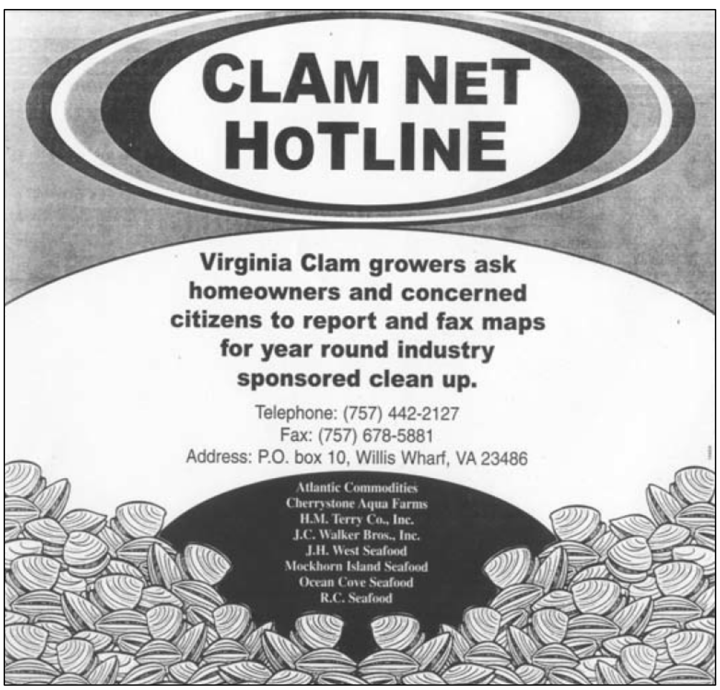

Figure 39. Image of a "Clam Net Hotline" newspaper advertisement
(Ayers 2006, p. 14)

The PCSGA and member growers/farm operators organize and conduct beach cleanups in the south and north Puget Sound (PCSGA 2016). According to the PCSGA, “Twice a year, shellfish farmers conduct beach cleanups near their farms, collecting tons of debris, the vast majority of which is not related to shellfish farming … [A recent] effort recovered five dump truck loads of debris – 85 percent of which had nothing to do with shellfish farming … Most of the debris recovered by … fourteen shellfish companies was … ‘junk’ … [including] chunks of styrofoam … [and] tires.” The PCSGA maintains and monitors a marine debris hotline (PCSGA 2016).

Historically, some oyster growers have used anchored vertical fencing or nets (drift fences or oyster corrals) to stabilize and prevent oysters and oyster shell from being moved off the cultured bed. Available information suggests this practice was never widely used in Washington State, and the Corps’ programmatic consultation does not provide coverage for the practice or activity; use of drift fences or oyster corrals is specifically excluded from coverage under the Corps programmatic consultation (Corps 2015, p. 39).

The use of berms or dikes constructed on the upper intertidal bed is a practice of historical but little apparent contemporary significance (Simenstad and Fresh 1995, pp. 46, 48). The Corps has stated that their programmatic consultation will not provide coverage for the construction of new berms or dikes, or “…the maintenance of current, authorized berms or dikes” (Corps 2015, p. 39). Despite the Service’s efforts to communicate concerns related to this practice (i.e., the risk of fish stranding, entrapment, and mortality), the Corps has declined to provide any relevant information to describe the ongoing use and prevalence of berms or dikes on the upper intertidal bed.

The Corps has included a conservation measure which the Service hopes and expects will collect and compile better, more comprehensive information to describe instances of fish and wildlife entrapment, entanglement, and stranding. Conservation measure No. 23 requires the following for all permitees seeking coverage under the programmatic Opinion (Corps 2015, p. 52):

> “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 a fish, bird, or mammal is found entangled, the grower shall: 1) provide immediate notice (within 24 hours) to WDFW (all species), the Services (ESA listed species), or the 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.”

Anti-predator netting presents the most obvious potential for physical entrapment or entanglement of fish and wildlife. Where clams and/or oysters are cultured directly on the intertidal bed (bottom culture), anti-predator cover nets are frequently installed over a portion, or all, of the planted area. These nets may be composed of either plastic or organic fibers, and are typically anchored at the periphery with embedded rebar or metal staking. Some growers bury the net edges, or weigh-down the edges with a lead line. Once placed over a seeded clam bed, anti-predator cover nets typically remain in place until harvest.

Geoduck culturing practices also use nets and tubes on the intertidal bed to prevent and minimize losses of seed and immature clams. Many, perhaps most, geoduck growers and farm operators install large, anti-predator, cover nets over the entire field of tubes. Cover nets minimize predation losses, but also serve to prevent tubes from becoming dislodged.

Oysters and mussels are both grown in Washington State using methods that suspend nets, screens, socks, ropes, wires, and/or longlines from floating rafts and buoys. Anti-predator exclusion nets are typically hung around the perimeter of the rafts. Depending on the farm location, these nets may only be necessary on a seasonal basis. Anti-predator, cover and exclusion nets are available from a variety of commercial sources, in varying mesh size and dimensions (Washington Sea Grant 2005, pp. 10, 17). Mesh size varies by application and/or preference, typically ranging from ¼ x ¼ inch to ¾ x ¾ inch or larger.

The Service is aware of anecdotal information suggesting that fish (especially small schooling fish) and wildlife do occasionally become entrapped or entangled in culturing equipment, including anti-predator cover and exclusion nets. Unfortunately, it appears that most instances have not been well-documented, and State and/or federal fish and wildlife authorities have rarely been contacted in Washington State. In most cases it seems plausible, indeed highly likely, that entrapped or entangled birds and marine fish quickly fall victim to predation, or are scavenged, and little or no evidence of the event may persist after only a short time.

Concerned citizens have documented instances of entrapment involving larger vertebrates, including birds. An instance of bald eagle (*Haliaeetus leucocephalus*) entrapment was reported to the advocacy group *ProtectOurShoreline.org* (Protect Our Shoreline 2015). Photos and a short narrative document the events (Figure 40), said to occur on July 23, 2006, wherein a juvenile bald eagle was observed by citizens to be caught and entrapped by an anchored geoduck net on the exposed intertidal bed off Harstene Island, Washington. The eagle is reported to have been exhausted, but not injured. Incapable of flight for a period of time, it appears the eagle became repeatedly entrapped or entangled as it attempted to walk across the geoduck net (Protect Our Shoreline 2015).

Another, similar instance of bald eagle entrapment was reported recently, during October 2014 (P. Sanguinetti pers. comm. 2014). A concerned citizen reported to the Corps that multiple eye witnesses observed a bald eagle and scoter entangled by nets on the shores of Henderson Bay (near Burley Lagoon), upper Carr Inlet, Washington. It appears, in these cases, that eye witnesses observed the animals struggling, but ultimately both succeeded in releasing themselves and did not require rescue (P. Sanguinetti pers. comm. 2014). These examples present evidence, albeit incomplete, that the risk of physical entrapment or entanglement is real and not hypothetical.

Figure 40. Juvenile bald eagle caught in anti-predator net on Harstene Island, Washington
(Protect Our Shoreline 2015)

Bendell (2015) reviewed the efficacy and impacts of anti-predator netting used on intensively farmed British Columbia tidelands, including Baynes Sound:

> "While there are studies which have addressed the effectiveness of [anti-predator netting] (APN) in the exclusion of crabs, there are few that have addressed the effectiveness of APN in preventing clam predation by sea ducks and shore birds. In Puget Sound, Taylor Shellfish report that significant losses would occur without the use of APN (Bill Dewey, pers comm. April 2014). But, the lines of evidence for Baynes Sound, BC and clam farming regions in Europe suggest differently" (p. 23).
>
> "Nets do not effectively exclude epibenthic predators such as crabs and fish. Indeed the findings of Bendell (2014) indicate that seeding is acting as an attractant for bivalve predators such as small fish and crabs … Poor husbandry of the nets results in gaps in the APN allowing for predation. Nets are often in disarray and not firmly attached" (p. 24).
>
> "Nets … wash up on shore [and present] hazards to humans and wildlife alike … APN entrains wildlife and poses a real threat to forage fish, such as [Pacific] herring, which use the intertidal regions for spawning [Figure 41]" (Bendell 2015, pp. 25, 26).

Figure 41. Marine forage fish entrapped in anti-predator netting
(Bendell 2015, p. 26)

Related or Additional Considerations (Ingestion of Plastics and Microplastic Pollution)

Shellfish culturing activities commonly place a significant amount of plastic material onto the tidelands (platic tubes, ties, nets, bags, etc.). These materials are subject to tidal, wind, and wave action that may in some instances dislodge and remove them from farm locations. These materials also breakdown in the marine environment and can become a source of microplastic pollution.

According to Moore (2014, pp. 207, 208), "The equipment used for both aquaculture and capture fishing up until the 1960s consisted of metal, wood, and natural fibers … The plastic age ushered in materials so resistant to natural decay that lost plastic aquaculture gear can last for centuries … Plastic exposed to sunlight becomes embrittled, principally through photodegradation and the leaching of monomeric conditioning agents into the surrounding water, and eventually breaks into bite-sized bits that last far longer than natural materials."

Moore (2014, pp. 208, 213, 214) claims that "…evidence from remote beaches and the high seas implicates aquaculture as a significant contributor to the ocean's plastic load," and bottom trawl survey estimates document tens of thousands of displaced geoduck tubes in the south Puget Sound alone. "The enormous amount of uncovered expanded polystyrene docks and floats used in aquaculture, and its tendency to readily fragment, means that untold trillions of particles the size of plankton and fish eggs are becoming a part of the marine food web" (Moore 2014, p. 215).

Davis and Murphy (2015) have summarized results of two independent studies evaluating the abundance of anthropogenic debris on beaches bordering the Salish Sea in Washington State and plastic debris in surface waters of the Salish Sea and the Inside Passage to Skagway, Alaska:

- "No previous studies have broadly documented plastic in enclosed waters of western North America with substantial urbanization [such as the Salish Sea], or the transboundary waters of the Inside Passage of Washington, British Columbia, and Alaska" (p. 169).

- "Both studies concluded that foam, primarily expanded polystyrene was the dominant pollutant … Plastic was found in surface waters the full length of the Inside Passage but was concentrated near harbors" (p. 169).

- "Anthropogenic debris was found in 363 of 402 quadrats (90.3 percent) … Foam comprised nearly 70 percent of the total count of anthropogenic debris … Plastic fragments and glass followed with approximately 11 percent each … 77 percent of the total count was microdebris … By weight plastic fragments and glass dominated with 37 percent and 32 percent of the total, respectively … Other components accounted for an additional 17 percent and foam was just under 7 percent … While microdebris dominated the count, it was only about 8 percent of the total weight" (p. 173).

- "Foam, virtually all of it expanded polystyrene, dominated the anthropogenic debris found in samples of surface water collected in the Inside Passage … Microfoam accounted for 94.7 percent of all anthropogenic debris collected, with another 1.4 percent being macro foam … Expanded polystyrene foam was particularly common in the vicinity of harbors/marinas the full length of the Inside Passage and low in remote areas" (p. 174).

- "Williams *et al*. (2011) assessed … [patterns] in coastal British Columbia … [and found] the most abundant types of debris detected were Styrofoam (48.8 percent), plastic bottles (14.7 percent), plastic grocery bags (10.5 percent), and fishing gear (6.3 percent) … It is interesting that, as in our studies, foam was by far the dominant pollutant" (Davis and Murphy 2015, pp. 175, 176).

Cole *et al*. (2011) have reviewed available literature examining microplastics as contaminants in the marine environment; they report the following:

- "Secondary microplastics describe tiny plastic fragments derived from the breakdown of larger plastic debris, both at sea and on land (Ryan *et al*. 2009; Thompson *et al*. 2004) … Over time a culmination of physical, biological, and chemical processes can reduce the structural integrity of plastic debris, resulting in fragmentation (Browne *et al*. 2007)" (p. 2589).

- "Owing to their small size, microplastics are considered bioavailable to organisms throughout the food-web … Their composition and relatively large surface area make them prone to adhering waterborne organic pollutants and to the leaching of plasticisers that are considered toxic … Ingestion of microplastics may therefore be introducing toxins to the base of the food chain, from where there is potential for bioaccumulation (Teuten *et al*. 2009)" (p. 2589).

- "Plastic debris on beaches … have high oxygen availability and direct exposure to sunlight … will degrade rapidly, in time turning brittle, forming cracks and ''yellowing'' (Andrady 2011; Barnes *et al*. 2009; Moore 2008) … With a loss of structural integrity, these plastics are increasingly susceptible to fragmentation resulting from abrasion, wave-action, and turbulence (Barnes *et al*. 2009; Browne *et al*. 2007) … This process is ongoing, with fragments becoming smaller over time until they become microplastic in size (Fendall and Sewell 2009; Rios *et al*. 2007; Ryan *et al*. 2009)" (p. 2590).

- "Plastics consist of many different polymers and, depending on their composition, density and shape, can be buoyant, neutrally buoyant or sink … As such, microplastics may be found throughout the water column" (p. 2592).

- "Incomplete polymerisation during the formation of plastics allows additives to migrate away from the synthetic matrix of plastic … Commonly used additives, including polybrominated diphenyl ethers, phthalates and the constituent monomer bisphenol A, are renowned for being endocrine-disrupting chemicals as they can mimic, compete with or disrupt the synthesis of endogenous hormones (Talsness *et al*. 2009)" (p. 2595).

- "A range of marine biota, including seabirds, crustaceans, and fish, can ingest microplastics (Blight and Burger 1997; Tourinho *et al*. 2010) … In all these examples, animals might have ingested microplastics voluntarily, which they confuse for their prey … Alternatively, microplastic ingestion may result from eating lower trophic organisms that have themselves consumed microplastics (Browne *et al*. 2008; Fendall and Sewell 2009)" (Cole *et al*. 2011, p. 2594).

Lindborg *et al*. (2012) analyzed dietary habits and the presence of plastic in glaucous-winged gulls (*Larus glaucescens*) from the Salish Sea; they report the following:

- "Glaucous-winged gulls are common seabirds in the Salish Sea (USA), Washington, whose plastic ingestion has not been well documented … Glaucous-winged gulls are omnivorous opportunists that feed on forage fish, invertebrates, and other birds (Trapp 1979; Schmutz and Hobson 1998)" (p. 2351).

- "Plastics comprise a notable but not dominant portion of gull bolus material, with 12.2 percent of collected boluses containing plastic … dominated by plastic film of the type used in plastic bags and wrappers … Hard plastic fragments were found in 4.1 percent of all boluses … [and] Filaments (such as fishing line), foam (such as polystyrene), and pre-production pellets were found less frequently, in 1.4 percent, 1.4 percent and 0.5 percent of all boluses, respectively" (p. 2353).

- "[The] Impact of ingestion of large quantities of plastic on gulls is at present unknown … While gulls regurgitate indigestible materials, Procellariiformes [albatross and petrels] in general do not" (Lindborg *et al*. 2012, p. 2355).

Avio *et al*. (2015) have examined microplastic pollutant bioavailability and toxicological risk for marine mussels:

- "Ingestion of microplastics has been demonstrated in various marine organisms with different feeding strategies; this phenomenon may negatively influence both the feeding activity and nutritional value of a plankton-based diet, particularly in those species which can not discriminate the food source (Moore *et al*. 2001; Browne *et al*. 2008)" (p. 211).

- "Recent evidences also suggest the potential role of microplastics as vectors of chemical pollutants, either used as additives during the polymer synthesis, or adsorbed directly from seawater (Rios *et al*. 2007; Teuten *et al*. 2009; Engler 2012)" (p. 211).

- "The results [here] … obtained with exposed mussels provide the first clear evidence that pyrene adsorbed on contaminated microplastics was transferred to organisms and concentrated in tissues … Significant immunological effects were observed … [and] Exposure to microplastics also determined the onset of various forms of genotoxicity" (Avio *et al*. 2015, pp. 218, 220).

Cauwenberghe and Janssen (2014) have examined microplastics found in bivalves cultured for human consumption:

- "Bivalves are of particular interest since their extensive filter-feeding activity exposes them directly to microplastics present in the water column" (p. 66).

- "Our results show that microplastic particles are present in shellfish, more specifically bivalves, cultured for human consumption" (p. 67).

- "Mathalon and Hill (2014) detected microfibres in wild and farmed mussels … Farmed mussels had significantly higher concentrations of microplastics compared to wild mussels: on average 178 microfibres per farmed mussel compared to an average of 126 microfibres per wild mussel in the most polluted site … These plastic body burdens are 500 times higher than the concentrations in mussels reported in [our] study" (p. 67).

- "This report is the first … on possible consequences of marine microplastics for humans … The presence of microplastics in seafood" (Cauwenberghe and Janssen 2014, p. 68).

The proposed action will introduce plastic debris that could exacerbate threats to marine life through direct ingestion of plastics/debris, indirect ingestion via prey, or bioaccumulation of toxic compounds in the food chain. These materials and debris may sink or float, but there is limited information to discern quantities that would sink or float. While available information clearly indicates significant amounts of plastic and microplastic pollution in the action area, it is not clear that shellfish activities contribute significantly to this pollution. The Service does expect that some amount of plastic shellfish culturing material will persist in the marine environment for long durations and will progressively break down into smaller and smaller fragments.

Among seabirds the highest prevalence of ingested plastics has been documented in surface feeders (Robards *et al*. 1997, p. 71). Blight and Burger (1997, p. 323) found plastics in the stomachs of surface-feeding seabirds, but not in pursuit dive-feeding seabirds, including marbled murrelets. Bond *et al*. (2013, p. 192) found that 7 percent of pursuit-dive feeding murres had ingested plastic, and Provencher *et al*. (2010, p. 1406) found that 11 percent of murres had plastic debris in their gastrointestinal tracts. Robards *et al*. (1997, p. 74) examined more than 80 marbled murrelets and found none that showed evidence of ingested plastic. Avery-Gomm *et al*. (2013, p. 1) have made a similar finding.

Bull trout and marbled murrelets prey on marine forage fish and may thereby indirectly ingest plastics, chemical plastic additives, and adsorbed contamination. Persistent, bioaccumulative, and toxic substances are found on recovered plastic debris (Hirai *et al*. 2011), bioaccumulate in foodwebs (Teuten *et al*. 2009), and are linked with several adverse effects including endocrine disruption (Guillette *et al*. 1994).

Plastic particles are reported in the gut content of several species of fish from pelagic habitats, estuaries, and bays (Rochman *et al*. 2013, p. 2). They concluded that polyethylene ingestion is a vector for the bioaccumulation of persistent, bioaccumulative, and toxic substances in fish, and that toxicity resulting from plastic ingestion is a consequence (Rochman *et al*. 2013, p. 5).

Risk of Exposure to Physical Entrapment and Stranding (Bull Trout and Murrelet)

The Service has little information to inform an assessment of the risk of entrapment, entanglement, or stranding for bull trout and marbled murrelets that forage in and around shellfish farms. To our knowledge, there have been no reported instances of these species becoming entrapped or entangled in shellfish culturing equipment. To our knowledge, there have been no reported instances of bull trout, or larger salmonids, becoming stranded behind berms or dikes, or within pools impounded by or around shellfish culturing equipment.

An earlier portion of the Opinion discussed derelict nets and fishing gear (see *Current Condition in the Action Area (Marbled Murrelet), Factors Responsible for the Condition of the Species*). Carter, McAllister, and Isleib (1995) documented accidental capture and mortality in commercial gill nets as one of the major threats to marbled murrelet populations. Laist (1997) compiled a comprehensive list of species with marine debris entanglement and ingestion records, described factors influencing entanglement rates, and problems associated with collecting and analyzing entanglement data. Good *et al*. (2010) reported on the progress made removing derelict gear in Puget Sound and the Northwest Straits (i.e., Canadian waters of the Salish Sea), and the pattern of remaining threats. Appendix D includes excerpts from Carter, McAllister, and Isleib (1995); Laist (1997); and, Good *et al*. (2010); those excerpts are incorporated here by reference.

Good *et al*. (2010) have reported the following:

> "Of the 902 derelict fishing nets recovered from Puget Sound and the Northwest Straits as of June 2008, 876 were gillnets. The remaining nets were purse seines (n = 23), trawl nets (n = 2), and aquaculture nets (n = 1) … 25 percent were derelict for somewhere between 5 and 24 years"; most of the recovered and removed gillnets were located in the San Juan Island archipelago and north Puget Sound (pp. 42, 43).
>
> "[Nets] are especially lethal for marine fish, as [most of these] nets are designed specifically for catching and killing them … [But nets] are also deadly for marine birds and mammals, which must periodically surface to breathe air … Diving birds and marine mammals appear to fall prey to nets while pursuing fish underwater … some of the forage fish and smaller fish species aggregate in and under the relative safety of the netting" (Good *et al*. 2010, pp. 48, 49).

Unfortunately, the Service has little information to inform an assessment of potential exposures and effects to marbled murrelets resulting from entrapment or entanglement in shellfish culturing equipment and gear. There is no information to meaningfully describe where and how often marbled murrelets may be exposed, and what measurable outcomes may result for individuals. Available information suggests that exposure of marbled murrelets is likely to occur very infrequently, if at all. We conclude that exposures are not discountable ("extremely unlikely"). However, the Service is not able to demonstrate that potential exposures are reasonably certain to result in a significant disruption of normal marbled murrelet behaviors (i.e., the ability to successfully feed, move, and/or shelter) or instances of direct injury or mortality.

The Corps has stated the following (Corps 2015, p. 110):

> "Given the prevalence of nets, inconsistent husbandry practices, difficulty fully securing nets in the aquatic environment, proximity to major spawning rivers, and the 20 year time period of the [programmatic], some unknown amount of bull trout entanglement in nets is likely to occur. Rack and/or bag culture may function in a similar manner resulting in the entrapment and/or stranding as the tide retreats from these areas … These would be considered adverse effects to this species."

We agree with the Corps and believe that the best available scientific information supports this conclusion. However, considering the size and mobility of subadult and adult anadromous bull trout, the Service believes that the incidence rate of entanglement, entrapment, and/or stranding must be very low across the whole of the industry. Despite the fact that shellfish farms occupy tens of thousands of nearshore marine acres in Washington State, and overlap significantly with habitats that are seasonally and regularly used by anadromous bull trout (e.g., approximately 12,000 acres of designated bull trout critical habitat), the Service expects that there will be very few instances of individual bull trout injury or mortality over the 20-year term of the programmatic (2016 to 2036).

The Service concludes that instances of bull trout injury or mortality resulting from entanglement, entrapment, and/or stranding are reasonably certain to occur over the 20-year term of the programmatic. We expect that instances of bull trout injury or mortality will occur more frequently in the north Puget Sound, where anadromous bull trout are relatively more abundant, and will occur less frequently in the other four geographic sub-areas (Willapa Bay, Grays Harbor, Hood Canal, and south Puget Sound). We expect that a maximum of six (6) subadult or adult bull trout will be injured or killed in the north Puget Sound geographic sub-area over the 20-year term of the programmatic. We expect that a maximum of two (2) subadult or adult bull trout will be injured or killed in each of the other four geographic sub-areas (Willapa Bay, Grays Harbor, Hood Canal, and south Puget Sound) over the 20-year term of the programmatic (2016 to 2036).

The Service expects that plastic shellfish culturing materials will not float on the surface or in the water column long enough to be a significant direct ingestion threat for bull trout or marbled murrelets. While there may be a small risk that bull trout or marbled murrelets will accidentally ingest debris, we expect that it is extremely unlikely to occur. Direct effects from exposure to these materials are extremely unlikely, and therefore considered discountable.

Based on available information regarding degradation of plastics in the marine environment and bioaccumulation of associated contaminants in the marine food web, we conclude that some individual bull trout and marbled murrelets are likely to be exposed to microplastic pollution and associated contaminants. These exposures may adversely affect some individuals. However, the Service is not able to demonstrate that potential exposures are reasonably certain to result in a significant disruption of normal behaviors (i.e., the ability to successfully feed, move, and/or shelter), instances of direct injury or mortality, or fitness consequences.

Persistent Stressors, Long Duration or Long-Term Exposures, and Effects

Indirect effects are caused by or result from the proposed action, are later in time, and are reasonably certain to occur. Indirect effects may occur outside of the area directly affected by the action.

Shellfish activities result in measurable and potentially significant effects to water quality, substrate condition, physical habitat structure and function, and benthic/epibenthic community structure and composition. Earlier portions of the Opinion discussed temporary stressors resulting from shellfish activities, and resulting short-term exposures and effects to the bull trout and marbled murrelet.

Shellfish activities alter physical, chemical, and biological conditions on varying temporal scales. Many of these effects to the physical, chemical, and biological environment (i.e., potential stressors) correspond closely to cycles of production and harvest. However, some of these effects also reflect variable patterns and rates of recovery from disturbance, and/or interactions with unrelated activities in the same nearshore environments. While earlier portions of the Opinion discussed temporary stressors resulting from shellfish activities, this portion addresses persistent stressors of long duration (months, years), including potential indirect effects that may result from altered patterns of prey availability and productivity (“prey-mediated effects”), and potential long-term effects to natural forms of nearshore marine habitat structure, function, and complexity. This portion of the Opinion describes long-term, direct and indirect effects on large spatial scales, corresponding to hundreds of farms and farm operations, and thousands of affected nearshore marine acres.

When viewed from a landscape perspective, or even from the perspective of a single waterbody (e.g., Willapa Bay) or portion thereof (e.g., Totten Inlet, Samish Bay), shellfish activities are variable in density and spatially discontinuous. At some locations, cultured tidelands extend with only occasional interruption along extended lengths of the nearshore. At other locations, cultured tidelands are interspersed along shorelines that support a range of other uses (residential, recreational, etc.). Where cultured tidelands extend with only occasional interruption, interspersed uncultured areas may experience direct or indirect effects, and are therefore considered part of the action area. The discernable direct and indirect effects of shellfish activities are generally superimposed on, and further influenced by, natural variability, patterns of disturbance and recovery from natural events, and the confounding effects of concurrent, unrelated activities occurring in the same nearshore environments and watersheds.

The Corps has stated the following (Corps 2015, p. 83):

> "The effects [of individual activities] may be relatively short-term or longer lasting … Of equal or more relevance to ESA listed species are the effects of the collective activities, their frequency, duration, timing, geographic location, and general scale across the landscape."

We agree with the Corps and believe that the best available scientific information supports this conclusion. Our Opinion finds that the most significant and biologically relevant effects are those that result in aggregate to nearshore marine habitat structure, function, and productivity, ecological processes, and ecosystem services. The sub-sections that follow attempt, where possible, to evaluate these effects to the physical, chemical, and biological environment on two scales: 1) the scale of a single large farm or grouping of smaller farms (e.g., 50 to 500 acres); and, 2) the scale of a large grouping of small and large farms, occupying a significant portion of a single waterbody (e.g., Willapa Bay) or portion thereof (e.g., Totten Inlet, Samish Bay). For wide-ranging species that depend on the action area's variety of nearshore marine environments and resources (e.g., anadromous bull trout, the marbled murrelet), it is ultimately at these larger scales that we can best interpret the significance of potential stressors, exposures, and responses.

<u>Effects to Ecosystem Services, including Water Quality</u>

Ecosystem services are benefits that people and communities derive or obtain from natural and managed ecosystems. They are commonly described as *supporting*, *provisioning*, *regulating*, and *cultural* services (Millennium Ecosystem Assessment 2005 *in* Saurel *et al*. 2014, p. 267). A number of authors have argued that bivalves and other filter-feeding shellfish, whether occurring naturally or in farmed/cultured settings, provide measurable benefits in the form of ecosystem services (Newell 2004; Coen *et al*. 2007; Forrest *et al*. 2009; Saurel *et al*. 2014; Banas and Cheng 2015).

Newell (2004) focused on bivalve feeding, "top-down" control of phytoplankton, "bottom-up" control of nutrient processing and regeneration, and how these processes interact and can contribute to improved marine and estuarine water quality. Coen *et al*. (2007) and Forrest *et al*. (2009) both emphasized filtration, benthic-pelagic coupling, interactions leading to the enhanced heath or recovery of submerged aquatic vegetation, and the provision of refugia and habitat for both sessile and mobile species. Saurel *et al*. (2014, p. 267) claim that cultured bivalves provide all four forms of ecosystem services, supporting, provisioning, regulating, and cultural. Banas and Cheng (2015 *In* Washington Sea Grant 2015) use an oceanographic circulation model developed for the south Puget Sound to demonstrate how naturally occurring and farmed/cultured bivalves could "…act as a brake on eutrophication" (p. 62).

"Suspension-feeding bivalves serve to couple pelagic and benthic processes … [and] can be extremely important in regulating water column processes … Verwey (1952) was the first to identify the important ecological role of bivalves … as key agents in benthic-pelagic coupling … Bivalves can exert 'top-down' grazer control on phytoplankton and in the process reduce turbidity … [potentially] extending the depth to which ecologically important … plants … seagrasses and benthic algae can grow" (Newell 2004, p. 51). "Bivalves can also exert 'bottom-up" nutrient control … by changing nutrient regeneration processes within the sediment … Large amounts of undigested particulate organic nitrogen [N] and phosphorus [P] are transferred to the sediment surface in feces and pseudofeces (biodeposits) …[where they] gradually become incorporated" (Newell 2004, pp. 51, 52).

Newell (2004, pp. 55) claims that one aspect of this 'bottom-up control' is frequently overlooked. "Burial of N and P, and removal of N from the ecosystem via denitrification, is enhanced by bivalve biodeposition … Within the anaerobic sediments, denitrifying bacteria reduce the … [N] to N_2 gas … [which] passes to the atmosphere without stimulating further primary production … [However, this requires] a close juxtaposition between oxygenated conditions that support nitrifying bacteria and anaerobic conditions that support denitrifying bacteria (Kaspar *et al*. 1985; Kristensen 1988)." Newell (2004, pp. 57) also claims that 'extractive aquaculture' can play a role in regulating or controlling nutrient levels and the impacts resulting or associated with eutrophication; when bivalves are harvested, N and P are permanently removed from the marine and estuarine ecosystems in the forms of tissue and shell.

Coen *et al*. (2007) and Forrest *et al*. (2009) both review published findings suggesting that bivalves create and enhance habitats for submerged aquatic vegetation, marine invertebrates, and finfish. Appendix D includes excerpts from Coen *et al*. (2007) and Forrest *et al*. (2009); those excerpts are incorporated here by reference, and are also addressed by a sub-section that follows (see *Effects to Nearshore Habitat Structure and Function*).

"Bivalve aquaculture may be seen as a green industry, providing ecosystem goods and services (Jackson *et al*. 2001; Smaal *et al*. 2001; Newell 2004; Coen *et al*. 2007, zu Ermgassen *et al*. 2013) that include: (1) reduction of turbidity and nutrient control through filtration of organic matter (Forrest *et al*. 2009; Carlsson *et al*. 2012; Pollack *et al*. 2013); (2) water quality improvement through reduction of primary eutrophication symptoms, thereby minimizing secondary symptoms such as hypoxia (Bricker *et al*. 2003; Ferreira *et al*. 2007); (3) provision of habitat for early stages of invertebrates, and food for local predators (Inglis and Gust 2003;

Dealteris *et al*. 2004; Segvic-Bubic *et al*. 2011); and (4) potential improvement of shellfish recruitment in adjacent areas, thereby helping restoration (Wilbur *et al*. 2005)" (Saurel *et al*. 2014, p. 256). Numerous authors have described how living bivalves, shells/shell fragments, and their aggregations in reefs or banks create novel substrates and contribute to spatially heterogenous habitats (Gutierrez *et al*. 2003; Sousa, Gutierrez, and Aldridge 2009; Gutierrez *et al*. 2011). Appendix D includes excerpts from Gutierrez *et al*. (2003); Sousa, Gutierrez, and Aldridge (2009); and, Gutierrez *et al*. (2011); those excerpts are incorporated here by reference, and are also addressed by a sub-section that follows (see *Effects to Nearshore Habitat Structure and Function*).

Banas and Cheng (2015 *In* Washington Sea Grant 2015) used an oceanographic circulation model developed for the south Puget Sound to investigate the potential influences of shellfish aquaculture on water quality and trophic status. "Results suggest a strong gradient in residence time from the central, deep channels to the small, western inlets, creating a potential for localized effects on water quality … Results suggest that Henderson Inlet, Eld Inlet, Totten Inlet, Hammersley Inlet, Oakland Bay, and upper Case Inlet have combinations of long residence time and high densities of aquacultured filter-feeders such that aquaculture operations there may potentially control local phytoplankton concentrations … One might hypothesize that these inlets are at noticeably lower risk of eutrophication than they would be in the absence of shellfish aquaculture" (Banas and Cheng 2015 pp. 59, 66). Appendix D includes excerpts from Banas and Cheng (2015); those excerpts are incorporated here by reference.

Bivalves and other filter-feeding shellfish, whether occurring naturally or in farmed/cultured settings, provide important benefits in the form of ecosystem services. The Service expects that shellfish activities will generally, and in the majority of cases, provide long-term benefits in the form of improved water quality and sequestration of carbon and nutrients. These ecosystem services may be important as a means to control and prevent the effects of excess nutrient additions occurring elsewhere in the contributing watersheds and may lessen or counteract the potential for climate-induced ocean acidification and hypoxia.

Carrying Capacity

Ecological carrying capacity is a useful concept for thinking about the possible erosion or loss of ecosystem services, and resulting consequences, under a scenario of pervasive and extremely high shellfish culturing densities. In its widest use, "carrying capacity" generally refers to the maximum production of a population (or output) in relation to available, finite resources (or inputs) that does not cause an unacceptable (or irreversible) change in the ecosystem. According to the Pacific Shellfish Institute (2014), the concept is similar to, but broader than the principle of "maximum and optimum sustainable yield".

Newell (2004, pp. 54, 55) observed the following:

> "In waters with substantial rates of bivalve grazing … [this] may possibly adversely affect food quality for other suspension-feeders … In systems that are either less productive, have limited water circulation, or have very high levels of bivalve biomass … competition for food may occur between natural and aquaculture stocks … There is likely to be an exponential increase in interspecific competition for food as bivalve stocks increase in a location from low to high."

Newell (2004, pp. 56, 57) also observed the following, regarding biodeposition and sediment overenrichment:

> "The ecosystem effects of an increase in bivalves on sediment nutrient regeneration … will vary depending on bivalve population density and the rate of mixing of oxygenated water down to the sediment surface … Excess biodeposition, especially in low flow environments … [may cause] sediments to become anoxic … and sediment-bound P to be mobilized … Local adverse effects can be ameliorated by moderate water currents or wave action that allows biodeposits to be spread across a larger bottom area … The adverse effects of sediment overenrichment … have been [most] often observed in sediments underlying … suspended raft culture … Findings suggest that extremely dense bivalve communities can adversely affect sediment microbial processes by shifting them from aerobic to anaerobic metabolism."

Similarly, Forrest *et al*. (2009, p. 3) reported the following:

> "Extreme enrichment effects as a result of oyster farming have been described historically only for suspended culture systems in Japan, and been attributed to repeated culturing and overstocking (Ito and Imai 1955; Kusuki 1981) … Hence, it is apparent that the magnitude of benthic enrichment from elevated intertidal culture [of shellfish] is generally relatively minor by comparison with suspended subtidal culture of fish (e.g. Brown *et al*. 1987; Karakassis *et al*. 2000; Forrest *et al*. 2007a) … The magnitude of effects from enrichment will depend primarily on stocking density and biomass in relation to the flushing characteristics of the environment (Pearson and Black 2001) … Additionally, the level of biodeposition for a given stocking density, and the assimilative capacity of the environment, may vary seasonally (Kusuki 1981; Souchu *et al*. 2001; Mitchell 2006) … The capacity of the environment to assimilate and disperse farm wastes will mainly depend on water current velocity and wave action (Souchu *et al*. 2001), as these factors control the size and concentration of the depositional 'footprint' … Generally, well-flushed aquaculture sites can be expected to have depositional footprints that are less intense but more widely dispersed than shallow or poorly flushed sites (Pearson and Black 2001)."

Forrest *et al*. (2009, p. 6) also directly addressed the science related to carrying capacity:

> "There has been considerable research into food depletion and modelling of carrying capacity for oyster culture (e.g. Ball *et al*. 1997; Bacher *et al*. 1998; Ferreira *et al*. 1998) as well as for other bivalves and polyculture systems (e.g. Carver and Mallet 1990; Prins *et al*. 1998; Smaal *et al*. 1998; Gibbs *et al*. 2002; Nunes *et al*. 2003) … Typically, this work has focused on phytoplankton depletion and maximum production capacity within growing regions … The literature in this field primarily addresses the role of natural or cultivated bivalve populations, whereas the filter-feeding activities of fouling organisms and other biota associated with shellfish cultures can also be functionally important (e.g. Mazouni *et al*. 2001; Mazouni 2004; Decottignies *et al*. 2007)."
>
> "Influences from oyster aquaculture on estuarine carrying capacity are inextricably linked to the issues of nutrient cycling, [solid particulate matter (SPM)] depletion, and coupling between the seabed and water column … There is compelling evidence that bivalve aquaculture can affect nutrient cycling and the quantity and quality of SPM across a range of spatial scales (Prins *et al*. 1998; Cerco and Noel 2007; Coen *et al*. 2007; Lin *et al*. 2009) … Empirically, phytoplankton depletion is certainly evident at local scales in the vicinity of oyster cultures (Dumbauld *et al*. 2009) or intensive culture zones (Lin *et al*. 2009), and serial depletion among multiple adjacent farms at larger spatial scales has been described for other types of suspended bivalve culture (Gibbs 2007; Grant *et al*. 2007)."
>
> "The potential for wider effects on ecological carrying capacity as a result of SPM depletion … is invariably situation specific and scale-dependent … (Anderson *et al*., 2006) … Carrying capacity is also … temporally variable, as the amount of phytoplankton and other SPM in estuaries is likely to be influenced by factors operating from tidal time scales to longer term climatic events … (Dame and Prins 1998; Prins *et al*. 1998; Zeldis *et al*. 2000)" (Forrest *et al*. 2009, p. 6).

"High shellfish culture density may … impact the ecosystem through food competition with wild filter-feeders (Dame and Prins 1997) and cause shifts in the phytoplankton community (Prins *et al*. 1997) … In general, [however] sediment organic enrichment due to shellfish farming is considered to be limited (Crawford *et al*. 2003; Forrest *et al*. 2009); farmers understand that stocking densities leading to these effects do not benefit production, due to high mortality and reduced growth rates" (Saurel *et al*. 2014, p. 256).

Meseck *et al*. (2012) investigated the influence of a commercial FLUPSY on water quality and sediment chemistry in a small temperate embayment. They reported the following (Meseck *et al*. 2012, pp. 65, 70, 71, 75, 77):

> "The output from the FLUPSY was compared to estuarine transects in the bay to determine if any outputs from the FLUPSY could be detected within the embayment … The FLUPSY was a source of total ammonia … and nitrate+nitrite … throughout the season … [However,] the output of total ammonia from the FLUPSY was within the concentration range observed in the embayment … The FLUPSY was a very minor source of total ammonia when

> compared to the salt marsh and sediments … Our results clearly show that the net effects of the FLUPSY … on the chemistry of the water column and the sediments were minimal compared to the temporal variability of the system."

Appendix D includes excerpts from Meseck *et al*. (2012); those excerpts are incorporated here by reference.

Greene *et al*. (2012) published a report evaluating the status of the Puget Sound's nearshore pelagic foodweb, a multi-trophic level assessment in six oceanographic basins. Greene *et al*. report (2012, pp. 4, 43):

> "Land use rarely explained more than 5 percent of the variation in observed data, indicating a dominant marine influence and the potential for resilience of the Puget Sound's pelagic waters to anthropogenic influence … [but] the strong spatial structure observed in our results [does] indicate that different pelagic food webs exist across the system."
>
> "Hood Canal and south [Puget] Sound were rated the lowest [or least 'healthy'] in our system … As has been summarized recently by EPA and the Department of Ecology, Hood Canal is naturally challenged by its unique geography and oceanography, and a recent report determined that it is premature to assign all these problems to anthropogenic activities (Kope and Roberts 2012)."

The work and findings reported by Greene *et al*. (2012) provide a useful context in which to consider available information regarding Puget Sound carrying capacity and the potential effects of intensive shellfish aquaculture. However, despite the growing interest in this topic, to date there has been little work performed that evaluates a scenario of pervasive and extremely high shellfish culturing densities in Washington's inland marine waters. Appendix D includes excerpts from Greene *et al*. (2012); those excerpts are incorporated here by reference.

Ferriss *et al*. (2015, pp. 15-33 *In* Washington Sea Grant 2015) used a trophic model incorporating mediation functions to examine potential food web implications associated with a future growth in central Puget Sound geoduck production. Ferriss *et al*. report (2015, pp. 21, 22):

> "A 120 percent increase in cultured geoduck biomass had a limited impact on phytoplankton biomass and measures of ecological resilience … The addition of cultured geoducks into the central Puget Sound food web without any mediation functions had very little impact on the simulated biomasses of other food web members."
>
> "Habitat modification and facilitation are the predominant ecological effects of geoduck aquaculture in a highly productive system such as central Puget Sound … The trophic impacts of cultured geoducks as both grazers and prey were not influential at the system level … Cultured geoducks did not substantially reduce the availability of phytoplankton for other species."

The work and findings reported by Ferriss *et al*. (2015 *In* Washington Sea Grant 2015) suggest that understanding the ecological effects of shellfish culturing will require going beyond the modeling of direct trophic-level effects and must incorporate non-trophic information when possible. Appendix D includes excerpts from Ferriss *et al*. (2015 *In* Washington Sea Grant 2015); those excerpts are incorporated here by reference.

According to the Pacific Shellfish Institute (2015), an expanded definition of carrying capacity should include the physical, production, ecological, and social carrying capacity elements (including public perception and acceptance). Saurel *et al*. (2014, pp. 255, 256) observed the following:

> "The aquaculture industry must comply with a broad range of natural and social conditions (Jonell *et al*. 2013; Maltby 2013): (1) social acceptance; (2) comprehensive governance with consistent environmental regulations and sustainable culture practices; (3) new culture technologies; (4) stakeholder collaboration and incentives; and (5) compliance … with best management practices."
>
> "Nevertheless, there is some controversy in Puget Sound concerning the use of intertidal areas (beaches) for shellfish cultivation, and licensing of new farms."

While we do not deny the role or significance of social carrying capacity and public acceptance, those aspects are beyond the scope of the Service's considerations, and therefore we limit here our discussion of carrying capacity to the physical and ecological (habitat) elements.

Totten Inlet Primary Productivity and Consumption (A Case Study)

Totten Inlet currently supports some of the highest densities of shellfish culturing in Puget Sound and a significant portion of the statewide subtidal wild geoduck resource (Corps 2015, pp. 40-49; Figures 26-33, pp. 66-72). In addition, based on projected or estimated future growth of the industry over the next 20 years (Corps 2015, pp. 40-43, 80), an increase of approximately 14 percent is expected in the south Puget Sound.

In support of their proposal to establish a new, large floating mussel raft facility (50 to 60 individual rafts) on north Totten Inlet, Taylor Resources, Inc. commissioned two studies and reports (MEC-Weston Solutions, Inc. 2004; New Fields Northwest 2008) evaluating potential direct and indirect effects to the "…physical, chemical, and biological characteristics of the water column; specifically, currents, dissolved oxygen, nutrients, phytoplankton abundance, biomass, primary productivity … [and] carbon-flow in the Totten Inlet food web" (New Fields Northwest 2008, p. vi). The studies evaluated potential near-field, mid-field, and far-field impacts, with the far-field area extending to all of Totten Inlet (MEC-Weston Solutions, Inc. 2004, pp. 1, 2).

MEC-Weston Solutions, Inc. (2004) found:

> "Carbon removed [as] mussel tissue and associated fouling organisms is equivalent to approximately 0.06 percent of the Totten Inlet water column carbon … production annually … This does not address the additional transfer of approximately 0.11 percent … from the water column to the sediment, some of which would be regenerated … The total loss of carbon … as a result of the proposed mussel rafts would range from 0.06 to 0.17 percent … [at the scale of] Totten Inlet" (p. 2).
>
> "Zooplankton standing stock was projected to decrease by 0.016 percent … Effects … to forage fish and juvenile salmonids … are substantially less, primarily due to the dilution effect with additional trophic transfer … Juvenile salmonids and forage fish are predicted to have standing stock reductions of 0.0016 and 0.0021 percent, respectively" (p. 3).
>
> "Fish on the fourth trophic level [e.g., adult salmonids] would be relatively unaffected, with 0.0006 to 0.0008 percent reductions in standing stock" (MEC-Weston Solutions, Inc. 2004, p. 70).

New Fields Northwest (2008) found:

> "Primary production by phytoplankton in Totten Inlet was estimated to be 40,614,000 kg C/year during the spring/summer period … Of this total production, [just] 7.4 percent is consumed by primary consumers … The proposed mussel raft was predicted to consume <1 percent of the production during the spring/summer period" (pp. vii, viii).
>
> "Based on the mean and [upper confidence interval] consumption estimates, the proposed mussel rafts [were] predicted to remove 0.1 to 0.4 percent of the primary production for Totten Inlet during the spring/summer period" and "0.1 to 0.7 percent … in the fall/winter period" (p. 79).
>
> "Relative to 10 percent of the area of Totten Inlet, the [proposed] rafts [are] predicted to remove 1.1 to 7.3 percent of the seasonal [phytoplankton] production [Figure 42] … These comparisons were made with the upper confidence interval values and can be considered a conservative estimate" (New Fields Northwest 2008, pp. 83, 86).

Appendix D includes excerpts from New Fields Northwest (2008); those excerpts are incorporated here by reference.

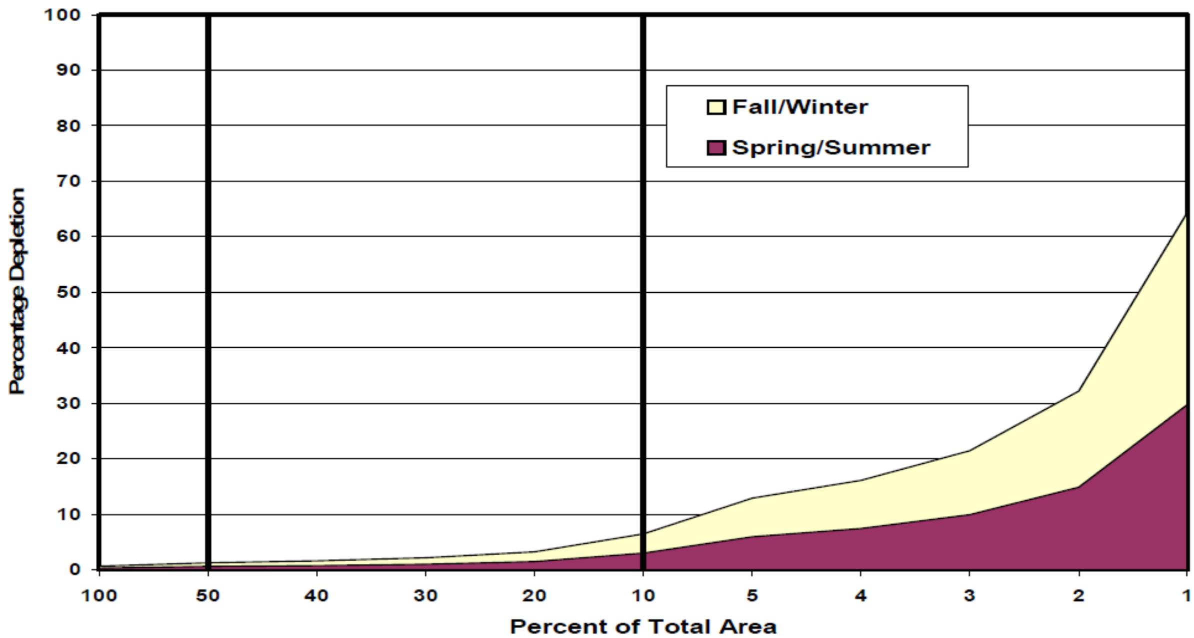

Figure 42. Incremental increase in phytoplankton depletion predicted for the proposed north Totten Inlet mussel rafts
(New Fields Northwest 2008, p. 81)

Totten Inlet's current natural/wild and cultured shellfish biomass is large, but available information suggests a relatively muted or small influence on primary production and trophic state. There is no indication that the Totten Inlet phytoplankton resource has been substantially diminished over time as a result of shellfish activities, and it appears that primary production still greatly exceeds the basin-scale demand of primary consumers. Even with the projected future growth of the industry in south Puget Sound, available information suggests little or no likelihood of approaching the ecological carrying capacity of this system.

While it would be premature to extend these tentative conclusions to the whole of Puget Sound (or to all of Washington's marine waters), the Service does have confidence that Totten Inlet and the south Puget Sound are an appropriately conservative geography and setting for considering these potential effects. Totten Inlet, like several of the other "small" western inlets, exhibits the conditions of extended (long) residence time and high densities of natural and cultured filter feeders (Banas and Cheng 2015 pp. 59, 66). Available information leads us to conclude it is unlikely that the projected 20-year future growth of the industry will approach or exceed ecological carrying capacity within the action area.

<u>Effects to Nearshore Habitat Structure, Function, and Productivity</u>

Shellfish culturing and harvesting have direct and indirect effects to nearshore marine habitat structure, function, and productivity. These effects may have significance for how well these habitats support the essential behaviors and needs of listed species. The sub-sections that follow discuss long-term and persistent effects to substrates and sediment; eelgrass, kelp, and submerged aquatic vegetation; benthic/epibenthic community structure and composition; and predator-prey dynamics and productivity ("prey-mediated effects").

Where possible, we evaluate these stressors and effects at two scales: 1) the scale of a single large farm or grouping of smaller farms (e.g., 50 to 500 acres); and, 2) the scale of a large grouping of small and large farms, occupying a significant portion of a single waterbody (e.g., Willapa Bay) or portion thereof (e.g., Totten Inlet, Samish Bay). For wide-ranging species that depend on the action area's variety of nearshore marine environments and resources (e.g., anadromous bull trout, the marbled murrelet), it is ultimately at these larger scales that we can best interpret the significance of potential stressors, exposures, and responses. The most significant and biologically relevant effects are likely to be those that result in aggregate to nearshore marine habitat structure, function, and productivity.

The final sub-sections included here synthesize and evaluate the patterns of foreseeable spatial and temporal effects to nearshore habitat structure, function, and productivity, and interpret their significance for the bull trout and marbled murrelet. This is followed by a description of the foreseeable direct and indirect effects to designated bull trout critical habitat, including natural forms of nearshore marine habitat structure and complexity.

Effects to Substrates and Sediment

Here we evaluate long-term and persistent effects to substrates and sediment. We consider a variety of shellfish activities and culturing techniques, including bed preparation; frosting and graveling; placement of culturing equipment and materials on and over the bed; mechanical leveling and harrowing; mechanical dredge harvesting; other mechanical harvesting techniques; and, geoduck harvest.

Bed preparation: Intertidal beds are almost always prepared for ground-based culturing of oysters, clams, or geoduck clams with some amount of raking and light grading, regardless of whether the farm uses direct bottom culturing, bag, rack-and-bag, stake, or longline culturing techniques. This is typically accomplished with the use of hand tools and may coincide with pre-harvest (also, see mechanical leveling and harrowing). Bed preparation with hand tools generally only disturbs the shallowest substrates. Available information suggests there are unlikely to be any measurable effects that persist more than a few days, or a few high and low tide cycles.

Frosting and graveling: Frosting and graveling are used to coarsen and firm substrates, either to promote and encourage a natural set of seed, or to improve conditions for the maturing and growth of planted clams or seeded cultch. Several thin layers of material are typically placed over a period of days. Some growers/farm operators gravel or frost their beds on an annual basis, while others do so less frequently.

The Corps and Services developed conservation measures under a SLOPES process, and the Corps has included the conservation measures in their proposed action (Corps 2015, pp. 49-53). The Corps has incorporated a conservation measure which limits the amount of material placed annually, and which should also prevent excessive mounding or piling of placed material (Corps 2015, p. 49). At the rates/amounts proposed we would not expect to see wholesale conversion of the substrate type, and no significant effects to sediment chemistry or nutrient status.

Placement of culturing equipment and materials on and over the bed: Equipment and materials placed on and over the bed directly influence hydrodynamics, including current velocities and patterns of localized sediment deposition and scour. Equipment and materials (e.g., nets, bags, racks, stakes, longlines, tubes) interact with currents, wave action, and natural patterns of sediment transport in ways that can be difficult to predict or generalize across individual sites. However, there is information to suggest that these localized effects to hydrodynamics, deposition, and scour can result in changes to grain size and other characteristics of the substrate. Over the long-term (i.e., "grow-out" and cycles of production), substrate characteristics are strongly influenced by the interactions between these physical characteristics, the benthic community, and intensively cultured shellfish.

When defining disturbance resulting from intertidal aquaculture, Simenstad and Fresh (1995, p. 45) included the "…altering [of] sediment structure by mechanical modification … or addition of different sediments … and altering [of] natural hydrologic and sedimentary regimes." "In addition to obvious shifts in substrate composition, other physicochemical characteristics and processes may be altered that are important to intertidal biota … Thompson (1995) and Thom *et al*. (1994) indicate that substrate modification … can significantly … increase benthic respiration and… nutrient fluxes … The magnitude of these responses, however, tend to be very site-specific" (Simenstad and Fresh 1995, p. 50).

Discussing the influence of nets placed on the intertidal bed, Simenstad and Fresh (1995, p. 54) reported that "… grain size was consistently finer in netted plots than on the natural beach … the increase in sediments <1-2 mm … implied that nets decreased near-bed resuspension and trapped more material … thus promoting a comparatively … muddier substrate." "Decreased current velocities at high tide due to the presence of intertidal structure may … increase the deposition of [fine] organic particles" (Madsen *et al*. 2001 *in* Hosack *et al*. 2006, p. 1157).

Forrest *et al*. reported (2009, pp. 3-5):

> "Changes in seabed topography … have been described beneath oyster farms in several studies (Ottmann and Sornin 1982; Everett *et al*. 1995; Forrest and Creese 2006) … Such changes can result from the accumulation of shell and inorganic debris, and erosion or accretion of sediment beneath and between farm structures (Forrest and Creese 2006) … Sedimentation rates directly beneath cultures are generally elevated by comparison with non-culture areas (Mariojouls and Sornin 1986; Sornin *et al*. 1987; Nugues *et al*. 1996), being as much as three times greater directly beneath farm structures than at control sites (Forrest and Creese 2006)."
>
> "Excessive sediment build-up within Pacific oyster leases can occur at sites where cultivation structures are in high density or aligned perpendicular to tidal currents, resulting in the entrapment of suspended sediments (Kirby 1994; Handley and Bergquist 1997)."

> "Biodeposits are heavier than their constituent particles, and readily settle on the seabed beneath culture areas (Haven and Morales-Alamo 1966; Kusuki 1981; Mitchell 2006) … Since biodeposits are organic-rich and consist of a substantial proportion of fine particles (i.e. silt and clay), seabed sediments beneath oyster cultures can become organically enriched and fine-textured relative to surrounding areas … (Forrest and Creese 2006)" (Forrest *et al*. 2009, pp. 3-5).

Appendix D includes fuller excerpts from Forrest *et al*. (2009); those excerpts are incorporated here by reference.

When discussing the history of intertidal culturing of Pacific oysters in Willapa Bay, Simenstad and Fresh (1995, p. 48) reported the following:

> "Once Pacific oysters became the focus of culturists, they were grown primarily on littoral flats above MLLW … Presently, ground-cultured oysters are distributed over broad intertidal flats in a relatively thin layer (at most one oyster thick) in order to maximize growth … Consequently, oyster culture appears to have changed the nature of oyster habitat from a thick reef-like structure to one that is analogous to fine sediments with a thin layer of large substrates (i.e., oysters) over it."

Mechanical leveling and harrowing; **mechanical dredge harvesting**: Mechanical leveling and harrowing turn over the surficial substrates and shallow subsurface. This has measurable effects on particle size, sediment chemistry, nutrient status, and aspects of benthic-water column dynamics (Rhoads and Germano 1986, Newell 2004, Forchino 2010, Gutierrez *et al*. 2011). Mechanical leveling and harrowing, and for that matter mechanical dredge harvesting, also disturb, physically alter, and can damage or kill benthic infauna and microalgae, sessile epibenthic invertebrates, and attached submerged aquatic vegetation. Some of these topics will be discussed in greater detail by a following sub-section (see *Effects to Eelgrass, Kelp, and Submerged Aquatic Vegetation* and *Effects to Benthic/Epibenthic Community Structure and Composition*).

Species richness and functional group diversity are inherent to undisturbed benthic systems, including within seemingly "plain" or "barren" sand and mud flats (Rhoads and Germano 1986, pp. 293, 294; Forchino 2010, pp. 16, 17; Gutierrez *et al*. 2011, pp. 39-45). Benthic communities are not static and the functional groups that dominate at points along the course of infaunal succession (Figure 37, p. 105) influence important benthic ecosystem attributes, including secondary production, nutrient cycling, and hypoxia (Rhoads and Germano 1986, pp. 291, 298-301). "Infaunal 'ecosystem engineers' affect three-dimensional structure and thus the diversity of microhabitats in marine soft sediments … When infaunal organisms recruit into soft sediment habitats, they seek refuge by entering into the sediments and – in many cases – by producing shells, tubes, or burrows (Marinelli and Woodin 2002) … All these structures generate a remarkably more diverse environment within the sediment matrix relative to the originally smooth soft sediment" (Gutierrez *et al*. 2011, pp. 44).

Infaunal succession commonly requires years, and therefore benthic species assemblages and their functional relationships can be disrupted by sources of disturbance. "[Disturbances that cause] long-term degradation … frequently involve the loss of equilibrium species … high-order seres are replaced by pioneering seres … [and] changes in organism-sediment relations and population dynamics accompany this change" (Rhoads and Germano 1986, p. 295).

Appendix D includes excerpts from Rhoads and Germano (1986), Forchino (2010), and Gutierrez *et al*. (2011); those fuller excerpts are incorporated here by reference.

There can be no question whether the acute physical disturbance caused by mechanical leveling, harrowing, and dredge harvesting measurably and significantly changes substrate conditions and the benthic community. These shellfish activities act as intense pulse disturbances, and clearly they will in many cases either interfere with or reset normal patterns of infaunal succession and development. [Geoduck harvesting may also act as an intense pulse disturbance, though generally it occurs at a much reduced frequency (e.g., once every 7 to 9 years).] The implications for sediment chemistry, nutrient status, benthic-water column dynamics, and benthic community richness and evenness are very difficult to predict or generalize across individual sites. However, when we consider that many sites and farms are harrowed and dredged repeatedly over the course of a single or successive cycles of shellfish culturing, it becomes obvious that many of these sites and farms are managed in a more or less permanently (or chronically) "disturbed" state.

"Complex physicochemical and ecological linkages among estuarine organisms and communities can be altered over the long-term by persistent disturbances that exceed natural regimes … Large-scale disturbances, such as those associated with some intensive oyster practices, may induce chronic shifts in the benthic community by removing or reducing the influence of community dominants such as eelgrass or … [by] altering the apparent … relationship between them" (Simenstad and Fresh 1995, pp. 65, 66). The sub-sections that follow will discuss these topics in greater detail (see *Effects to Eelgrass, Kelp, and Submerged Aquatic Vegetation* and *Effects to Benthic/Epibenthic Community Structure and Composition*).

Other mechanical harvesting techniques: Bottom cultured clams are sometimes harvested mechanically, most notably in Samish Bay. Mechanical clam harvesters are driven or pulled across the exposed bed at low tide, and the clams are "swept" onto a conveyor belt. Another type of mechanical harvesting equipment, the hydraulic escalator, has been mostly or completely phased out and is excluded from coverage under the Corps programmatic consultation (Corps 2015, p. 26).

The mechanical clam harvesters used in Samish Bay, and perhaps at a growing but uncertain number of additional locations, are repurposed and re-configured tulip harvesters (Saurel *et al*. 2014, p. 263). While only a few studies considering the use of this equipment are either completed or underway, available information suggests that the practice is relatively benign and no significant impacts to substrates or sediment have been observed (Saurel *et al*. 2014, p. 263).

Geoduck harvest: Geoduck are harvested from intertidal beds at low tide ("beach harvest"), or by divers at middle or high tides ("dive harvest"). In either case, geoduck clams are typically harvested using hand-operated water jet probes. Seawater pumped at a pressure of approximately 40 pounds per square inch, and 20 gallons per minute, is injected at the vicinity of each harvestable geoduck, liquefying the substrate and allowing extraction of the clam by hand.

"Geoduck… [harvest] may alter abiotic conditions in the sediment (e.g., grain size, oxygen [and] nutrient levels)" (Straus *et al*. 2013, p. 20). Willner (2006) considered the effects of geoduck dive harvest and observed the following:

> "This method of harvesting is considered to be the most environmentally benign method available (Palazzi *et al*. 2001)" (p. 11).
>
> "[However,] The physical disturbance associated with … geoduck harvest has the potential … [to alter] the availability and distribution of physical microhabitat and biogenic structures" (p. 2).
>
> "Disturbances, such as geoduck harvesting, homogenize the area by breaking up structures and disturbing materials … reducing the structural complexity of the area (Hewitt *et al*. 2005) … As the water jet overturns sediments, organic material and organisms in and adjacent to the harvesting hole are resuspended and/or buried" (p. 31).
>
> "With larger particles settling quickly and finer materials being carried away, the result is a larger sediment grain composition with a lower concentration of nutrients" (pp. 31, 32).
>
> "Artificially resuspended sediments have important implications for nutrient cycling (Pilskaln *et al*. 1998) … Resuspension can result in higher nutrient concentrations in the water column … [and] increase[d] oxygen consumption … (Tengberg *et al*. 2003)" (Willner 2006, pp. 45, 46).

Appendix D includes excerpts from Willner (2006); those fuller excerpts are incorporated here by reference.

All of the shellfish activities and culturing techniques that have been described here result in measurable effects to substrates and sediment. Some of these shellfish activities and culturing techniques are more likely than others to result in measurable long-term and persistent effects. Based on the available information, we conclude that the placement of culturing equipment and materials on and over the bed, mechanical leveling and harrowing, and mechanical dredge harvesting, are most likely to result in measurable long-term and persistent effects to substrates and sediment.

Mechanical leveling, harrowing, and dredge harvesting act as intense pulse disturbances, and clearly they will in many cases either interfere with or reset normal patterns of infaunal succession and development. When we consider that many sites and farms are harrowed and dredged repeatedly over the course of a single or successive cycles of shellfish culturing, it becomes obvious that many of these sites and farms are managed in a more or less permanently (or chronically) “disturbed” state. The sub-sections that follow will discuss these topics in greater detail (see *Effects to Eelgrass, Kelp, and Submerged Aquatic Vegetation* and *Effects to Benthic/Epibenthic Community Structure and Composition*).

Effects to Eelgrass, Kelp, and Submerged Aquatic Vegetation

Here we evaluate long-term and persistent effects to eelgrass, kelp, and submerged aquatic vegetation. We consider a variety of shellfish activities and culturing techniques, including bed preparation; frosting and graveling; placement of culturing equipment and materials on and over the bed; mechanical leveling and harrowing; mechanical dredge harvesting; other mechanical harvesting techniques; and, geoduck harvest.

The local ecology and function of eelgrass and kelp: Phillips (1984) described the Ecology of Eelgrass Meadows in the Pacific Northwest. Mumford (2007) described the ecology of Kelp and Eelgrass in Puget Sound. These excellent reports discuss in detail how submerged aquatic vegetation contributes to and influences natural marine and estuarine functions (biotic and abiotic). Appendix D includes excerpts from Phillips (1984) and Mumford (2007); those excerpts are incorporated here by reference.

Interactions between submerged aquatic vegetation and shellfish activities: Interactions between submerged aquatic vegetation (native eelgrass, rooted kelp) and shellfish activities are complex and not easily characterized with simple generalizations. These interactions include competition for space, competition for light (or shading), and physical damage that results from some activities, practices, and techniques. However, not all of these interactions are detrimental to the health of native eelgrass and rooted kelp. For instance, shellfish culturing provides a source of nutrient enhancement, which supports plant growth and vigor, and frequently improves water quality. Furthermore, when evaluating potential interactions and outcomes, we must also consider that the current conditions for submerged aquatic vegetation in the action area represent at many locations a dynamic equilibrium influenced by shellfish and other activities conducted over years and decades. Despite the intensive shellfish culturing that has characterized the recent history at the scale of whole sub-basins (Samish Bay) and whole waterbodies (Willapa Bay), submerged aquatic vegetation continues to show good or consistent health in some of these same geographies (Gaeckle *et al*. 2011, 2015)(see *Environmental Baseline, Puget Sound and Hood Canal, Existing Conditions for Native Eelgrass*).

Competition for space: While studies considering the potential role of shading and competition for light have produced inconclusive or equivocal findings, they demonstrate more consistently that cultured shellfish compete directly with eelgrass for space. “Oysters use space in direct competition with eelgrass … Eelgrass shoots cannot grow in areas occupied by shell, so direct … competition [should] lower eelgrass density” (Tallis *et al*. 2009, p. 256).

Wagner *et al*. (2012) looked specifically at density-dependent effects of oyster cultivation on native eelgrass:

> "A key consideration for the coexistence of bivalves and eelgrass involves the functional shape of potential tradeoffs (Koch et al. 2009) … specifically, thresholds beyond which eelgrass responds more strongly than expected from the effects of displacement and space competition with bivalves alone" (p. 150).
>
> "Steep declines [in eelgrass shoot density and size,] indicating density-dependent space competition, occurred at different thresholds after 1 (1.3 percent oyster cover), 2 (12.4 percent), and 3 years (21.9 percent) … Eelgrass responded to the presence of oysters (both live adults and empty shells) by reducing shoot density and size" (pp. 149, 157).
>
> "The superior fit … models relating eelgrass density to oyster cover … [show] exponential declines in eelgrass shoot density when oyster cover exceeded 10 to 20 percent" (p. 158).
>
> "Our results indicate that low densities of oysters can be compatible with eelgrass … but that tradeoffs reliably occur both after initial establishment and above 20 percent oyster cover … Ecological consequences … are likely to be location-specific and density dependent … [but] our results indicated disproportionately large tradeoffs between space occupants at high oyster density" (Wagner *et al*. 2012, p. 158).

Appendix D includes excerpts from Wagner *et al*. (2012); those fuller excerpts are incorporated here by reference.

"Distribution of eelgrass reflects a balance of space competition, pulse disturbance, and recovery, and is therefore at dynamic equilibrium on aquaculture beds" (Dumbauld, Ruesink, and Rumrill 2009, p. 196). "If eelgrass impact reduction, rather than avoidance, is identified as the management goal, the degree of tradeoff between eelgrass habitat and oyster production can be minimized by managing aquaculture methods or oyster planting densities, depending on the eelgrass measure of interest" (Tallis *et al*. 2009, p. 251). "Similar to Tallis *et al*. (2009), we noted a negative relationship between eelgrass above-ground biomass and culture density" (Skinner, Courtenay, and McKindsey 2013, p. 115).

Life history characteristics and growth forms would suggest that competition for space is a significant interaction for kelp species too: "The habitat requirements for kelp include not only those conditions needed for the large kelp plant, but also for the tiny and cryptic gametophytes, for induction of reproduction, and for fertilization (Foster and Schiel 1985; Dayton 1985; Druehl and Wheeler 1986)" (Mumford 2007, p. 4). "Competitors of kelp … include any shallow … space-occupying organism … The tiny gametophytes and small sporophytes can be out-competed for space or light by a variety of algae and sessile invertebrates … Once grown out of these small stages, however, kelps can outcompete most other seaweeds and sessile invertebrates because of their rapid elongation (10 cm per day in *Nereocystis*) and large adult size … Even the smaller, non-floating kelps can overtop and shade other algae" (Mumford 2007, p. 12).

Physical damage: "Eelgrass rhizomes are buried … up to 20 cm (8.0 inches) deep in sediment, depending on the sediment consistency … In firmer substrates, rhizomes may be only half as deep as in soft muddy substrates" (Phillips 1984, p. 9). "Significant injury to roots, rhizomes, and meristems is lethal to seagrass shoots" (Neckles *et al*. 2005, p. 58). "Eelgrass may … be impacted by dredging, harrowing, and leveling, all of which extensively disrupt surface sediments … destroy aboveground eelgrass shoots and leaves, and perhaps belowground roots and rhizomes as well" (Simenstad and Fresh 1995, p. 54). "Direct stressors to eelgrass include harrowing or roto-tilling for on-ground oyster culture and damage from propellers … Similarly, [for] kelp, if … [cut] below the meristem, or growing region, [this] will result in the death of the entire plant" (Mumford 2007, p. 14).

"The extent to which a particular disturbance alters structure or function and thereby affects recovery time depends on the frequency and/or duration of the disturbance (den Hartog 1971), the physiological condition of the plants, and the characteristics of the particular seagrass species involved (McRoy and Lloyd 1981; Zieman and Zieman 1989; Williams 1990; Alberte *et al*. 1994) … Additionally, recovery from disturbance can vary depending on the level of damage sustained" (Short and Wyllie-Echeverria 1996, p. 18). "The effect of physical disturbance on plant communities depends on the size, frequency, and intensity of disruption, and on ecological, physiological, and life history characteristics affecting ecosystem recovery (Pickett and White 1985)" (Neckles *et al*. 2005, p. 58).

"Fishing gear has been shown repeatedly to reduce the structural complexity of benthic habitats by smoothing sedimentary bedforms and physically removing biota that produce habitat structure (Auster and Langton 1999, National Research Council 2002) … Mobile gear has been found to affect seagrass beds similarly through removal of the vegetation (Fonseca *et al*. 1984, Peterson *et al*. 1987, Orth *et al*. 2002; but see Meyer *et al*. 1999) … Mussel dragging … had a comparably severe impact on localized habitat structure by eliminating large amounts of vegetation … Our model of within-bed eelgrass recovery emphasized the importance of initial dragging intensity" (Neckles *et al*. 2005, pp. 67-69).

"Previous work has shown that recovery periods for eelgrass following oyster harvest vary depending on a combination of factors, including the type of oyster culture, duration of culture, spatial configuration of culture operations and nearby meadows, and the frequency of oyster harvest events (Waddell 1964; Orth *et al*. 2002) … Our data have important management implications … but we know little about how these results vary among sites (either within or among estuaries) … Tidelands used for aquaculture in Willapa Bay comprise a mosaic of disturbance … some beds may have little to no eelgrass cover due to frequent harvest and management activities, while other beds are left unmanipulated for long periods, enabling dense stands of eelgrass to form and persist" (Wisehart *et al*. 2007, pp. 78, 79).

"Studies of onground culture systems have … demonstrated physical effects during intermittent shellfish harvesting, and the recovery of soft-sediment communities in a matter of weeks to months in unvegetated habitats (McKindsey *et al*. 2006 and references therein) … By contrast, recovery from physical disturbance by eelgrass … may take several years (McKindsey *et al*. 2006; Dumbauld *et al*. 2009 and references therein)" (Forrest *et al*. 2009, p. 4). "Published recovery rates of eelgrass are almost all slower than reported for other soft-sediment organisms exposed to intertidal shellfish harvest; they appear more similar to [the approximate] 2-year recovery rates of biogenic habitats (corals and sponges) after subtidal trawling or dredging (Kaiser *et al*. 2006)" (Ruesink and Rowell 2012, p. 718).

"Individual activities act as pulse disturbances and the recovery of eelgrass … to pre-disturbance levels is variable [2 to 5 years] … The extent of disturbance depends on the aquaculture practice and the distribution of eelgrass reflects a balance of space competition, pulse disturbance, and recovery, and is therefore at dynamic equilibrium on aquaculture beds" (Dumbauld, Ruesink, and Rumrill 2009, p. 196). "The negative and positive effects of aquaculture on eelgrass are likely caused by the direct disturbance of aquaculture and the indirect response of plants to that disturbance … Although eelgrass does grow back in the beds over time (both via rhizomes and seeds; Wisehart *et al*. 2007), densities may not reach those of uncultivated beds within the typical harvest cycle (approximately 3 years)" (Tallis *et al*. 2009, p. 256). Damage to eelgrass may be lessened if activities are conducted during winter months, when aboveground shoot densities are lowest (Wisehart *et al*. 2007, p. 72).

Recovery from physical damage: Eelgrass recovery from physical damage is influenced by a number of factors, including capacity for seed production, germination, and seedling survival; capacity for vegetative patch expansion; the persistence of remnant, undisturbed or lightly disturbed patches of eelgrass; intraspecific competition; and a host of other variable (and sometimes site-specific) environmental and culturing conditions and factors. Neckles *et al*. (2005), Wisehart *et al*. (2007), and Tallis *et al*. (2009) have each reported relevant findings.

Neckles *et al*. (2005) reported:

> "Dramatic differences in the habitat characteristics of disturbed and reference sites were seen in the areas of the most recent [mussel] dragging activity" (p. 63).
>
> "The broadly overlapping zones of statistical similarity in measured plant characteristics … suggest considerable variability in the actual length of time that would be required for newly vegetated substrate to achieve reference conditions" (p. 66).
>
> "The measured effect of disturbance … depended on the scale of observation and the apparent intensity of [mussel] dragging effort … Presumably, the number, sizes, and distribution of remnant patches of eelgrass following dragging are a function of the dragging intensity, with patches occurring on substrate that was missed by the dredge … This difference in dragging intensity most likely reflects the pattern of mussel distribution rather than any difference in gear efficiency" (Neckles *et al*. 2005, p. 68).

Wisehart *et al*. (2007) reported:

> "Oyster growers have reported that eelgrass rapidly reappears in areas planted with oysters … There are two potential mechanisms to explain high recruitment: (1) oysters influence eelgrass seed production, seed germination, and/or seedling survival by altering the nutrient or light environment … or by trapping/protecting seeds, and (2) aquaculture disturbance affects eelgrass seed production, seed germination, and/or seedling survival by removing neighboring adult eelgrass plants" (p. 72).
>
> "More seeds were produced in the dredged beds than in the reference beds" (p. 74).
>
> "We found higher seedling densities in dredged beds … compared to reference areas where adult density was significantly greater … When neighbors were removed, seedlings survived better … and were significantly larger … Dredge harvest of oysters, which results in decreased eelgrass density due to the removal of above ground plant structures, may facilitate seed germination and/or seedling growth and survival, by reducing competition for light or other resources" (Wisehart *et al*. 2007, p. 77).

Tallis *et al*. (2009) reported:

> "Surprisingly, eelgrass relative growth rates were faster in dredged and hand picked beds than in uncultivated areas … [However,] In contrast, all aquaculture areas had smaller plants (above-ground biomass) and lower production than uncultivated areas" (p. 254).
>
> "Higher growth rates of eelgrass in oyster beds are likely related to lower eelgrass density rather than the direct effect of oysters per se … Eelgrass growth is generally light limited in this region (Thom and Albright 1990, Wisehart *et al*. 2007), so lower eelgrass densities in dredged and hand picked beds … may release individual plants from intraspecific competition, increasing light levels, and leading to higher relative growth rates" (p. 256).
>
> "When the cumulative effects of oyster aquaculture (oysters and practices) are considered, higher growth rates in dredged, and perhaps hand picked beds are cancelled out by lower plant densities and size in these areas … As a result, all current aquaculture methods have … relatively large impacts on plant size and eelgrass production" (Tallis *et al*. 2009, p. 257).

Appendix D includes excerpts from Neckles *et al*. (2005), Wisehart *et al*. (2007), and Tallis *et al*. (2009); those fuller excerpts are incorporated here by reference.

The Corps has stated "… for recovery times on the order of years, such as [recovery from] disturbance to eelgrass, an annual or every few year repeat disturbance may never allow a full recovery" (Corps 2015, p. 92). We agree with the Corps and believe that the best available scientific information supports this conclusion. However, the number and variety of factors influencing eelgrass recovery suggest the potential for significant site-by-site and temporal variability. It is therefore difficult (or impossible) to state with certainty the likely pattern or rate of recovery, at either a fine or coarse scale. Furthermore, there appear to be few general rules that accurately characterize this complex set of interactions. Nevertheless, the weight of available evidence does lead the Service to conclude that in most cases and settings where shellfish activities result in physical damage to eelgrass beds, and/or displace eelgrass beds or other submerged aquatic vegetation, they will result in at least temporal loss of production and associated ecosystem services, including habitat functions (Figure 43).

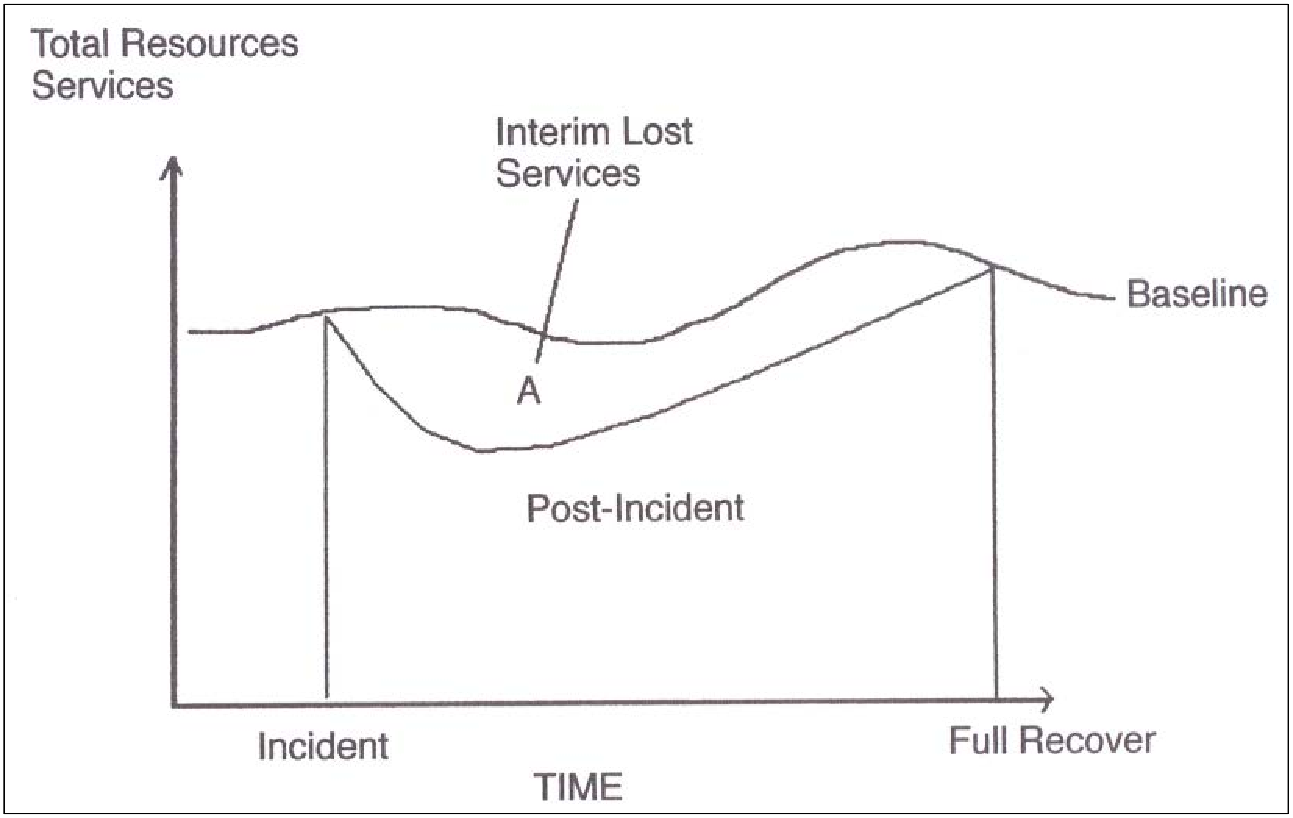

Figure 43. Diagrammatic representation of the interim or temporal loss of ecosystem services (Fonseca *et al*. 1998, p. 68)

Longline culturing: A number of studies have looked specifically at longline culturing techniques, damage to eelgrass, and recovery, including those reported by Wisehart *et al*. (2007), Tallis *et al*. (2009), and Rumrill and Poulton (2004). Where intertidal longline culturing is practiced, oysters are grown in clusters, attached to rope lines suspended above the bed between upright stakes. Stakes and longlines prevent oysters from sinking and smothering, and also serve to control and minimize exposure to predators inhabiting the intertidal bed.

Wisehart *et al*. (2007) reported the following:

> "Significantly fewer seedlings were observed in the longline beds compared to [both] the dredged and reference beds, which did not significantly differ" (p. 74).
>
> "More seeds were produced in the dredged beds than in the reference beds, and lowest seed production occurred in the longline beds" (p. 74).

> "We observed very few naturally recruiting seedlings in longline areas, and survivorship of seedlings in longline seed addition plots was zero … Our data suggest that seed production and seed bank densities are high in dredged areas compared to longline areas … Longlines may also act as 'clotheslines,' causing plants to become entwined in the ropes at high tide resulting in severe desiccation at low tide, thus reducing the density of both vegetative and flowering shoots (Pregnall 1993, Everett *et al*. 1995)" (p. 78).
>
> "Seed dispersal and deposition in longline beds may be limited due to altered water flow … the reduction in flow causes longline areas to accrete sediment at much greater rates than would naturally occur (Everett *et al*. 1995) and could lead to burial of seeds and young seedlings" (Wisehart *et al*. 2007, p. 78).

Tallis *et al*. (2009) reported the following:

> "Both on-bottom aquaculture methods (hand picked and dredge) had lower eelgrass densities than uncultivated areas … [but] results were less clear for long line beds … We found that long lines and hand-picking tend to have smaller effects on eelgrass density than dredging … There was no clear link between oysters, aquaculture structures, and eelgrass density in long line areas" (p. 254).
>
> "We show that tradeoffs exist between oyster aquaculture and native eelgrass populations … None of the existing aquaculture methods in this region can be conducted whereas avoiding all impacts on eelgrass … Oysters can be cultivated using long lines with the least impact on eelgrass density, but eelgrass biomass (shoot size) and production will decline (as will eelgrass seed recruitment, Wisehart *et al*. 2007)" (Tallis *et al*. 2009, p. 260).

Rumrill and Poulton (2004) reported the following:

> "It is clear … that intensive commercial cultivation of oysters typically results in chronic and variable levels of disturbance to eelgrass beds and their associated communities (Simenstad and Fresh 1995; Griffin 1997; Dumbauld 1997) … [However,] empirical studies are needed to investigate the ecological impacts of oyster cultivation on long-lines suspended between stakes" (p. 3).
>
> "Twelve study sites were established … with variable spacings of 1.5 [ft], 2.5, 5, and 10 [ft] between the suspended lines … We conducted additional field sampling … to compare eelgrass presence, size, and biomass in the experimental plots … [and] commercial long-line plots" (p. 6).

> “We observed a strong trend toward decreased spatial cover and density … with decreased distance between suspended oyster long-lines … Low eelgrass metrics were consistently observed within the narrow line spacing / high-density oyster plots [1.5 and 2.5 ft], where eelgrass cover was generally less than 15 percent … [However,] eelgrass beds in the ‘wide’ oyster long-line spacing plots [5 ft] were intermediate (35-45 percent cover) … and high spatial cover (55-65 percent cover) and density values … were observed in the ‘very wide’ oyster longline plot [10 ft spacing]” (p. 11).

> “Results suggest that the shading effect of oyster long-lines … is probably negligible … [and] factors other than light availability are probably responsible for the reduced abundance of eelgrass in closely-spaced off-bottom oyster culture sites … Changes in sediment deposition and erosion were clearly evident in the plots with high densities of oyster lines [1.5, 2.5, and 5 ft spacing] … The seasonal build-up of sediments was particularly evident … around the PVC stakes that support the oyster lines … Substantial and rapid sediment deposition was observed … [but] these soft and flocculent sediments were … [also] eroded away … Sediments were deposited more slowly over time within [the 10 ft spacing] oyster long-line plot” (Rumrill and Poulton 2004, pp. 15, 16).

Geoduck cultivation and harvest: Studies conducted in the Pacific Northwest demonstrate that geoduck cultivation also results in measurable impacts to eelgrass. A 2-year experiment investigating seasonal effects of geoduck production at a site in the south Puget Sound found that the largest impacts (70 percent shoot loss) occurred during harvest (Ruesink and Rowell 2012, p. 718).

Horwith (2013) investigated changes in eelgrass over a 5-year crop cycle in Samish Bay, located in the north Puget Sound:

> “Immediately following harvest … eelgrass remained patchily distributed within the farm (being present in 64 percent of quadrats), but where it was present, *Z. marina* was now 78 percent more dense in the unfarmed area ... Eelgrass was no longer present on the farm 1 year after harvest … following a period of heavy [algae] biofouling on the blanket nets” (p. 111).

> “[However] … the first signs of recovery for eelgrass began 1 year after the removal of tubes and nets, and continued evidence for recovery appeared in the following year … Geoduck aquaculture practices do not appear to have made this site unsuitable for later recolonization by eelgrass” (Horwith 2013, p. 112).

Saurel *et al*. (2014, pp. 261, 264) considered the effects of fouling (algal growth) on geoduck cover nets:

> “A macroalgal individual growth model was implemented to simulate fouling of predator nets by seaweeds … [The] model simulates sweeping at regular intervals, and the subsequent new growth of macroalgae on the nets … Increased fouling in farm sections with larger clams (higher year classes) is … [evident] and reflects a greater emission of ammonia [nutrient] from … larger animals.”

Summary: Interactions between submerged aquatic vegetation (eelgrass, kelp) and shellfish activities are complex. The number and variety of factors influencing recovery from disturbance or damage suggest the potential for significant temporal and site-by-site variability. However, in most cases and settings where shellfish activities result in physical damage to submerged aquatic vegetation, they will result in at least temporal loss of production and associated ecosystem services, including habitat functions (Figure 43, p. 151).

Not all of the potential interactions with shellfish activities are detrimental to the health of native eelgrass and rooted kelp. For instance, shellfish culturing provides a source of nutrient enhancement, which supports plant growth and vigor, and frequently improves water quality. Therefore, when evaluating potential interactions and outcomes, we must also consider that the current conditions for submerged aquatic vegetation in the action area represent at many locations a dynamic equilibrium influenced by shellfish and other activities conducted over years and decades. Despite the intensive shellfish culturing that has characterized the recent history at the scale of whole sub-basins (Samish Bay) and whole waterbodies (Willapa Bay), submerged aquatic vegetation continues to show good or consistent health in some of these same geographies (Gaeckle *et al*. 2011, 2015)(see *Environmental Baseline, Puget Sound and Hood Canal, Existing Conditions for Native Eelgrass*).

Landscape scale interactions and dynamics: Whereas there have been many studies evaluating interactions and outcomes at the scale of a single bed or a single farm, there have been relatively few that describe interactions between submerged aquatic vegetation and shellfish activities on a landscape scale in the Pacific Northwest.

Dumbauld and McCoy (2015) evaluated the effect of oyster aquaculture on eelgrass at the estuarine landscape scale in Willapa Bay:

> "We … use [several] factors to predict *Z. marina* distribution for each aquaculture bed, and compare the model-predicted, interpolated, and actual quantities … [We] determine whether any impacts of oyster aquaculture … were chronic or transitory by analyzing data from 3 separate years" (p. 31).
>
> "We predicted that mechanically harvested beds would either exhibit chronically low proportions of *Z. marina*, if the effects of dredging are long-lived, or high variability, due to a rapid removal (mechanical harvest) and recovery (regrowth), relative to more stable hand-picked beds" (p. 34).
>
> "The total area of *Z. marina* estimated to be missing using a model prediction in 2005 and 2006 was only 22 and 8 ha, respectively … In 2009, there were 0.4 ha, more *Z. marina* present than predicted by the model … The total area … estimated to be missing using the interpolation prediction was higher for all years, at 80, 84, and 60 ha, respectively … Although large in aggregate, even the highest estimate is <1.5 percent of the total amount of *Z. marina* cover found in Willapa Bay in these 3 years" (p. 35).

> “The majority of beds exhibited expected levels of *Z. marina* with low variation across years … [However,] All of the beds with <65 percent of the mean expected amount of … cover (n = 24) were mechanically harvested beds and demonstrated a chronically low level of *Z. marina* cover … across years” (p. 36).
>
> “While the total area of *Z. marina* declined slightly over time in our study, <1.5 percent of either the total predicted or interpolated amount … was missing (maximum of 80 ha) and could thus potentially be attributed to aquaculture in any single year … This lack of substantial overall impact is similar to the few studies conducted at the estuarine landscape scale elsewhere” (p. 38).
>
> “Our results suggest that the majority of oyster aquaculture impacts are not persistent at the landscape scale … Our results suggest that current oyster aquaculture practices do not substantially reduce and may even enhance the presence of *Z. marina* at the estuarine landscape scale” (Dumbauld and McCoy 2015, p. 41).

Appendix D includes excerpts from Dumbauld and McCoy (2015); those fuller excerpts are incorporated here by reference.

These findings direct appropriate attention to the scale of observation, but do not wholly undermine or refute the position voiced previously by some of these same authors: “Bivalve culture clearly modifies estuarine habitat at local community and at landscape scales … Effects are most often evaluated against existing structured habitat in the form of submerged aquatic vegetation” (Dumbauld, Ruesink, and Rumrill 2009, p. 196).

Impacts to submerged aquatic vegetation resulting from programmatic shellfish activities: The BA submitted by the Corps in support of programmatic consultation provides an excellent summary of available data, and the limitations of available data, to describe eelgrass distribution in the action area, and its co-location with continuing shellfish activities (Corps 2015, pp. 90, 94, 95; Appendix D). The Service regards these data, and the Corps’ analyses, as the best available information to describe the likely physical extent of potential impacts to submerged aquatic vegetation resulting from programmatic shellfish activities in Washington’s marine waters. The Service does acknowledge that there is no current, comprehensive mapping of eelgrass and kelp in Puget Sound, Hood Canal, or the coastal embayments of Willapa Bay and Grays Harbor.

The Corps has stated the following regarding potential impacts to native eelgrass (Corps 2015, pp. 94, 95):

> “The continuing active and fallow [shellfish] acres could potentially occur in areas with eelgrass … A geographic analysis was conducted to estimate the acreage potentially co-located with eelgrass … There is substantial overlap between eelgrass and much of the continuing active and fallow [shellfish] acreage … This pattern occurs in all the geographic regions … An estimated 11,227 acres … [continuing fallow] would be co-located with eelgrass.”

> "Activities (active and fallow) are more often than not co-located with eelgrass in Willapa Bay, Grays Harbor, and the north Puget Sound region … In the Hood Canal region, acreage is equally split between areas with and without eelgrass … The south Puget Sound region appears to be the notable exception where a minority of the acreage is collocated with eelgrass … Continuing activities would occur in 49 percent of the total mapped eelgrass acreage in Willapa Bay, and 21 percent of the [total mapped eelgrass acreage] in Hood Canal … Percentages are less in the other [geographic] regions."

Table 8 presents the Service's best approximation of the likely physical extent of potential impacts to submerged aquatic vegetation resulting from programmatic shellfish activities in Washington's marine waters. Across the geographies and acreages summarized here, the Service expects there will be measurable losses of production and associated ecosystem services, including habitat functions.

Table 8. Likely physical extent of potential impacts to submerged aquatic vegetation

GEOGRAPHY	Affected Nearshore Acres (Action Area)	Continuing Shellfish Activities (Acres)		Affected Submerged Aquatic Vegetation (Acres)[2]
		Total	Co-Located with Eelgrass	
Willapa Bay	30,000	25,840	19,618	Approx. 19,620
Grays Harbor[1]	4,000	2,965	1,918	Approx. 1,920
Hood Canal[1]	3,000	1,356	685	Approx. 790
North Puget Sound[1]	5,000	3,687	3,370	Approx. 3,370
South Puget Sound	5,000	3,133	275	Approx. 320
Total	45,000 to 50,000	~37,000	~25,900	Approx. 26,000

[1] These geographies include designated bull trout critical habitat (see Table 4, p. 77).
[2] All estimates reflect a degree of uncertainty and imprecision. In Hood Canal and south Puget Sound, our estimates include an additional 15 percent to account for potential co-location with rooted kelp.

However, the Service also expects that many of these impacts and measurable losses will be temporary. In most cases, and in most settings where continuing shellfish activities result in physical damage to submerged aquatic vegetation, we expect that much of the lost production and function will be recovered over time. Furthermore, we expect that the conservation measures included by the Corps as elements of their proposed action (see *Project Description, Conservation Measures*) will largely avoid and effectively reduce impacts to submerged aquatic vegetation that might otherwise result from proposed, *new* shellfish activities and farms.

Native eelgrass, rooted kelp, and other submerged aquatic vegetation experience loss and recovery on continuing farms. Native eelgrass and other submerged aquatic vegetation will also experience loss and recovery when fallow farms or farm footprints are re-cultivated and put into production. The Service acknowledges that chronic suppression of eelgrass growth and production may be a reality on some farms. We also acknowledge that fallow farm footprints are extensively co-located with submerged aquatic vegetation; most extensively and importantly for bull trout, in the north Puget Sound (approximately 2,239 acres) (Corps 2015, p. 95).

The weight of available evidence suggests and leads the Service to conclude that permanent losses of submerged aquatic vegetation (native eelgrass and rooted kelp), production, and function will not be typical of most outcomes. While it is likely there will be instances where limited, permanent losses (or chronic suppression) are attributable to shellfish activities, the Service expects that permanent losses will me small (e.g., a fraction of the submerged aquatic vegetation resource) at the scale of the five geographic sub-areas (Willapa Bay, Grays Harbor, Hood Canal, south and north Puget Sound), at the scale of any whole waterbody (e.g., Willapa Bay), or sub-basin (e.g., Totten Inlet, Samish Bay).

Effects to Benthic/Epibenthic Community Structure and Composition

Here we evaluate long-term and persistent effects to benthic/epibenthic community structure and composition. We consider a variety of shellfish activities and culturing techniques, including pre-harvest; bed preparation; frosting and graveling; placement of culturing equipment and materials on and over the bed; mechanical leveling and harrowing; mechanical dredge harvesting; other mechanical harvesting techniques; and geoduck harvest.

Pre-harvest: Pre-harvest removes marketable product and removes, or more commonly relocates, undesirable species. Native shellfish predators, which are sometimes actively removed from farm plots, include moon snails, sea stars, and sand dollars, including the eccentric sand dollar or sea-cake. The non-native eastern oyster drill and Japanese oyster drill are commonly removed from oyster beds. For a period following pre-harvest, and until the cultured species and colonizing species become re-established, most cultured farm plots exhibit a benthic community that is reduced in abundance, biomass, and diversity (Corps 2015, p. 85; Straus *et al*. 2013, p. 20; Vanblaricom *et al*. 2015, pp. 171, 178, 180).

Simenstad and Fresh (1995) reviewed the scale and intensity of disturbance, and the response of intertidal communities to aquaculture activities in Pacific Northwest estuaries. The authors state, "On a community scale, responses to chronic, low intensity or infrequent, intermediate intensity disturbances tend to be within the scope of behavioral or ecological adaptability of the flora and fauna … Dispersal of most epibenthic populations is often continuous and dynamic as a function of tidal advection and resuspension … [and] meiofaunal animals tend to have high … turnover rates that facilitate rapid recolonization" (Simenstad and Fresh 1995, p. 62).

Bed preparation: Intertidal beds are almost always prepared for ground-based culturing of oysters, clams, or geoduck clams with some amount of raking and light grading, regardless of whether the farm uses direct bottom culturing, bag, rack-and-bag, stake, or longline culturing techniques. This is typically accomplished with the use of hand tools and may coincide with pre-harvest (also, see mechanical leveling and harrowing). Bed preparation with hand tools generally only disturbs the shallowest substrates. Available information suggests there are unlikely to be measurable effects that persist more than a few days, or a few high and low tide cycles.

Frosting and graveling: Frosting and graveling are used to coarsen and firm substrates, either to promote and encourage a natural set of seed, or to improve conditions for the maturing and growth of planted clams or seeded cultch. Several thin layers of material are typically placed over a period of days. Some growers/farm operators gravel or frost their beds on an annual basis, while others do so less frequently.

The Corps and Services developed conservation measures under a SLOPES process, and the Corps has included the conservation measures in their proposed action (Corps 2015, pp. 49-53). The Corps has incorporated a conservation measure which limits the amount of material placed annually, and which should also prevent excessive mounding or piling of placed material (Corps 2015, p. 49). At the rates/amounts proposed we would not expect to see wholesale conversion of the substrate type.

Simenstad *et al*. (1991 *In* Simenstad and Fresh 1995, p. 52) found that these practices can alter the benthic infaunal community, especially the dominant or co-dominant taxa, but unless there is total replacement of the natural substrate, effects to the epibenthic community (crustaceans and decapod crustaceans, mobile and sessile echinoderms, mobile and sessile gastropods, etc.) are less pronounced and often site-specific. The authors do acknowledge that (Simenstad and Fresh 1995, p. 50), "the Washington Department of Fisheries has investigated differences in benthic infauna composition and densities at sites that have been graveled to enhance clam production … [and] their results (Washington Department of Fisheries 1988; Thompson and Cooke 1991; Thompson, 1995; Washington Department of Fisheries and Fisheries Research Institute, University of Washington unpublished data) indicate a shift away from communities numerically dominated by glycerid, sabellid, and nereid polychaetes [bloodworms, feather duster tube worms, and rag or clam worms] to ones dominated by bivalve molluscs and nemerteans [ribbonworms]."

Placement of culturing equipment and materials on and over the bed: The benthic community interacts with, and is influenced by, equipment and materials placed on and over the bed (e.g., nets, bags, racks, stakes, longlines, tubes), currents, wave action, patterns of sediment transport, and the intensively cultured shellfish. Over the long-term (i.e., "grow-out" and cycles of production), benthic community structure and composition may be strongly influenced by these interactions.

Straus *et al*. (2013), when discussing the effects of geoduck cultivation, have emphasized the following:

> "The effects of shellfish aquaculture on benthic faunal communities are strongly debated, as many contrasting effects have been reported" (p. 18).

> "In general, effects on benthic infauna are most pronounced in soft sediment habitats directly below, or immediately adjacent to, shellfish aquaculture operations as a function of organic enrichment via biodeposits (Dumbauld *et al*. 2009) … Crawford *et al*. (2003) … found that benthic community structure was not significantly different between farm and reference sites … Greater differences in benthic infauna were found among farms than between farm and reference sites, suggesting that local conditions may dictate how the benthic environment is affected by shellfish aquaculture" (pp. 18, 19).
>
> "Grant *et al*. (1995) found relatively minor changes … Reference sites showed higher abundance of benthic macrofauna but lower biomass, and species diversity was higher at the farm sites … Conversely, the benthic community under a … longline mussel farm experienced dramatic declines in species diversity, from a healthy and diverse complex … to a community consisting entirely of infaunal polychaetes (Kaspar *et al*. 1985)" (p. 19).
>
> "In studies comparing benthic habitats in Willapa Bay… abundance was higher in on-bottom oyster aquaculture and eelgrass beds than in unstructured mudflat (Hosack *et al*. 2006), and diversity was similar (Ferraro and Cole 2007)" (p. 19).
>
> "Hard structures placed on or above low-relief mud or sand habitats represent a novel substrate in the form of solid surfaces fixed in space (e.g., Wolfson *et al*. 1979) … Mobile consumers such as fish and macroinvertebrates are often drawn to structures on low-relief soft-sediment habitats (e.g., Davis *et al*. 1982) … Moreover, these structures may serve as refugia that reduce predation risk (e.g., Dealteris *et al*. 2004), especially for juvenile life-history stages (e.g., Powers *et al*. 2007)" (Straus *et al*. 2013, p. 19).

Numerous authors have described how living bivalves, shells/shell fragments, and their aggregations in reefs or banks create novel substrates and contribute to spatially heterogenous habitats (Gutierrez *et al*. 2003; Sousa, Gutierrez, and Aldridge 2009; Gutierrez *et al*. 2011). Coen *et al*. (2007) and Forrest *et al*. (2009) both review published findings suggesting that bivalves create and enhance habitats for submerged aquatic vegetation, marine invertebrates, and finfish. Appendix D includes excerpts from Gutierrez *et al*. (2003); Coen *et al*. (2007); Forrest *et al*. (2009); Sousa, Gutierrez, and Aldridge (2009); and, Gutierrez *et al*. (2011); those excerpts are incorporated here by reference.

Dealteris *et al*. (2004) assessed the structural habitat complexity inherent to submerged aquatic vegetation, shallow nonvegetated seabeds, and shellfish aquaculture gear, and the abundance, composition, and diversity of associated benthic communities. Appendix D includes excerpts from Dealteris *et al*. (2004); those excerpts are incorporated here by reference.

Dealteris *et al*. (2004, pp. 867, 873) concluded that, "Shellfish aquaculture gear … has habitat value at least equal to and possibly superior to submerged aquatic vegetation." However, we do not reach the same conclusion, and for reasons made evident by this same study. Dealteris *et al*. (2004) reported:

> "The [shellfish aquaculture gear] habitat showed consistently lower Smith and Wilson species evenness values than either the [submerged aquatic vegetation] or [shallow nonvegetated seabeds] because a few species tended to dominate this habitat … The [shellfish aquaculture gear] habitat was significantly lower in species evenness than either the [submerged aquatic vegetation] or [shallow nonvegetated seabed] habitats" (p. 870).

> "The [shellfish aquaculture gear] habitat had consistently lower evenness than the other ecotypes because of the hyperdominance of several species within the aquaculture gear … In contrast, the [submerged aquatic vegetation] habitat was rarely dominated by a few species, but rather supported a more equal distribution of organisms" (p. 873).

> "The species evenness data clearly show that whereas the abundances may be greater in the [shellfish aquaculture gear] habitat, the [shellfish aquaculture gear] habitat is dominated by a few species" (Dealteris *et al*. 2004, p. 873).

Thrush *et al*. (2001) and Gutierrez *et al*. (2011) have both emphasized the often-ignored structural and biological diversity of soft-sediment habitats. "We found local variation in surficial sediment characteristics and the presence of other immobile features, many of which are biogenic, to be strongly related to diversity" (Thrush *et al*. 2001, p. 262). "The overall abiotic impact of an engineered structure will also depend on the baseline abiotic state … While mussels have little influence on the availability of hard substrates on rocky shores, they have a very large effect in soft-sediment systems (Gutierrez *et al*. 2003) … Initial establishment of mussels in areas dominated by soft-substrates increases the availability of hard substrate (i.e., abiotic change) with a positive feedback effect on subsequent mussel recruitment (Bayne 1964)" (Gutierrez *et al*. 2011pp. 10-12). Appendix D includes excerpts from Thrush *et al*. (2001) and Gutierrez *et al*. (2011); those excerpts are incorporated here by reference.

Ferraro and Cole (2012) investigated recurring empirical relationships between operationally-defined biotic communities and habitat types in Willapa Bay, Grays Harbor, and Tillamook Bay, Oregon. They observed the following:

> "Bathymetry, sediment type, and the presence of ecosystem engineering (Jones *et al*. 1994) or niche constructing (Boogert *et al*. 2006) species are habitat characters that operationally define estuarine habitats with different benthic macrofaunal communities in the U.S. Pacific Northwest (Posey 1986; Ferraro and Cole 2004, 2007, 2011; Berkenbusch and Rowden 2007)" (p. 2).

> “There were a total of 107 benthic macrofauna taxa … Twenty-three … species were collected in one and only one habitat type … [but] unique species accounted for <1 percent of the benthic macrofaunal abundance in the habitat in which they were found … Even though many of the more common benthic macrofaunal taxa occurred in multiple habitats … and few benthic macrofaunal species were unique to a single habitat … benthic macrofaunal Bray-Curtis similarity was significantly different among the habitats” (pp. 5, 6).

> “The benthic macrofaunal habitat usage patterns … surpass in detail common generalizations, such as that benthic macrofaunal species richness, abundance, and diversity are typically greater in more structurally complex habitats (Hemminga and Duarte, 2000)” (Ferraro and Cole 2012, p. 10).

Appendix D includes excerpts from Ferraro and Cole (2012); those fuller excerpts are incorporated here by reference.

Hosack *et al*. (2006) compared the fish and invertebrate communities occupying intertidal mudflat, eelgrass, and oyster habitats in Willapa Bay. They observed the following:

> “The introduction of estuarine organisms, such as oysters or other forms of aquaculture, that compete with existing forms of habitat structure, such as seagrass, may affect the availability of important habitat refugia and foraging resources for mobile estuarine fish and decapods” (p. 1150).

> “Habitat types were distinct … between-habitat dissimilarities ranged 82–88 percent, but within-habitat dissimilarities ranged 31–63 percent” (pp. 1153).

> “Densities of epibenthic invertebrates, harpacticoid copepods, and benthic invertebrates varied significantly among habitat types and were generally higher in structured eelgrass and oyster habitats … The assemblage composition … differed between adjacent patches of low intertidal eelgrass, oyster, and unvegetated mudflat” (p. 1156).

> “Results for mobile fish and decapods were somewhat different than the generally accepted view of greater diversity and abundance in vegetated versus unvegetated habitats (Heck *et al*. 1989; Connolly 1994; Edgar and Shaw 1995) … While the composition of fish and decapods varied strongly across both time and space, habitat type explained little of the variation in composition, richness, or size of this component” (p. 1156).

> “Species richness of fish and decapods was not related to habitat [type] … and abundance was [also] unrelated to habitat type” (p. 1155).

> "Benthic invertebrate densities were significantly higher in eelgrass … The rhizome structure of eelgrass beds may support high densities of benthic invertebrates … [But,] Reduced diversity and density of benthic infauna on open mudflats, particularly those adjacent to structured habitat, could be due to increased predation (Orth *et al*. 1984; Summerson and Peterson 1984)" (p. 1157).

> "The fish and decapod assemblage as a whole, which is highly mobile relative to epifauna and infauna, showed little habitat association in Willapa Bay, despite the habitat-specific associations of the invertebrate organisms that would be expected to serve as important prey resources … Fish and decapods frequently exhibit diel cycles in habitat use … Fish [and decapods] caught in this study were sufficiently mobile to forage over much larger spatial scales than the patches of habitat we selected for sampling" (Hosack *et al*. 2006, p. 1158).

Appendix D includes excerpts from Hosack *et al*. (2006); those fuller excerpts are incorporated here by reference.

These studies and findings indicate to us that culturing equipment and materials placed on and over the bed (including nets, bags, racks, stakes, longlines, and tubes), and the intensively cultured shellfish (many of which are non-native species), modify habitat and may create new habitat types (or habitat variants). Culturing equipment/materials and intensively cultured shellfish do clearly influence benthic community structure and composition. However, the weight of available evidence leads the Service to conclude that the direction of these influences are variable (e.g., toward greater abundance and biomass, but reduced species evenness), and the nature of some relationships remains poorly understood. Issues of scale and spatial resolution are evident, exemplified by a general lack of appreciation for the structural and biological diversity inherent to seemingly "barren" or "plain" soft-sediment habitats. The significant roles played by ecosystem engineering or niche constructing species (e.g., eelgrass, oysters, other), and biogenic structures (e.g., kelp forest, oyster reef, other), are also evident.

Mechanical leveling and harrowing: Mechanical leveling and harrowing turn over the surficial substrates and shallow subsurface. This has measurable effects on the benthic community, particle size, sediment chemistry, and nutrient status. Mechanical leveling and harrowing, and for that matter mechanical dredge harvesting, also disturb, physically alter, and can damage or kill benthic infauna and microalgae, sessile epibenthic invertebrates, and attached submerged aquatic vegetation.

Mechanical dredge harvesting: Mechanical dredge harvesting is among the most physically-intrusive and disruptive of all the shellfish activities discussed in this Opinion. Dredge harvesting directly impacts substrate conditions, submerged aquatic vegetation (including its many important physical, chemical, biological, and habitat functions), and the benthic community.

"[Disturbances that cause] long-term degradation … frequently involve the loss of equilibrium species … These high-order seres are replaced by pioneering seres … Changes in organism-sediment relations and population dynamics accompany this change … High-order seres … are deeply burrowing errant or tube-dwelling infauna … for example, maldanid, pectinid, and orbinid polychaetes, caudate holothurians, protobranch bivalves, infaunal ophiuroids, and irregular urchins … [while] early or low-order successional stages … [include] tubiculous polychaetes or oligochaetes … [which] feed at, or near, the sediment surface … A transitional stage [and sere] … [may include] a diverse assemblage of tubiculous amphipods, molluscs, and polychaetes" (Rhoads and Germano 1986, p. 295).

Simenstad and Fresh (1995, p. 65, 66) state: "Complex physicochemical and ecological linkages among estuarine organisms and communities can be altered over the long-term by persistent disturbances that exceed natural regimes … Large-scale disturbances, such as those associated with some intensive oyster practices, may induce chronic shifts in the benthic community by removing or reducing the influence of community dominants … or [by] altering the apparent … relationship between them."

Collie *et al*. (2000) published a meta-analysis looking at the effects of towed bottom-fishing gear on benthic communities. They observed the following:

> "Fishing gears used to catch demersal fish and shellfish often disturb both the seabed and the organisms living within or on it … The potential impact of this disturbance has become a subject of heated debate (Malakoff 1998) … The results of any single study are highly specific with respect to fishing gear, disturbance regime, habitat, and environment … Viewing each study in isolation makes it difficult to draw general conclusions" (p. 785).
>
> "We found 57 different manipulations or observations of the effects of fishing disturbance on benthic fauna and communities, extracted from 39 separate publications … [they examine] … gear type … regime [or] number of discrete periods of disturbance … [and] habitat" (p. 786).
>
> "Most (89 percent) of the studies were undertaken at depths less than 60 m; of these 13 (23 percent) were intertidal … All the intertidal studies were conducted at small spatial scales (<50 m) … The largest scale studies were those that compared commercially-fished grounds with closed areas or areas of different fishing intensity … We used the 'regime' variable to distinguish experimental studies (acute disturbance) from the 12 studies comparing fished and unfished areas (chronic disturbance)" (p. 789).
>
> "Dredging had a more negative impact than trawling, which is not surprising as dredges tend to penetrate deeper into the sediments than trawls … The mean response for number of species was … a 27 percent reduction … Larger impacts were observed in mud and gravel habitats than in sand … Intertidal dredging had the most negative impact on species richness" (p. 790).
>
> "Gear type was highly significant, with intertidal dredging having the most negative impact, followed by scallop dredging, and inter-tidal raking" (pp. 790).

> "The variable 'Class' also had a significant effect on the response to disturbance …The largest negative impacts were observed for Anthoza and Malacostraca … Polychaetes were more negatively affected than oligochaetes, which appeared to be the least sensitive class … None of the predicted means were positive … Taxa differed in their response to disturbance, but on average, none increased in abundance" (p. 791).
>
> "The genera least impacted by disturbance were bivalves … Many of these bivalves are small in size or have particularly well armoured shells that protect them from physical damage" (p. 792).
>
> "Patterns of recovery … Depth and scale were either insignificant or had inconsistent effects among models … With respect to gear type, the plots suggest that the source of the statistically significant interaction term is the greater initial impact for intertidal dredging … Intertidal dredging gives the greatest initial responses because it is the most efficient gear … [often] completely removing the … fauna" (pp. 792, 793).
>
> "It is clear that intensively fished areas are likely to be maintained in a permanently altered state, inhabited by fauna adapted to frequent physical disturbance" (Collie *et al*. 2000, p. 795).

Appendix D includes excerpts from Collie *et al*. (2000); those fuller excerpts are incorporated here by reference.

There can be no question whether the acute physical disturbance caused by mechanical leveling, harrowing, and dredge harvesting measurably and significantly changes substrate conditions and the benthic community. These shellfish activities act as intense pulse disturbances, and clearly they will in many cases either interfere with or reset normal patterns of infaunal succession and development. The implications for sediment chemistry, nutrient status, and benthic community richness and evenness are very difficult to predict or generalize across individual sites. However, when we consider that many sites and farms are harrowed and dredged repeatedly over the course of a single or successive cycles of shellfish culturing, it becomes obvious that many of these sites and farms are managed in a more or less permanently (or chronically) "disturbed" state. We can expect that initial effects or impacts to ecological and habitat functions will persist for durations extending months or years. If, however, on some sites and farms the disturbance regimes routinely and repetitively exceed natural patterns of frequency and intensity, those sites may never recover, or may only recover after long periods in a fallowed state.

Other mechanical harvesting techniques: As stated earlier, bottom cultured clams are sometimes harvested mechanically, most notably in Samish Bay. Mechanical clam harvesters are driven or pulled across the exposed bed at low tide, and the clams are "swept" onto a conveyor belt. Another type of mechanical harvesting equipment, the hydraulic escalator, has been mostly or completely phased out and is excluded from coverage under the Corps programmatic consultation (Corps 2015, p. 26).

The mechanical clam harvesters used in Samish Bay are repurposed and re-configured tulip harvesters (Saurel *et al*. 2014, p. 263). The practice is relatively benign; no significant impacts to benthos have been observed (Saurel *et al*. 2014, p. 263).

Geoduck cultivation and harvest: For a full description of the species life history, reproduction, distribution, and habitat, and for a review of relevant research findings regarding the ecological effects of geoduck cultivation (including effects to benthic community dynamics and predator-prey relationships), the reader is referred to the Washington Sea Grant publication Effects of Geoduck Aquaculture on the Environment: A Synthesis of Current Knowledge (Straus *et al*. 2013, pp. 1- 22).

Environ International Corporation (2011) has cited several studies that suggest geoduck culturing and harvest have only a modest impact on benthic invertebrates:

> "Ecological theory suggests that many species typical of wave-exposed sandy environments … exhibit behaviors that enable them to survive daily tidal scouring events (Gorselany and Nelson 1987 as cited in Dernie *et al*. 2003) … It is generally assumed that benthos found in more dynamic sandy habitats will recover more quickly following physical disturbance than those found in less energetic muddy habitats, based on the adaptive strategies of the respective assemblages found in these environments (Kaiser *et al*. 1998, Ferns *et al*. 2000) … Microcosm studies appear to support this hypothesis (Dernie *et al*. 2003)" (p. 50).
>
> "Pearce *et al*. (2007, unpublished) … observed that recovery rates of benthic invertebrates varied in response to timing (season), magnitude, and location of the disturbance in relation to the species involved and level of mobility of those organisms … Kaiser *et al*. (2006) commented that recovery may take longer in cases where recolonization through larval recruitment is the dominant mechanism" (p. 51).
>
> "Spencer *et al*. (1997 as cited in Straus *et al*. 2008) found that the netting used to reduce Manila clam predation led to an increase in surface deposit-feeding worms compared to a community dominated by subsurface deposit-feeding worms in non-netted plots" (p. 51).
>
> "Fleece *et al*. (2004, unpublished) completed a dive study at three locations in Case Inlet that compared epibenthic fauna between geoduck beds with individually netted tubes, adjacent eelgrass beds, and control sites … The authors observed a higher density of epibenthic fauna in geoduck beds in relation to control sites, and similar densities in relation to adjacent eelgrass beds … The structure created by tubes most likely provides additional habitat structure for many epibenthic invertebrate species" (Environ International Corporation 2011, p. 53).

Appendix D includes excerpts from Environ International Corporation (2011); those fuller excerpts are incorporated here by reference.

Brown and Thuesen (2011) assessed the biodiversity of mobile benthic fauna in cultured south Puget Sound geoduck beds. They observed the following:

> "Both sites were commercial-scale geoduck farming operations and were representative of typical geoduck farms in Puget Sound" (p. 772).
>
> "Using Coleman rarefaction analysis, species richness was significantly higher (P < 0.05) in the structured geoduck site … compared with its control site … However, there was no significant difference observed between the [un-structured] geoduck grow-out site … [and] its control" (p. 773).
>
> "[At the structured Eld Inlet site] low species evenness was observed … [At the un-structured Nisqually Reach site] there was greater species evenness … [Graceful crab] *C. gracilis* was [still] the most abundant species, comprising 35.0 percent of the individuals … [but] staghorn sculpin, *Leptocottus armatus*, and red rock crab, *Cancer productus*, each made up 26.5 percent of the individuals" (p. 773).
>
> "In southern Puget Sound, even small differences in habitats can demonstrate broad variability in community member assemblages, as evidenced by the differences between the study sites in Eld Inlet and Nisqually Reach" (Brown and Thuesen 2011, p. 774).

Appendix D includes excerpts from Brown and Thuesen (2011); those fuller excerpts are incorporated here by reference.

McDonald *et al*. (2013) looked at the effects of geoduck aquaculture gear on resident and transient macrofaunal communities. They report the following:

> "The Shannon index was utilized to compare differences in diversity between plots … This measure is commonly used in ecological studies and combines aspects of species richness and relative abundance … (Shannon 1948, Shannon and Weaver 1949) … A higher index value indicates higher diversity" (p. 54).
>
> "All sites were characterized by substantial seasonal variation … We collected and identified 68 taxa … [Our] analyses illustrate differences in community structure across months …, plot types, and phases at each site … Within each site … community data from the pre-gear phase were similar at culture and reference plots … Similarly, there were no significant differences … for culture and reference plots at any site when aquaculture structures were in place (gear-present)" (p. 54).
>
> "Taxa showed no consistent response to geoduck aquaculture … Only two taxa experienced persistent negative effects: the polychaete Families Spionidae … and Orbiniidae" (p. 55).
>
> "Of the significant functional groups, true crab and other nearshore fish show[ed] strongest associations with culture plots during the gear-present phase, when PVC tubes and nets were in place" (p. 55).

> "Resident invertebrate communities were characterized by strong seasonal patterns of abundance and site-specific differences in composition … Effects on resident … infauna and epifauna may be site-specific … Elucidating potential mechanisms responsible for differences in the response of infauna will require additional study" (p. 56).
>
> "Unlike resident macrofauna, the transient fish and macroinvertebrate community was clearly affected by aquaculture activities … Presence of PVC tubes and nets significantly altered abundance and composition, but not diversity, of transient macrofauna … Over two times more organisms were observed during surveys at the culture plots than at reference areas during the structured phase of geoduck aquaculture, indicating that geoduck aquaculture gear created favorable habitat for some types of Puget Sound macrofauna" (McDonald *et al*. 2013, p. 56).

Appendix D includes excerpts from McDonald *et al*. (2013); those fuller excerpts are incorporated here by reference.

Geoduck clams are typically harvested using hand-operated water jet probes. Seawater is pumped under pressure into the substrate, liquefying the substrate and allowing extraction of the clam by hand. Willner (2006) considered the effects of geoduck dive harvest. Appendix D includes excerpts from Willner (2006); those excerpts are incorporated here by reference.

Vanblaricom *et al*. (2015) recently reported the findings of a multi-site study evaluating the effects of geoduck harvest on benthic infaunal communities in the south Puget Sound. The authors use a treatment and control experimental design to describe spatial and temporal (i.e., seasonal) patterns of abundance and diversity, and to evaluate the effects of harvest both on and adjacent to cultured farm plots. "There was scant evidence of effects on the community structure … [and] no indications of significant 'spillover' effects of harvest on uncultured habitat adjacent to cultured plots" (p. 171). The authors suggest: "…a principal reason for the apparent insensitivity of resident infauna … is accommodation of the infaunal assemblage to a significant natural disturbance regime ... natural disturbances typical of the area provide a rate of physical intervention … substantially greater than rates of significant disturbance caused by geoduck aquaculture operations in a given plot" (p. 183). The authors go on to say, "…the prevailing natural disturbance climate in the region has effectively selected the infaunal assemblage toward tolerance of and resilience to the types of disturbances associated with geoduck aquaculture operations", but also warn that "…the data may not provide a sufficient basis for unequivocal extrapolation to cases when a given plot is exposed to a long series of successive geoduck aquaculture cycles" (Vanblaricom *et al*. 2015, pp. 183, 184).

Summary: Interactions between benthic/epibenthic communities and shellfish activities are complex. Culturing equipment and materials placed on and over the bed, and the intensively cultured shellfish that they promote (many of which are non-native species), modify habitat, and/or create new habitat types (or habitat variants). Shellfish activities do clearly influence benthic community structure and composition. However, studies consistently indicate significant seasonal and site-by-site variability, issues of scale and spatial resolution are evident, and the nature of some relationships remains poorly understood. Some interactions with shellfish activities do appear to benefit and favor specific benthic/epibenthic taxa and functional groups.

Mechanical leveling, harrowing, and dredge harvesting act as intense pulse disturbances. Geoduck harvesting may also act as an intense pulse disturbance, though generally it occurs at a much reduced frequency (e.g., once every 7 to 9 years). These activities have implications for substrate conditions, sediment chemistry, nutrient status, and benthic community richness and evenness. While clearly they will in many cases either interfere with or reset normal patterns of infaunal succession and development, and many sites and farms are therefore managed in a chronically disturbed state, the long-term implications for benthic/epibenthic community health are difficult to predict or generalize across individual sites. When evaluating potential interactions and outcomes, we must consider that the current conditions in the action area represent at many locations a dynamic equilibrium influenced by shellfish and other activities conducted over years and decades. The significant roles played by ecosystem engineering or niche constructing species (e.g., eelgrass, oysters, other), and biogenic structures (e.g., kelp forest, oyster reef, other), are evident.

Effects to Predator-Prey Dynamics and Productivity (Prey-Mediated Effects)

Here we evaluate potential effects to predator-prey relationships and dynamics, and prey productivity and availability. Shellfish activities have measurable, persistent or long-term effects to substrates, submerged aquatic vegetation, and benthic/epibenthic community structure and composition. These, in turn, may influence habitat function and productivity for a variety of prey resources that are important to listed species.

Unfortunately, there are relatively few studies that provide relevant and specific information to describe interactions between shellfish activities and the prey resources that are considered most important to bull trout and marbled murrelets foraging in the marine environment (e.g., marine forage fish, juvenile salmonids). Further complicating matters, conditions resulting from shellfish activities reflect variable patterns and rates of recovery from disturbance, and the discernable direct and indirect effects of shellfish activities are generally also superimposed on, and further influenced by, natural variability, patterns of disturbance and recovery from natural events, and the confounding effects of concurrent, unrelated activities occurring in the same nearshore environments and watersheds.

Simenstad and Fresh (1995, pp. 44, 63) offered useful examples to help explain potential interactions, and also warned of potential cascading trophic affects:

> "In [the] Pacific Northwest … a number of economically-important fishes feed preferentially on specific taxa of intertidal soft-bottom meiofauna and small macrofauna … Of prime interest are juvenile chum, Chinook, and coho salmon that exhibit a high fidelity for shallow estuarine habitats … These fish feed on a restricted suite of epibenthic harpacticoid copepods, gammarid amphipods, [and] cumaceans … When feeding in estuarine habitats, particularly in eelgrass meadows and mud flats, juvenile chum salmon prey extensively on only a few taxa of harpacticoid copepods such as *Harpacticus uniremis*, *Tisbe* spp., and *Zaus* sp. (Healey 1979; Simenstad *et al*. 1982, 1988; D'Amours 1987, 1988) … A number of other species, including smelts ([Family] Osmeridae), sand lances ([Family] Ammodytidae), and sticklebacks ([Family] Gasterosteidae) also prey heavily on these same prey taxa … early in their life histories

(Simenstad *et al*. 1988) … Similarly, amphipods such as *Corophium salmonis* and *C. spinicorne* and cumaceans are preyed upon extensively by juvenile Chinook salmon (Dunford 1975; Northcote *et al*. 1979; Levy and Northcote 1982; Simenstad *et al*. 1982) and by migratory waterfowl and shorebirds such as sandpipers [Family Scolopacidae] and dunlin (*Caladris alpina*) … (Albright and Armstrong 1982; Baldwin and Lovvorn 1994)."

> "Aquaculture … may disturb benthic-epibenthic habitats beyond natural intensities or frequencies, perhaps for years or decades … When scales of human disturbance exceed that of natural regimes … effects can potentially cascade … to affect production of other estuarine, marine, and anadromous populations" (Simenstad and Fresh 1995, pp. 44, 63).

Doney *et al*. (2012) also emphasize the significance of altered species interactions and trophic pathways: "Shifts in the size structure, spatial range, and seasonal abundance of populations … in turn, lead to altered species interactions and trophic pathways as change cascades from primary producers to upper-trophic-level fish, seabirds, and marine mammals … in both bottom-up and top-down directions … Investigating the responses of individual species to single forcing factors, although essential, provides an incomplete story and highlights the need for more comprehensive, multispecies- to ecosystem-level analyses" (Doney *et al*. 2012, p. 12).

The nusery-role concept: There is wide acknowledgement that eelgrass meadows, kelp forests, and other structured habitats of the estuarine environment (e.g., oyster reefs, estuarine wetlands, mangroves) provide a diversity of microhabitats (Figure 44), and may also confer significant benefits in the forms of enhanced growth, survival, and recruitment for a huge variety of organisms. These structured habitats are therefore frequently described as "nurseries". A number of authors have examined and critiqued the nusery-role concept as it relates to the function and value of structured estuarine habitats, including eelgrass meadows.

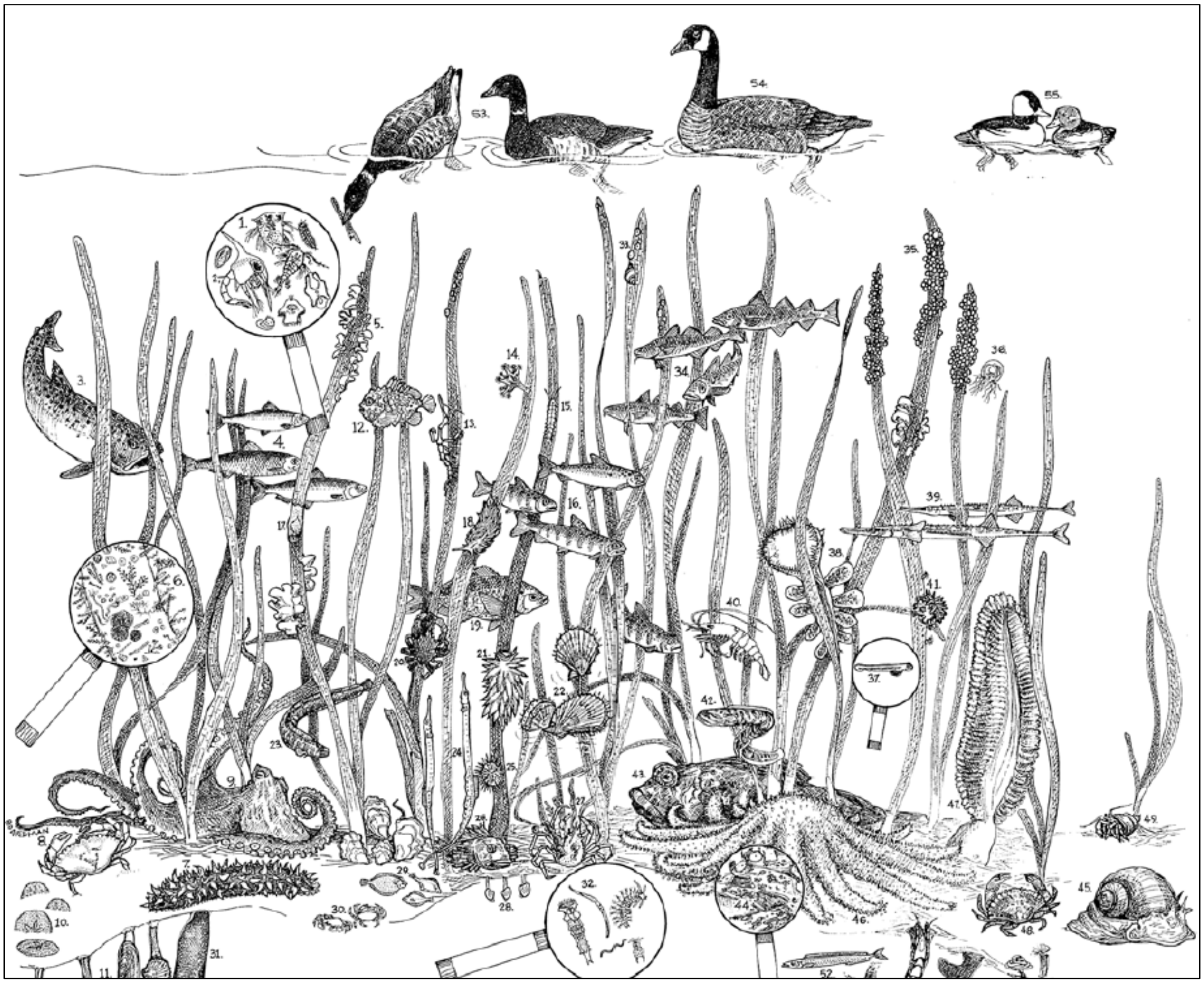

Figure 44. The eelgrass meadow; a world of microhabitats
(Mumford 2007, p. 3)

Beck *et al*. (2001) have argued that "…a better understanding of the habitats that serve as nurseries for marine species, and the factors that create site-specific variability in nursery quality, will improve conservation and management." They observed the following:

> "Comparisons are often limited to vegetated versus unvegetated habitats (Edgar and Shaw 1995, Gray *et al*. 1996) … Generally, an area has been called a nursery if a juvenile fish or invertebrate species occurs at higher densities, avoids predation more successfully, or grows faster there than in a different habitat" (p. 634).
>
> "The few studies that have focused on differences in juvenile survival … indicate that survival of a species is generally greater in vegetated than in unvegetated habitats (Orth *et al*. 1984, Heck and Crowder 1991, Able 1999) … [But] Even fewer studies have focused on the effects … [to] growth of fish and invertebrates (Heck *et al*. 1997, Phelan *et al*.

> 2000) … In seagrass meadows, evidence regarding growth is, surprisingly, equivocal … Only about half of the studies report that the growth rate of individuals is higher in seagrass habitats than in adjacent habitats (Heck *et al*. 1997)" (p. 634).
>
> "There is growing recognition that there are exceptions to the nursery-role concept … [few] species of fish and invertebrates appear to rely exclusively on seagrass meadows … (Heck *et al*. 1995) … (Able and Fahay 1998) … Instead, most of these species use seagrass meadows opportunistically but can survive well in unvegetated areas" (p. 635).
>
> "The ecological processes operating in nursery habitats, as compared with other habitats, must support greater contributions to adult recruitment from any combination of four factors: (1) density, (2) growth, (3) survival of juveniles, and (4) movement to adult habitats" (p. 635).
>
> "The nursery value of seagrass meadows … may vary geographically … Many biotic and abiotic factors can influence the nursery value of habitats for a species [including predation, competition, food availability, water depth, location, tidal regime, disturbance regime, fragmentation, and connectivity] … For example, Heck and Crowder (1991) found that predation on target species in seagrass beds was lower in more structurally complex beds, which suggests that more complex beds may serve as better nurseries for many species because they increase survivorship" (Beck *et al*. 2001, p. 638).

Heck, Hays, and Orth (2003) used meta-analytic techniques to examine whether seagrass meadows function as effective nursey grounds. They observed the following:

> "Surprisingly, few significant differences existed in abundance, growth, or survival when seagrass meadows were compared to other structured habitats, such as oyster or cobble reefs, or macroalgal beds … Nor were there decreases in harvests of commercially important species that could be clearly attributed to significant seagrass declines in 3 well studied areas … One important implication of these results is that structure per se, rather than the type of structure, appears to be an important determinant of nursery value" (p. 123).
>
> "Of the total 193 comparisons, 89 (46 percent) showed greater abundance in seagrass, 50 (26 percent) showed greater abundance in other habitats, and 54 (28 percent) showed no difference between seagrass and other habitats … Thus, for slightly more than half of the species studied, seagrass meadows did not support abundances that were significantly greater than those in surrounding habitats … [However,] There is stronger evidence of the importance of seagrass meadows in the northern hemisphere, where 58 of 77 comparisons (75 percent) showed significantly greater abundances in seagrass" (pp. 126, 127).

> "When all studies were considered together in the unlumped data set, seagrasses had a significantly positive effect on juvenile survival when compared to other habitats … [But] The effect of seagrass meadows on juvenile survival clearly varied across species … with no discernible patterns by taxonomy (fish vs decapod crustaceans) or geography (tropical vs temperate)" (pp. 127, 129).

> "The enhanced survival of organisms in seagrass compared to that observed on unvegetated substrates seems to be due primarily to the simple effect of structure and not some intrinsic property of the seagrasses themselves … [Still] Over a period of more than 20 years, virtually all studies have found significantly greater survival in the presence than in the absence of seagrasses, whether in the laboratory (Nelson 1979, Coen *et al*. 1981, Main 1987, Mattila 1995) or in the field (Leber 1985, Heck and Wilson 1987, Heck and Valentine 1995)" (p. 131).

> "Growth was also significantly greater in seagrass than on unvegetated substrates, although there was little difference between growth in seagrass and other structured habitats … It may well be that greater growth in structured habitats occurs because structure provides more protection from predators and thereby allows more time for feeding, and thus significantly greater growth rates, than is possible in unstructured habitats … It is also true that structure provides more substrate for food resource to grow upon, which can be an important factor influencing growth rates" (Heck, Hays, and Orth 2003, p. 132).

Appendix D includes excerpts from Beck *et al*. (2001) and Heck, Hays, and Orth (2003); those fuller excerpts are incorporated here by reference.

Sheaves, Baker, and Johnston (2006) have argued that tests of the nursery-role hypothesis are often overly simplistic, and therefore likely to misunderstand and/or misrepresent important relationships:

> "While some species use particular habitats within an area as 'nurseries', for others nursery ground value is derived from the whole area (Aiken *et al*. 2002) … In essence, nursery ground provision needs to be considered at different scales for different species" (p. 304).

> "In many cases, the situation is complex, with many habitat types or habitat areas contributing to support juvenile nutrition and provide refuge from predation (Dorenbosch *et al*. 2004a, Niklitschek and Secor 2005, Sheaves 2005) … Where this occurs, untangling the contribution of the various constituents of the mosaic could prove very difficult … The effectiveness of habitats may be additive, with many different habitats utilised over time and space (Hernandez *et al*. 2001, Pederson and Peterson 2002, Niklitschek and Secor 2005), making identification of the exact contribution of each, and unambiguously quantifying the importance of a particular habitat, fraught with difficulties" (p. 304).

> "Breaking complex systems into simpler units can provide insights, but it is dangerous to apply such piece-by-piece understanding in isolation from the complexity … The approach of applying a rigid and overly simplistic 'recipe book' classification of complex and dynamic systems may lead to a failure to adequately recognise and understand critical links and processes which support marine nurseries" (Sheaves, Baker, and Johnston 2006, pp. 304, 305).

Landscape scale interactions and dynamics: Bostrom, Jackson, and Simenstad (2006) reviewed and synthesized a large body of literature describing the landscape ecology of seagrasses and their effects on associated fauna; they observed the following:

> "Patterns (e.g., abundance, diversity, biomass) and processes (e.g., recruitment, predation, flows and productivity) at a specific site can only be fully understood by including broad-scale … variables and landscape attributes … We review landscape patterns and [the] processes that cause them, and then present models for faunal distribution" (pp. 383, 384).

> "The landscape mosaic model … [takes] into account that organisms rarely show a preference for a specific structured habitat, i.e. seagrass, oyster reefs, macroalgae, and mangrove … An alternative view is to see the species/process/question-specific landscape as a mosaic of different habitats (McGarigal and Cushman, 2002) … [The model] proposes that optimal foraging, movement, and fitness strategies vary for different animals within a mosaic" (p. 386).

> "A total of 33 papers published between 1994 and 2004 met our search criteria … skewed towards the temperate northern latitudes … *Zostera* spp. … [were among] the most studied landscape-forming genera/species … 50 percent of the papers examined the role of patch size and 43 percent examined edge effects, i.e., possible differences in response variables between the seagrass boundary and the interior parts of a patch or meadow" (pp. 391, 392).

> "About 50 percent of all studies focused on some aspect of seagrass ecosystem configuration based on a variety of partly correlating metrics, including fragmentation, proximity, connectivity, isolation, fractal dimension, total linear edge, number of patches, edge contrast, and patch orientation … At its simplest, fragmentation is usually observed as a reduction in seagrass cover and a decrease in patch size over time, causing an increase in the proportion of habitat edge and distance between patches, i.e. decreased connectivity and increased amount of unvegetated corridors" (p. 393).

> "In two thirds of the studies examined, seagrass patch size was a significant predictor of [faunal] density (n = 7), growth (n = 5), and mortality (n = 4), respectively … However, half of the studies examined showed non-significant results for the same response variables, mainly due to confounding effects of sites, seasons, and target taxa … This exemplifies the difficulty in linking effects of seagrass landscape pattern to faunal structure" (p. 393).

> "We found mixed effects of fragmentation in seagrass landscapes, with about equal proportions of significant … and non-significant effects … suggesting that seagrass fragmentation is not necessarily detrimental for associated animals" (p. 396).
>
> "Studies in terrestrial landscapes have demonstrated critical thresholds in fragmentation, where mobility and diversity patterns change dramatically and nonlinearly (Gardner and Milne, 1987; Rosen, 1989) … Demonstration of such threshold responses … [in seagrass landscapes] warrants further investigation" (p. 396).
>
> "In accordance with Turner *et al*. (2001), it might be summarized that effects of spatial patterns/fragmentation on organisms are not likely to be important if habitat patches are abundant … and well connected, edge effects are not central to the process/species under study, and movement between suitable habitats is relatively unlimited" (p. 397).
>
> "The importance of unvegetated strips as corridors for large mobile predators (e.g., Irlandi *et al*., 1995) is likely to vary depending on target species and water depth … In very shallow seagrass landscapes, where the leaf canopy reaches the water surface, unvegetated corridors may provide the only avenue for movement/foraging in an unstructured environment, while in deeper seagrass landscapes the space above the leaf canopy can also be utilized by mobile fauna" (p. 398).
>
> "Nonlinear relationships between ensemble faunal variables and landscape metrics were identified by a number of studies, and are to be expected when assessing species with different perception of the seagrass landscape … This may also account for the lack of relationships in some studies and the opposing results of comparable studies … In order to contrast patterns across regions and to allow the synergistic development of our knowledge in this field, we need to standardise our use of landscape metric and terms in relation to seagrass landscapes … Perhaps the more daunting need is a much better understanding of the various processes operating at various scales and possible cascading effects across scales that influence fauna-environment relationships in seagrass landscapes … It is obvious from this literature that they are complex, difficult to predict, and still relatively under-studied" (Bostrom, Jackson, and Simenstad 2006, p. 399).

Appendix D includes excerpts from Bostrom, Jackson, and Simenstad (2006); those fuller excerpts are incorporated here by reference.

Summary: There are relatively few studies that provide relevant and specific information to describe interactions between shellfish activities and the prey resources that are considered most important to bull trout and marbled murrelets foraging in the marine environment (e.g., marine forage fish, juvenile salmonids). Lacking information from these types of studies, we have instead considered available information describing the nursery function of structured estuarine habitats, including eelgrass meadows, and available information regarding the altered species assemblages, and altered species and trophic interactions, that are likely to result from loss or fragmentation of structured estuarine habitat.

Whereas, we have already concluded that (1) shellfish activities resulting in physical damage to submerged aquatic vegetation will result in losses of production and associated ecosystem services (including habitat functions), and (2) some activities (e.g., mechanical leveling, harrowing, and dredge harvesting) will in many cases either interfere with or reset normal patterns of infaunal succession and development, available information regarding predator-prey relationships, and prey productivity and availability, is more ambiguous and therefore also less compelling. Further complicating matters, conditions resulting from shellfish activities are generally superimposed on, and further influenced by, natural variability, patterns of disturbance and recovery from natural events, and the confounding effects of concurrent, unrelated activities occurring in the same nearshore environments and watersheds. While there is some information to indicate a decline in the health of marine forage fish resources in the action area (see *Environmental Baseline*, *Willapa Bay*, *Grays Harbor*, *Puget Sound and Hood Canal*), and the decline of many salmonid populations is both obvious and widespread, there is little or no information attributing those conditions to shellfish activities specifically.

Furthermore, not all of the potential shellfish interactions are detrimental to the health of native eelgrass and rooted kelp, or nearsore habitat complexity, function, and productivity. Bivalves and other filter-feeding shellfish, whether occurring naturally or in farmed/cultured settings, do provide important benefits in the form of ecosystem services (e.g., improved water quality; sequestration of carbon and nutrients). Culturing equipment and materials, and the intensively cultured shellfish that they promote, create new habitat types (or habitat variants). Biodeposition, as a source of nutrient enhancement supporting plant growth and vigor, and improved water quality may well act to enhance eelgrass and kelp health in some settings. And, importantly, cultured shellfish are themselves ecosystem engineering or niche constructing species, and the habitat value of the biogenic structures they create is evident.

Impacts to marine forage fish spawning habitat resulting from programmatic shellfish activities: The BA submitted by the Corps in support of programmatic consultation provides a summary of available data, and the limitations of available data, to describe the distribution of marine forage fish spawning habitat in the action area, and its co-location with continuing shellfish activities (Corps 2015, pp. 90, 95-97; Appendix D). The Service regards these data, and the Corps' analyses, as the best available information to describe the likely physical extent of potential impacts to marine forage fish spawning habitat resulting from programmatic shellfish activities in Washington's marine waters. The Service does acknowledge that there is no current, comprehensive mapping of marine forage fish spawning habitat in Puget Sound, Hood Canal, or the coastal embayments of Willapa Bay and Grays Harbor.

The Corps has stated the following regarding potential impacts to marine forage fish spawning habitats located on fallowed farm footprints (Corps 2015, pp. 95-97):

> "There is substantial overlap between forage fish spawning locations and [shellfish] activities … There are an estimated total of 3,297 fallow acres across all [geographic] regions co-located with forage fish spawning areas … The analysis suggests that Willapa Bay and north Puget Sound are the [geographic] regions where the most overlap may occur on an acreage basis … Relative to the total mapped herring spawning area in each region, activities in Willapa Bay tend to occur in well over half of the mapped spawning

area, by far the largest proportion of any of the [geographic] regions … The north Puget Sound region contains the most fallow acres (2,241 acres) potentially co-located with forage fish spawning areas … Much of this is overlap with the herring spawning area in Samish Bay."

Table 9, below, presents the Service's best approximation of the likely physical extent of potential impacts to marine forage fish spawning habitat resulting from programmatic shellfish activities in Washington's marine waters. Across the geographies and acreages summarized here, the Service expects there will be measurable, temporal losses of marine forage fish spawning habitat and production. However, the Service also expects that most of these impacts and measurable losses will be temporary. In most cases, and in most settings where continuing shellfish activities result in temporal losses of marine forage fish production, we expect that much of the lost function and production will be recovered over time. Furthermore, we expect that the conservation measures included by the Corps as elements of their proposed action (see *Project Description*, *Conservation Measures*) will largely avoid and effectively reduce impacts to marine forage fish spawning habitat that might otherwise result from proposed, new shellfish activities and farms.

Marine forage fish spawning habitat experiences loss and recovery on continuing farms. Marine forage fish spawning habitat will also experience loss and recovery when fallow farms or farm footprints are re-cultivated and put into production. The Service acknowledges that fallow farm footprints are extensively co-located with marine forage fish habitat; most extensively and importantly for bull trout, in the north Puget Sound (approximately 2,239 acres)(Corps 2015, p. 95).

The weight of available evidence suggests and leads the Service to conclude that permanent losses of marine forage fish spawning habitat and production will be uncommon, and not typical of most outcomes. The Service does not expect that permanent losses attributable to shellfish activities will be measurable at the scale of the five geographic sub-areas (Willapa Bay, Grays Harbor, Hood Canal, south and north Puget Sound), at the scale of any whole waterbody (e.g., Willapa Bay), or sub-basin (e.g., Totten Inlet, Samish Bay). We expect that these temporal losses will rarely, if ever, occur at a scale, or with a duration or severity, sufficient to measurably reduce the quality or availability of bull trout prey resources in any portion of the action area.

Table 9. Likely physical extent of potential impacts to marine forage fish spawning areas.

GEOGRAPHY	Affected Nearshore Acres (Action Area)	Continuing Shellfish Activities (Acres)		
		Total	Co-Located with Mapped Herring	Co-Located with Mapped Other[2]
Willapa Bay	30,000	25,840	2,710	---
Grays Harbor[1]	4,000	2,965	73	---
Hood Canal[1]	3,000	1,356	269	394
North Puget Sound[1]	5,000	3,687	2,670	195
South Puget Sound	5,000	3,133	93	989
Total	45,000 to 50,000	~37,000	Approx. 5,815	Approx. 1,578

[1] These geographies include designated bull trout critical habitat (see Table 4, p. 77).
[2] Mapped "Other" combines mapped Pacific sand lance and mapped surf smelt spawning habitat.

Related or additional considerations for marine birds and shorebirds: Straus *et al*. (2013, p. 20) discuss briefly the variety of potential interactions with marine birds (waterfowl) and shorebirds. Some of these interactions and effects are likely to be beneficial (e.g., increased concentration of cultured bivalve prey, provision of perching and roosting structures), while others are clearly not (e.g., disturbance, displacement, risk of entanglement). "Responses depend largely on species-specific food and habitat requirements … waders (e.g., plovers and oystercatchers) and divers (e.g., scaup and scoters) may benefit from an increased concentration of … prey" (Straus *et al*. 2013, p. 20).

However, there are disturbing lines of evidence to suggest the severity of potential long-term shellfish interactions and outcomes for marine birds (waterfowl), shorebirds, and raptors. Studies conducted in Europe, Canada, and the United States have contributed a large body of literature and findings addressing prey depletion and conversion or displacement from preferred, highly productive foraging areas.

"Coastal aquaculture and fisheries are expanding industries, and their further development is accepted by society … With increasing industrialization of the landscape, it has also become important to protect ecologically important habitats from further human impact" (Hilgerloh and Young 2006, p. 535). "Coastal sites and habitats where birds are especially vulnerable have to be identified, with modeling to predict the impacts of three particular effects: (1) habitat loss, including bird exclosures, (2) competition for food between humans and birds, and (3) disturbance … Behavior-based models employing optimal decision rules are needed to make predictions on the fitness of birds, quantified in terms of survival rate and body condition" (Hilgerloh and Young 2006, p. 535).

Norris, Bannister, and Walker (1998) reported evidence of prey depletion, its relationship to fishery exploitation, and the numbers of oystercatchers remaining on overwintering grounds during the spring:

> "The abundance of oystercatchers during spring (measured as total bird-days during March and April) was positively correlated with the biomass of cockles at the start of the winter, and negatively correlated with the biomass landed by the fishery over the winter … The most likely explanation for this is that birds disperse from the Burry Inlet earlier in spring when the biomass of cockles at the start of the winter is small and/or the biomass landed by the fishery is large" (p. 75).
>
> "The Burry Inlet cockle fishery is a low intensity fishery, removing < 25 percent of the available stock, and using traditional fishing methods such as hand gathering … Even at these low levels of fishing effort oystercatcher abundance was reduced during spring … The introduction of more efficient modern fishing methods, such as tractor or suction dredging, could therefore cause a decline in the abundance of oystercatchers within the estuary, if the level of exploitation increased as a result" (p. 75).
>
> "Both autumn cockle biomass and winter cockle landings do seem to affect the number of birds left in March and April at the end of the winter … Results suggest that the declining trend in spring oystercatcher abundance has resulted from a decline in the biomass of cockles and an increase in the biomass landed by the fishery during the winter" (Norris, Bannister, and Walker 1998, p. 82).

Stillman *et al*. (2001) used a behaviour-based model to evaluate the impacts of current and alternative shellfishery regimes on oystercatcher health, mortality, and population size:

> "This study explored the impacts of the present-day management regime of the mussel fishery on the Exe estuary, south-west England … and of the cockle fishery on the Burry inlet, south Wales … on the survival and numbers of overwintering oystercatchers … It also explored the effect on birds of some possible alternative ways of managing these shellfisheries" (p. 858).
>
> "Present-day methods and fishing effort did not affect the body condition of model oystercatchers on either the Exe or Burry … But with increased shellfishing, and the use of dredging, a point came when many oystercatchers could not compensate by feeding for longer or eating more smaller prey … Unsuccessful birds then drew on their energy reserves and so lost mass … The model predicted that increasing fishing effort substantially above current levels would reduce the average mass of surviving birds for all methods, except hand-raking cockles" (pp. 862, 863).
>
> "Mussel-fishing techniques that reduced bed area (hand-raking and dredging) both reduced the food available and forced birds to feed at higher densities, thus increasing both exploitation and interference competition" (p. 865).

> "The simulations … showed that relatively small increases in mortality due to intensive shellfishing could indeed greatly reduce population size … Small increases in mortality caused by fishing should not be assumed to be of little importance" (p. 864).
>
> "Small changes in oystercatcher mortality caused larger changes in the long-term population size because the oystercatcher population did not recover from the effects of shellfishing between winters … The model predicted that the impact of shellfishing on oystercatchers depends not only on fishing effort but also on environmental factors such as the weather and overall food abundance" (Stillman *et al*. 2001, p. 866).

Godet *et al*. (2009) considered the effects of intensive clam cultivation on *Lanice conchilega* [sand mason worm] beds and found that beds were both degraded and less attractive to foraging oystercatchers; they observed the following:

> "In 2005, we studied the impacts of Manila clam cultivation on the Chausey's *L. conchilega* beds focusing on the macrobenthic compartment (Toupoint *et al*., 2008) … This study mainly revealed that clam cultivation induced a decrease of both the *L. conchilega* densities and of the abundance and the diversity of the associated macrofauna … In this paper, we aimed at assessing the impacts of the degradation of Chausey's *L. conchilega* beds by this activity on the spatial distribution of a secondary consumer: the Eurasian Oystercatcher *Haematopus ostralegus*" (p. 590).
>
> "Before the creation of the new clam concessions, *L. conchilega* beds were significantly selected by Oystercatchers as a major feeding ground … We highlighted (Godet *et al*., 2008) the important abundances of large bivalves especially the Cockle (*Cerastoderma edule*) … known to be an important prey for the Oystercatcher (Cramp and Simmons, 1983)" (pp. 591, 593).
>
> "The present study revealed that the positive effects of the *L. conchilega* beds for birds are ephemeral … The regression or the disappearance of *L. conchilega* beds involved directly a loss of attractiveness for the feeding Oystercatchers" (p. 593).
>
> "During the first year of the production cycle, clam concessions are not attractive for Oystercatchers because: (1) during six months nets prevent any predation, (2) during the following months, clam are hardly large enough to be profitable for the birds, and (3) the associated benthic macrofauna is less abundant in one-year concessions … Clam concessions are potentially the most attractive during the second year of the production cycle until the beginning of the third year, before harvesting … Nevertheless, we did not find any differences between the different concessions of one, two, or three years for the attractiveness of the birds" (p. 593).
>
> "The rapid … [growth] of shellfish farming activities along the world's coasts may have irreversible and increasing negative impacts on secondary consumers which have only just begun to be explored by the scientific community" (Godet *et al*. 2009, p. 594).

Kraan *et al*. (2009) provide evidence that intensive, landscape-scale shellfish activities have caused or contributed to prey depletion, reductions in available foraging habitat, reduced survival, and reduced numbers of red knots (*Calidris canutus islandica*):

> "Whether intertidal areas are used to capacity by shorebirds can best be answered by large-scale manipulation of foraging areas … The recent overexploitation of benthic resources in the western Dutch Wadden Sea offers such an 'experimental' setting … We review the effects of declining food abundances on red knot [*Calidris canutus islandica*] numbers, based on a yearly large-scale benthic mapping effort, long-term colour-ringing, and regular bird-counts from 1996 to 2005 … We focus on the three-way relationships between suitable foraging area, the spatial predictability of food, and red knot survival … Over the 10 years, when accounting for a threshold value to meet energetic demands, red knots lost 55 percent of their suitable foraging area … This ran parallel to a decrease in red knot numbers by 42 percent … Densities of red knots per unit suitable foraging area remained constant at 10 knots [per] ha between 1996 and 2005, which suggests that red knots have been using the Dutch Wadden Sea to full capacity" (p. 1259).
>
> "The mechanical harvesting of cockles *Cerastoderma edule*, allowed in three-quarters of the intertidal flats, has decreased both the quality (flesh-to-shell ratio) and the abundance of available cockles for red knots *Calidris canutus* (Van Gils *et al*. 2006a)" (p. 1260).
>
> "Knots, visiting the area in winter … [over] the period 1996-2005 … were faced with a decline in the extent of suitable foraging area, especially from 2002 onwards … For a benthivorous predator, which also has to deal with tidal cycles (Van Gils *et al*. 2005b, 2006b, 2007), interference competition (Van Gils and Piersma 2004; Vahl *et al*. 2005), and predation by raptors (Piersma *et al*. 1993; Van den Hout, Spaans and Piersma 2008), these landscape-scale changes have population-level impacts" (p. 1265).
>
> "Following the … decline of suitable foraging area … survival of *islandica* knots decreased from 89 percent to 82 percent … Reduced survival (with constant recruitment) only explained … 42 percent of the loss in numbers: more red knots 'disappeared' from the Dutch Wadden Sea than could be explained by the increased mortality (e.g. Van Gils *et al*. 2006a) … Apparently, many surviving red knots emigrated permanently out of this marine protected area … and reduced food abundance may have indirectly lead to reduced breeding success (Ebbinge and Spaans 1995; Baker *et al*. 2004; Morrison, Davidson and Wilson 2007) … In any case, the reduced annual survival clearly supports the suggestion that the Wadden Sea was filled to capacity in the decade during which this study took place (Goss-Custard 1985; Goss-Custard *et al*. 2002)" (Kraan *et al*. 2009, p. 1266).

Bendell and Wan (2011) used high resolution aerial photography and Geographic Information Systems to evaluate the effect of intensive, landscape-scale shellfish activities on patterns of avian habitat utilization; they reported the following:

> "The case study presented here is unique in that the region under study is an Important Bird Area … of global significance (Booth 2001) … The Baynes Sound region supports globally important populations of the Western Grebe (*Aechmophorus occidentalis*), the White-winged (*Melanitta fusca*) and Surf Scoter (*Melanitta perspicillata*), and the Pacific Loon (*Gavia pacifica*) (Booth 2001) … It also serves as a major centre for the BC shellfish aquaculture industry with half of the industries economies being generated from this region (British Columbia Ministry of Sustainable Resource Management (BCMSRM) 2002))."
>
> "On the west coast of BC … there has been [an] attempt by industry and the federal and provincial governments to aggressively expand shellfish aquaculture, with the Manila clam (*Venerupis philippinarum*), and Pacific oyster (*Crassostrea gigas*), the main product farmed … Baynes Sound has a long history of shellfish aquaculture dating back to the 1900's (BCMSRM 2002) … [But] The number of leases and the numbers of approved species for farming on the individual leases has greatly increased since 1984 … In addition to shellfish aquaculture, increasing urban development also results in habitat loss within this region" (pp. 418, 419).
>
> "After the maximum and relevant intertidal [habitats] were digitized, regions of the intertidal covered by anti-predator netting were determined … A multi-step analysis by GIS modelling was applied to the four layers (maximum intertidal, viable intertidal, antipredator netting, and oyster grow-out beds) to determine that region of the foreshore not compromised by shellfish farming activities … We use the information obtained by spatially characterizing the anthropogenic footprint to assess its role in influencing the distribution of shore and water birds such as the dunlin, grebe, and scoter" (pp. 422, 423).
>
> "In Baynes Sound, netted areas … [and] oyster grow-out beds occupy 27 percent and 34 percent of the intertidal area respectively … The amount of foreshore habitat in Baynes Sound used for shellfish farming is … 56 percent of the viable intertidal" (p. 424).
>
> "There were distinct differences in the locations of high bird use in 1980 as compared to 2003-2005 … In 2003-2005 birds were located all along the coastline, with no one particular region of high use" (p. 425).
>
> "Within Baynes Sound, the primary change in intertidal use during this 30 year period has been the development of the foreshore within polygons 33–46 for aquaculture, with the true extent of its footprint determined by high resolution aerial photography coupled with GIS … As the majority of overwintering birds are now found within the Courtenay River Estuary (Comox Harbour) or are distributed along the coastline with no one significant region of high bird use, it would appear that key habitat historically used by these species is no longer available" (Bendell and Wan 2011, p. 429).

Ferriss *et al*. (2015, pp. 15-33) used a trophic model incorporating mediation functions to examine potential food web implications associated with a future growth in central Puget Sound geoduck production; they reported the following:

> "The nontrophic effects of increased geoduck aquaculture, related to the influence of anti-predator structure, had a stronger influence on the food web than the trophic role of cultured geoducks as filter feeders and prey to other species … Increased geoduck culture caused substantial increases in biomass densities of surf perches, nearshore demersal fishes, and small crabs, and decreases in seabirds, flatfishes, and certain invertebrates (e.g., predatory gastropods and small crustaceans)" (p. 15).
>
> "The addition of cultured geoduck mediation functions had a notable impact on the food web [Figure 45] … The biomass of food web members that were linked to geoduck culture through mediation functions changed considerably, with the biomass densities of some members increasing and decreasing by more than 20 percent (e.g., surf perches, small crabs, predatory gastropods, and small mouth flatfishes) … In addition, changes in the biomass of food web members directly linked to geoduck culture propagated through the food web, contributing to additional changes in other members' biomass … In total, the biomasses of 9 of the 10 functional groups with cultured geoduck mediation functions changed substantially" (pp. 21, 22).
>
> "Geoduck mediation functions linked to demersal fishes and small crustaceans had substantial effects on the food web … For example, the cultured geoduck-demersal fish mediation function resulted in decreases in herons (-23 percent) and resident birds (-17 percent), and increases in Pacific cod (+7 percent) and harbor seals (+7 percent) ... The cultured geoduck–small crustacean mediation functions resulted in reductions in the biomasses of juvenile wild salmon (-7 percent) and juvenile hatchery salmon (-4 percent)" (p. 22).
>
> "Geoduck predators (moon snails, starfish, flatfishes, red rock crab, and sea birds) are all generalists to varying degrees and showed limited change in biomass in response to increased geoduck aquaculture … However, the impact of antipredator structure (tubes and nets) placed on geoduck plots had a larger influence on the surrounding food web by providing predation refuge or by changing foraging opportunities … In turn, these effects propagated throughout the food web" (p. 22).
>
> "The substantial decrease of most bird groups in the model is important to note, as these are important ecologically, culturally, and socio-economically … [There was a] decrease in eagle populations … [and] the biomass of other bird groups decrease[d], implying bottom-up control … reduced access to key prey (e.g., demersal fishes and small crustaceans) because of the predator refuge provided by anti-predator nets on geoduck farms … Migratory shore birds (biomass increase) do not primarily prey upon demersal fishes and small crustaceans, and are likely benefiting from a release of eagle predation while not suffering prey depletion … Further empirical study is required to understand the relationship between shellfish aquaculture and birds" (Ferriss *et al*. 2015, p. 24).

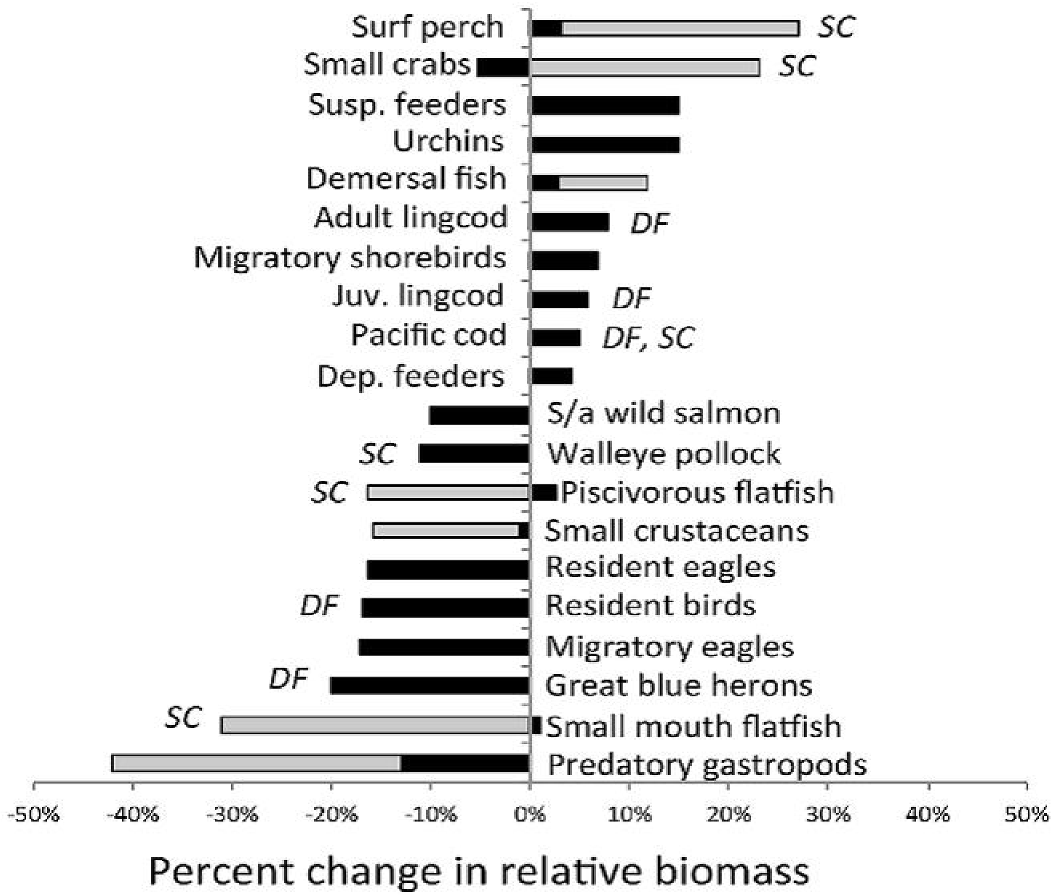

Figure 45. Functional groups with the greatest change in relative biomass
(Ferriss *et al*. 2015, p. 22)

Appendix D includes excerpts from Norris, Bannister, and Walker (1998); Stillman *et al*. (2001); Godet *et al*. (2009); Kraan *et al*. (2009); Bendell and Wan (2011); and, Ferriss *et al*. (2015, pp. 15-33 *In* Washington Sea Grant 2015); those fuller excerpts are incorporated here by reference.

Exposures and Responses to Persistent Stressors (Bull Trout and Murrelet)

Shellfish activities alter physical, chemical, and biological conditions on varying temporal scales. Many of these effects to the physical, chemical, and biological environment (i.e., potential stressors) correspond closely to cycles of production and harvest. However, some of these effects are more persistent, and also reflect variable patterns and rates of recovery from disturbance, and/or interactions with unrelated activities in the same nearshore environments.

This portion of the Opinion has addressed persistent stressors of long duration (months, years), including potential indirect effects that may result from altered patterns of prey availability and productivity ("prey-mediated effects"), and potential long-term effects to natural forms of nearshore marine habitat structure, function, and complexity. These portions of the Opinion have described long-term, direct and indirect effects on large spatial scales, corresponding to hundreds of farms and farm operations, and thousands of affected nearshore marine acres.

Our Opinion finds that the most significant and biologically relevant effects are those that result in aggregate to nearshore marine habitat structure, function, and productivity, ecological processes, and ecosystem services. For wide-ranging species that depend on the action area's variety of nearshore marine environments and resources (e.g., anadromous bull trout), it is ultimately at these larger scales that we can best interpret the significance of potential stressors, exposures, and responses.

Bivalves and other filter-feeding shellfish, whether occurring naturally or in farmed/cultured settings, do provide important benefits in the form of ecosystem services. The Service expects that shellfish activities will generally, and in the majority of cases, provide long-term benefits in the form of improved water quality and sequestration of carbon and nutrients. These ecosystem services may be important as a means to control and prevent the effects of excess nutrient additions occurring elsewhere in the contributing watersheds and may lessen or counteract the potential for climate-induced ocean acidification and hypoxia.

Ecological carrying capacity is a useful concept for thinking about the possible erosion or loss of ecosystem services, and resulting consequences, under a scenario of pervasive and extremely high shellfish culturing densities. While we do not deny the role or significance of social carrying capacity and public acceptance, those aspects are beyond the scope of the Service's considerations, and therefore we limit our consideration of carrying capacity to the physical and ecological elements.

Our Opinion includes a case study of Totten Inlet primary productivity and consumption (MEC-Weston Solutions, Inc. 2004; New Fields Northwest 2008). Totten Inlet's current natural/wild and cultured shellfish biomass is large, but available information suggests a relatively muted or small influence on primary production and trophic state. There is no indication that the Totten Inlet phytoplankton resource has been substantially diminished as a result of shellfish activities, and it appears that primary production still greatly exceeds the basin-scale demand of primary consumers. Even with the projected future growth of the industry in south Puget Sound, available information suggests little or no likelihood of approaching the ecological carrying capacity of this system. While it would be premature to extend these tentative conclusions to the whole of Puget Sound (or to all of Washington's marine waters), the Service does have confidence that Totten Inlet and the south Puget Sound are an appropriately conservative geography and setting for considering these potential effects. Available information leads us to conclude it is unlikely that the projected 20-year future growth of the industry will approach or exceed ecological carrying capacity within the action area.

Shellfish activities have direct and indirect effects to nearshore marine habitat structure, function, and productivity. These effects may have significance for how well these habitats support the essential behaviors and needs of listed species, including bull trout and marbled murrelets that forage in the marine environment. This portion of the Opinion has discussed long-term and persistent effects to substrates and sediment; eelgrass, kelp, and submerged aquatic vegetation; benthic/epibenthic community structure and composition; and predator-prey dynamics and productivity ("prey-mediated effects").

All of the shellfish culturing and harvesting practices that have been described here result in measurable effects to substrates and sediment. Some of these shellfish activities and practices are more likely than others to result in measurable long-term and persistent effects. Based on the available information, we conclude that the placement of culturing equipment and materials on and over the bed, mechanical leveling and harrowing, and mechanical dredge harvesting, are most likely to result in measurable long-term and persistent effects to substrates and sediment. Sites and farms that are harrowed and dredged repeatedly are managed in a chronically "disturbed" state.

Interactions between submerged aquatic vegetation (native eelgrass, rooted kelp) and shellfish activities are complex and not easily characterized with simple generalizations. These interactions include competition for space, competition for light (or shading), and physical damage that results from some activities, practices, and techniques. However, not all of these interactions are detrimental to the health of native eelgrass and rooted kelp. For instance, shellfish culturing provides a source of nutrient enhancement, which supports plant growth and vigor, and frequently improves water quality. Furthermore, when evaluating potential interactions and outcomes, we must also consider that the current conditions for submerged aquatic vegetation in the action area represent at many locations a dynamic equilibrium influenced by shellfish and other activities conducted over years and decades. Despite the intensive shellfish culturing that has characterized the recent history at the scale of whole sub-basins and whole waterbodies, submerged aquatic vegetation continues to show good or consistent health in some of these same geographies (Gaeckle *et al*. 2011, 2015)(see *Environmental Baseline, Puget Sound and Hood Canal, Existing Conditions for Native Eelgrass*).

The variety of factors influencing eelgrass recovery suggests the potential for significant site-by-site and temporal variability. It is therefore difficult (or impossible) to state with certainty the likely pattern or rate of recovery, at either a fine or coarse scale. Furthermore, there appear to be few general rules that accurately characterize this complex set of interactions. Nevertheless, the weight of available evidence does lead the Service to conclude that in most cases and settings where shellfish activities result in physical damage to eelgrass beds, and/or displace eelgrass beds or other submerged aquatic vegetation, they will result in at least temporal loss of production and associated ecosystem services, including habitat functions and prey production that are important to bull trout and marbled murrelets that forage in the marine environment.

Whereas there have been many studies evaluating interactions and outcomes at the scale of a single bed or a single farm, there have been relatively few that describe interactions between submerged aquatic vegetation and shellfish activities on a landscape scale in the Pacific Northwest. However, Dumbauld and McCoy (2015) did recently complete a multi-year study evaluating the effects of oyster aquaculture on eelgrass at the estuarine landscape scale in Willapa Bay. Their findings suggest to us that culturing methods and techniques do have variable effects to patterns of eelgrass disturbance, recovery, and persistence, but the majority of these temporal impacts are not likely to be persistent at the estuarine landscape scale (Dumbauld and McCoy 2015, pp. 38, 41).

The Corps has provided an excellent summary of the available data, and the limitations of these data, to describe eelgrass distribution in the action area, and its co-location with continuing shellfish activities (Corps 2015, pp. 90, 94, 95; Appendix D). The Service used this information to inform our best, conservative approximation of the likely physical extent of potential impacts to submerged aquatic vegetation resulting from programmatic shellfish activities in Washington's marine waters (Table 8, p. 156). We conclude that regulated shellfish activities in Washington State, specifically those for which this Opinion provides programmatic coverage, are likely to directly or indirectly affect more than 26,000 acres of submerged aquatic vegetation, including more than 6,000 acres located within or near designated bull trout critical habitat (Table 8, p. 156).

The Service expects that shellfish activities will result in measurable losses of eelgrass and kelp production, and associated habitat functions and prey productivity that are important to anadromous bull trout and marbled murrelets. However, the Service also expects that most of these impacts and measurable losses will be temporary. In most cases and settings where continuing shellfish activities result in physical damage to submerged aquatic vegetation, we expect that much of the lost production and function will be recovered over time. And, we expect that the conservation measures included by the Corps as elements of their proposed action (see *Project Description, Conservation Measures*) will largely avoid and effectively reduce impacts to submerged aquatic vegetation that might otherwise result from proposed, new shellfish activities and farms.

Native eelgrass, rooted kelp, and other submerged aquatic vegetation experience loss and recovery on continuing farms. Native eelgrass and other submerged aquatic vegetation will also experience loss and recovery when fallow farms or farm footprints are re-cultivated and put into production. The Service acknowledges that chronic suppression of eelgrass growth and production may be a reality on some farms. We also acknowledge that fallow farm footprints are extensively co-located with submerged aquatic vegetation; most extensively and importantly for bull trout, in the north Puget Sound (approximately 2,239 acres) (Corps 2015, p. 95).

The weight of available evidence suggests and leads the Service to conclude that permanent losses of submerged aquatic vegetation (native eelgrass and rooted kelp), production, and function will not be typical of most outcomes. While it is likely there will be instances where limited, permanent losses (or chronic suppression) are attributable to shellfish activities, the Service expects that permanent losses will me small (e.g., a fraction of the submerged aquatic vegetation resource) at the scale of the five geographic sub-areas (Willapa Bay, Grays Harbor, Hood Canal, south and north Puget Sound), at the scale of any whole waterbody (e.g., Willapa Bay), or sub-basin (e.g., Totten Inlet, Samish Bay).

Interactions between benthic/epibenthic communities and shellfish activities are complex and not easily characterized with simple generalizations. Shellfish activities clearly influence benthic community structure and composition. However, studies consistently indicate significant seasonal and site-by-site variability, and the nature of some relationships remains poorly understood.

Shellfish activities have measurable, persistent or long-term effects to substrates, submerged aquatic vegetation, and benthic/epibenthic community structure and composition. These, in turn, may influence habitat function and productivity for a variety of prey resources that are important to listed species. Unfortunately, there are relatively few studies that provide relevant and specific information to describe interactions between shellfish culturing and harvesting activities and the prey resources that are considered most important to anadromous bull trout and marbled murrelets. Lacking information from these types of studies, we instead considered available information describing the nursery function of structured estuarine habitats, including eelgrass meadows, and available information regarding the altered species assemblages, and altered species and trophic interactions, that are likely to result from loss or fragmentation of structured estuarine habitat.

Whereas, we have already concluded that (1) shellfish activities resulting in physical damage to submerged aquatic vegetation will result in losses of production and associated ecosystem services (including habitat functions), and (2) some activities (e.g., mechanical leveling, harrowing, and dredge harvesting) will in many cases either interfere with or reset normal patterns of infaunal succession and development, available information regarding predator-prey relationships, and prey productivity and availability, is more ambiguous and therefore also less compelling. Further complicating matters, conditions resulting from shellfish activities are generally superimposed on, and further influenced by, natural variability, patterns of disturbance and recovery from natural events, and the confounding effects of concurrent, unrelated activities occurring in the same nearshore environments and watersheds. While there is some information to indicate a decline in the health of marine forage fish resources in the action area (see *Environmental Baseline*, *Willapa Bay*, *Grays Harbor*, *Puget Sound and Hood Canal*), and the decline of many salmonid populations is both obvious and widespread, there is little or no information attributing those conditions to shellfish activities specifically.

During 2008, the Service and NMFS approved a low-effect HCP developed in coordination with the DNR for their commercial geoduck fishery. That record of HCP approval indicates minor and small-scale effects resulting from elevated turbidity and sedimentation during harvest activities (Service Ref. No. PRT-TE187810-0). The Service stated:

> "Pacific herring are the [marine forage fish] species most likely to spawn on or near commercial geoduck tracts … Injury and or mortality to juvenile and adult forage fish from sediment are not anticipated … Temporary displacement of forage fish from sediment plumes may occur during harvest activities … [but] will have little effect on forage fish's ability to feed … A small amount of Pacific herring egg mortality and the temporary displacement of adult forage fish during geoducks harvest activities [are] anticipated, but adverse effects to forage fish populations at the tract level or within the action area are not anticipated" (USFWS 2009b, pp. 128-130).

The Corps has provided a summary of available data, and the limitations of available data, to describe the distribution of marine forage fish spawning habitat in the action area, and its co-location with continuing shellfish activities (Corps 2015, pp. 90, 95-97; Appendix D). The Service used this information to inform our best, conservative approximation of the likely physical extent of potential impacts to marine forage fish spawning habitat resulting from programmatic shellfish activities in Washington's marine waters (Table 9, p. 177). We conclude that regulated shellfish activities in Washington State, specifically those for which this Opinion provides programmatic coverage, are likely to directly or indirectly affect more than 5,500 acres of mapped Pacific herring spawning habitat, and more than 1,500 acres of mapped Pacific sand lance and surf smelt spawning habitat, including more than 3,600 acres located within or near designated bull trout critical habitat (Table 9, p. 177).

The Service expects there will be measurable, temporal losses of marine forage fish spawning habitat and production. However, the Service also expects that most of these impacts and measurable losses will be temporary. In most cases, and in most settings where continuing shellfish activities result in temporal losses of marine forage fish production, we expect that much of the lost function and production will be recovered over time. And, we expect that the conservation measures included by the Corps as elements of their proposed action (see *Project Description*, *Conservation Measures*) will largely avoid and effectively reduce impacts to marine forage fish spawning habitat that might otherwise result from proposed, new shellfish activities and farms. The weight of available evidence suggests and leads the Service to conclude that permanent losses of marine forage fish spawning habitat and production will be uncommon, and not typical of most outcomes.

Regulated shellfish activities occur on large spatial scales in Washington State (approximately 38,716 acres; Corps 2015, pp. 40-49, 77-82). The larger action area, where measurable direct and indirect effects are likely to occur, is expansive (i.e., more than 45,000 acres of nearshore marine habitat). There is also substantial overlap with designated bull trout critical habitat (i.e., approximately 12,000 acres in Grays Harbor, the north Puget Sound, and Hood Canal) which is used seasonally by anadromous bull trout when foraging and migrating.

Nevertheless, given the above-described variable effects of regulated shellfish activities on nearshore marine habitat structure, function, and productivity, ecological processes, and ecosystem services (i.e., including those that are neutral or beneficial, some that are adverse, but few that are measurable, persistent, and adverse), it is difficult to identify specific practices, instances, or scenarios which will have measurable adverse effects to individual bull trout.

Available information suggests to us that mechanical leveling, harrowing, and dredge harvesting are the most physically-intrusive and disruptive of all the shellfish activities discussed in this Opinion. These practices are focused most intensively in Washington's coastal embayments, especially Willapa Bay. Bull trout have been documented in Willapa Bay and its tributaries, though infrequently and in low numbers, and no portion of Willapa Bay has been designated as bull trout critical habitat. Willapa Bay is one of the few geographies in Washington State where landscape scale impacts have been evaluated (Dumbauld and McCoy 2015), and it appears that temporal impacts to eelgrass meadows, a viable general habitat surrogate for natural nearshore habitat complexity, are not likely to be persistent at the estuarine landscape scale.

The weight of available evidence suggests and leads the Service to conclude that permanent losses of marine forage fish spawning habitat and production will be uncommon, and not typical of most outcomes. The Service does not expect that permanent losses attributable to shellfish activities will be measurable at the scale of the five geographic sub-areas (Willapa Bay, Grays

Harbor, Hood Canal, south and north Puget Sound), at the scale of any whole waterbody (e.g., Willapa Bay), or sub-basin (e.g., Totten Inlet, Samish Bay). We expect that these temporal losses will rarely, if ever, occur at a scale, or with a duration or severity, sufficient to measurably reduce the quality or availability of bull trout prey resources in any portion of the action area.

Bull trout will be exposed to the measurable, persistent and long-term effects of regulated shellfish activities. The Service expects that persistent and long-term stressors and exposures resulting directly and indirectly from continuing and proposed, new shellfish activities and farms will in some instances have adverse effects to bull trout. However, we are not able to demonstrate that exposures are reasonably certain to result in a significant disruption of normal bull trout behaviors (i.e., the ability to successfully feed, move, and/or shelter). The best available information is currently insuffcient to demonstrate that persistent and long-term stressors and exposures are reasonably certain to result in measurable adverse effects to energetics, growth, fitness, or long-term survival (injury or mortality).

Marbled murrelets will be exposed to the measurable, persistent and long-term effects of regulated shellfish activities. The Service expects that persistent and long-term stressors and exposures resulting directly and indirectly from continuing and proposed, new shellfish activities and farms will in some instances have adverse effects to marbled murrelets. However, we are not able to demonstrate that exposures are reasonably certain to result in a significant disruption of normal marbled murrelet behaviors (i.e., the ability to successfully feed, move, and/or shelter). The best available information is currently insufficient to demonstrate that persistent and long-term stressors and exposures are reasonably certain to result in measurable adverse effects to energetics, growth, fitness, or long-term survival (injury or mortality).

Effects of Interrelated and Interdependent Actions

Interrelated actions are defined as actions "that are part of a larger action and depend on the larger action for their justification"; interdependent actions are defined as actions "that have no independent utility apart from the action under consideration" (50 CFR section 402.02).

No measurable effects to bull trout individuals, their prey base, or habitat are expected to result from interrelated or interdependent actions. No measurable effects to marbled murrelet individuals, their prey base, or habitat are expected to result from interrelated or interdependent actions.

Effects to the PCEs of Designated Bull Trout Critical Habitat

In nearshore marine areas, the inshore extent of critical habitat is the MHHW line, including the uppermost reach of the saltwater wedge within tidally influenced, freshwater heads of estuaries. Critical habitat extends offshore to a depth of 10 meters (33 ft) relative to the MLLW line (75 FR 63935; October 18, 2010).

When viewed from a landscape perspective, or even from the perspective of a single waterbody (e.g., Willapa Bay) or portion thereof (e.g., Totten Inlet, Samish Bay), shellfish activities are variable in density and spatially discontinuous. At some locations, cultured tidelands extend with only occasional interruption along extended lengths of the nearshore. At other locations, cultured tidelands are interspersed along shorelines that support a range of other uses (residential, recreational, etc.). Where cultured tidelands extend with only occasional interruption, interspersed uncultured areas may experience direct or indirect effects, and are therefore considered part of the action area.

The action area includes approximately 12,000 acres of designated bull trout critical habitat, mostly located in Grays Harbor (approximately 4,000 acres), the north Puget Sound (approximately 5,000 acres), and Hood Canal (approximately 3,000 acres) (Corps 2015 Appendix H, Figures H-1 through H-8) (Table 4, p. 77). South of Tacoma, designated bull trout critical habitat only extends as far as the Nisqually River delta. No portion of Willapa Bay has been designated as critical habitat for the bull trout.

Within the action area, the current condition of designated bull trout critical habitat varies considerably. Current conditions reflect natural variability, patterns of disturbance and recovery from both natural and man-made events, and the effects of earlier and concurrent, unrelated activities occurring in the same nearshore environments and watersheds.

Where shellfish activities have been conducted for many years and will continue to impact habitat conditions, most of the action area cannot be regarded as pristine in its current state. Also, at many locations this habitat exhibits the pervasive effects of shoreline development and alteration. Armored and hardened shorelines, diking and filling of marine and estuarine areas, and overwater structures are all characteristic of the action area. At many locations these features impair important natural processes that create and maintain functional nearshore marine habitat for bull trout and marine forage fish. Natural nearshore habitat complexity is either mildly or moderately impaired throughout much of the action area. The same can be said for the condition of bull trout prey resources. At some locations either or both of these functions may be severely impaired.

An earlier portion of this Opinion identified the PCEs of designated bull trout critical habitat and described their baseline condition in the action area (see *Environmental Baseline*, *Current Condition in the Action Area*, *Bull Trout Critical Habitat*). This portion of the Opinion discusses the foreseeable direct and indirect effects of the action, with reference to the specific PCEs which are present and may be affected.

[<u>Note</u>: New critical habitat regulations (81 FR 7214; February 11, 2016) use PBFs rather than PCEs. The shift in terminology does not change the approach used in conducting a “destruction or adverse modification” analysis, which is the same regardless of whether the original designation identified PCEs, PBFs, or essential features. References here to PCEs should be viewed as synonymous with PBFs.]

The action area includes nearshore marine environments providing five of the nine PCEs of designated bull trout critical habitat (50 FR 63898; October 18, 2010):

(2) *Migration habitats with minimal physical, biological, or water quality impediments between spawning, rearing, overwintering, and freshwater and marine foraging habitats, including but not limited to permanent, partial, intermittent, or seasonal barriers*.

Within the action area this PCE is generally only mildly impaired and still functions well. However, in locations where armored and hardened shorelines, marine and estuarine fill, and overwater structures are more pervasive, this PCE is moderately or severely impaired.

Shellfish activities result in measurable, temporary impacts to water quality. Where these temporary impacts to water quality are concerned, our primary focus is on four biologically and behaviorally relevant water quality parameters: turbidity, DO, BOD, and nutrients (e.g., nitrogen and ammonium). ENVIRON International Corp. (2011, p. 41) has observed that water quality conditions typically reflect the pervasive influence of oceanic conditions, residence time, and other human activities in these same nearshore environments and watersheds. Forrest *et al*. (2009, p. 5) have observed, "…the potential for adverse water quality-related effects … is low, which is perhaps not surprising considering that intertidal farm sites are substantially or completely flushed on every tidal cycle." Shellfish activities result in temporary effects to water quality that are localized, limited in physical extent, and low intensity.

During 2008, the Service evaluated the effects of commercial geoduck harvest. That review indicated minor and small-scale effects resulting from elevated turbidity and sedimentation during harvest activities. The described impacts to designated bull trout critical habitat included temporary elevation of sediment levels, and temporary disruption of migratory corridors from diver and vessel activities (USFWS 2009b, p. 134).

Shellfish culturing and harvest activities result in temporary impacts to the sound and visual environment. Most activities associated with ground-based culturing are conducted as bouts of intermittent activity, with each bout lasting a few hours. While some activities may be relieved or partially relieved of strict timing constraints, many still target specific tidal elevations and therefore proceed as bouts of intermittent activity. Effects to the sound and visual environment are temporal and limited in physical extent, intensity, and duration.

Placement of culturing equipment and materials on and over the bed is the most obvious, persistent or long-term effect to nearshore migratory habitat. These materials take a variety of forms, including nets, bags, racks, stakes, longlines, and tubes. Culturing equipment and materials placed on and over the bed, and the intensively cultured shellfish that they promote (many of which are non-native species), do modify habitat, and/or create new habitat types (or habitat variants). The Service has concluded that regulated shellfish activities in Washington State are likely to directly or indirectly affect more than 6,000 acres of submerged aquatic vegetation (native eelgrass and rooted kelp) located within or near designated bull trout critical habitat, mostly in Grays Harbor and the north Puget Sound (Table 4, p. 77; Table 8, p. 156).

Although the Corps has included a number of conservation measures addressing the security of culturing equipment (Corps 2015, pp. 49-53) and many growers and farm operators invest significant time and resources to prevent the loss of equipment, the Service is aware of information documenting instances where equipment has become dislodged and moved from farmed areas by wind and waves (see *Temporary Stressors, Resulting Exposures, and Effects*; *Physical Entrapment and Stranding*). However, to our knowledge, there have been no reported instances of bull trout becoming entrapped or entangled in shellfish culturing equipment, and no reported instances of bull trout becoming stranded within pools impounded by or around shellfish culturing equipment.

Considering the size and mobility of subadult and adult anadromous bull trout, the Service believes that the incidence rate of bull trout entanglement, entrapment, and/or stranding must be very low across the whole of the industry. Aside from the rare instances where individual bull trout become entangled, entrapped, or stranded, the Service expects that these structures and materials do not generally pose a barrier to migration, or hinder or prevent bull trout movement and migration though nearshore marine habitats.

The Service concludes that the proposed action, consisting of the issuance of Corps permits and permit verifications for continuing and proposed, new shellfish activities and farms, will not permanently degrade PCE #2 or prevent nearshore migratory corridors from functioning as intended. The proposed action will result in temporary impacts to water quality and the sound and visual environment, but these effects will be limited in physical extent, intensity, and duration, and are not likely to measurably impair the current function of nearshore migratory corridors. The proposed action will cause or contribute to losses of submerged aquatic vegetation. However, we conclude that permanent losses of submerged aquatic vegetation, production, and function will not be typical of most outcomes. The Service expects no measurable adverse effects to PCE #2.

(3) *An abundant food base, including terrestrial organisms of riparian origin, aquatic macroinvertebrates, and forage fish.*

Within the action area this PCE is either mildly or moderately impaired. Across most portions of the action area, it would appear that both salmonid and marine forage fish prey resources are well below historic, long-term peaks of production. However, year-to-year and geographic variability is significant and not easy to generalize with recognizable trends.

Shellfish culturing and harvesting have direct and indirect effects to nearshore marine habitat structure, function, and productivity. These effects may have significance for how well these habitats support the essential behaviors and needs of listed species, including bull trout that forage in the marine environment.

The Service has concluded that regulated shellfish activities in Washington State are likely to directly or indirectly affect more than 6,000 acres of submerged aquatic vegetation (native eelgrass and rooted kelp) located within or near designated bull trout critical habitat, mostly in

Grays Harbor and the north Puget Sound (Table 4, p. 77; Table 8, p. 156). The Service expects that there will be measurable losses of native eelgrass, rooted kelp, and associated ecosystem services, including habitat functions and prey productivity.

Interactions between benthic/epibenthic communities and shellfish activities are complex and not easily characterized with simple generalizations. Culturing equipment and materials, and the intensively cultured shellfish that they promote, create new habitat types. Cultured shellfish are themselves ecosystem engineering or niche constructing species, and the habitat value of the biogenic structures they create is evident.

Some shellfish culturing and harvesting activities have measurable, persistent or long-term effects to substrates, submerged aquatic vegetation, and benthic/epibenthic community structure and composition. Unfortunately, there are relatively few studies that provide relevant and specific information to describe interactions between shellfish activities and the prey resources that are considered most important to marine foraging bull trout (e.g., marine forage fish, juvenile salmonids).

Whereas, we have already concluded that (1) shellfish activities resulting in physical damage to submerged aquatic vegetation will result in losses of production and associated ecosystem services (including habitat functions), and (2) some activities (e.g., mechanical leveling, harrowing, and dredge harvesting) will in many cases either interfere with or reset normal patterns of infaunal succession and development, available information regarding predator-prey relationships, and prey productivity and availability, is more ambiguous and therefore also less compelling. While there is some information to indicate a decline in the health of marine forage fish resources in the action area (see *Environmental Baseline*, *Willapa Bay*, *Grays Harbor*, *Puget Sound and Hood Canal*), and the decline of many salmonid populations is both obvious and widespread, there is little or no information attributing those conditions to shellfish activities specifically.

We conclude that regulated shellfish activities in Washington State, specifically those for which this Opinion provides programmatic coverage, are likely to directly or indirectly affect more than 5,500 acres of mapped Pacific herring spawning habitat, and more than 1,500 acres of mapped Pacific sand lance and surf smelt spawning habitat (Table 9, p. 177). This includes more than 3,600 acres located within or near designated bull trout critical habitat, mostly in the north Puget Sound and Hood Canal (Table 4, p. 77; Table 9, p. 177).

Marine forage fish spawning habitat experiences loss and recovery on continuing farms. Marine forage fish spawning habitat will also experience loss and recovery when fallow farms or farm footprints are re-cultivated and put into production. The Service acknowledges that fallow farm footprints are extensively co-located with marine forage fish habitat; most extensively and importantly for bull trout, in the north Puget Sound (approximately 2,239 acres) (Corps 2015, p. 95).

The Service expects there will be measurable, adverse effects to PCE #3 associated with losses of marine forage fish spawning habitat and production. However, the Service also expects that most of these impacts and measurable losses will be temporary. In most cases, and in most settings where shellfish culturing and harvesting activities result in temporal losses of marine forage fish production, we expect that much of the lost function and production will be recovered over time.

The weight of available evidence suggests and leads the Service to conclude that permanent losses of marine forage fish spawning habitat and production will be uncommon, and not typical of most outcomes. The Service does not expect that permanent losses attributable to shellfish activities will be measurable at the scale of the five geographic sub-areas (Willapa Bay, Grays Harbor, Hood Canal, south and north Puget Sound), at the scale of any whole waterbody (e.g., Willapa Bay), or sub-basin (e.g., Totten Inlet, Samish Bay).

The Service concludes that the proposed action, consisting of the issuance of Corps permits and permit verifications for continuing and proposed, new shellfish activities and farms, will not permanently degrade PCE #3 or prevent nearshore marine critical habitat from functioning as intended. The proposed action will result in instances of significant temporal loss of marine forage fish spawning habitat and production (temporary adverse effects to PCE #3). We expect that these temporal losses will rarely, if ever, occur at a scale, or with a duration or severity, sufficient to measurably reduce the quality or availability of bull trout prey resources in any portion of the action area.

(4) *Complex river, stream, lake, reservoir, and marine shoreline aquatic environments, and processes that establish and maintain these aquatic environments, with features such as large wood, side channels, pools, undercut banks and unembedded substrates, to provide a variety of depths, gradients, velocities, and structure.*

Within the action area this PCE is moderately impaired, but still functions. At some locations, where armored and hardened shorelines, marine and estuarine fill, and overwater structures are more pervasive, and where important natural processes that create and maintain functional nearshore marine habitat are impeded, this PCE is severely impaired.

Shellfish culturing and harvesting have direct and indirect effects to nearshore marine habitat structure, function, and productivity. These effects may have significance for how well these habitats support the essential behaviors and needs of listed species, including bull trout that forage in the marine environment.

Placement of culturing equipment and materials on and over the bed is an obvious, persistent or long-term effect to nearshore habitat structure and complexity. These materials take a variety of forms, including nets, bags, racks, stakes, longlines, and tubes. Culturing equipment and materials placed on and over the bed, and the intensively cultured shellfish that they promote (many of which are non-native species), do modify habitat, and/or create new habitat types (or habitat variants). Cultured shellfish are themselves ecosystem engineering or niche constructing species, and the habitat value of the biogenic structures they create is evident.

Interactions between submerged aquatic vegetation (native eelgrass, rooted kelp) and shellfish activities are complex and not easily characterized with simple generalizations. These interactions include competition for space, competition for light (or shading), and physical damage that results from some activities, practices, and techniques. However, not all of these interactions are detrimental to the health of native eelgrass and rooted kelp. For instance, shellfish culturing provides a source of nutrient enhancement, which supports plant growth and vigor, and frequently improves water quality. The variety of factors influencing eelgrass recovery suggests the potential for significant site-by-site and temporal variability. Culturing methods and techniques have variable effects to patterns of eelgrass disturbance, recovery, and persistence, but the majority of these temporal impacts are not likely to be persistent at the estuarine landscape scale.

The Service has concluded that regulated shellfish activities in Washington State are likely to directly or indirectly affect more than 6,000 acres of submerged aquatic vegetation (native eelgrass and rooted kelp) located within or near designated bull trout critical habitat, mostly in Grays Harbor and the north Puget Sound (Table 4, p. 77; Table 8, p. 156). The Service expects that there will be measurable losses of native eelgrass, rooted kelp, and associated ecosystem services, including habitat functions.

Native eelgrass, rooted kelp, and other submerged aquatic vegetation experience loss and recovery on continuing farms. Native eelgrass and other submerged aquatic vegetation will also experience loss and recovery when fallow farms or farm footprints are re-cultivated and put into production. The Service acknowledges that chronic suppression of eelgrass growth and production may be a reality on some farms. We also acknowledge that fallow farm footprints are extensively co-located with submerged aquatic vegetation; most extensively and importantly for bull trout, in the north Puget Sound (approximately 2,239 acres) (Corps 2015, p. 95).

The Service concludes that the proposed action, consisting of the issuance of Corps permits and permit verifications for continuing and proposed, new shellfish activities and farms, will not permanently degrade PCE #4 or prevent nearshore marine critical habitat from functioning as intended. The weight of available evidence suggests and leads the Service to conclude that permanent losses of submerged aquatic vegetation (native eelgrass and rooted kelp), production, and function will not be typical of most outcomes. While it is likely there will be instances where limited, permanent losses (or chronic suppression) are attributable to shellfish activities, the Service expects that permanent losses will be relatively small (e.g., a fraction of the submerged aquatic vegetation resource) at the scale of the five geographic sub-areas (Willapa Bay, Grays Harbor, Hood Canal, south and north Puget Sound), at the scale of any whole waterbody (e.g., Willapa Bay), or the sub-basin (e.g., Totten Inlet, Samish Bay).

The proposed action will have spatially and temporally adverse effects to PCE #4. The action will result in instances of significant loss of submerged aquatic vegetation and associated habitat function. The action will reduce natural forms of nearshore marine habitat structure and complexity at some locations.

(5) *Water temperatures ranging from 2 to 15 °C (36 to 59 °F), with adequate thermal refugia available for temperatures that exceed the upper end of this range. Specific temperatures within this range will depend on bull trout life-history stage and form; geography; elevation; diurnal and seasonal variation; shading, such as that provided by riparian habitat; stream flow; and local groundwater influence.*

Conditions are not degraded. Within the action area this PCE is fully functioning, with little or no significant impairment.

The proposed action will not cause or contribute to measurable increases in surface water temperature, or degrade thermal refugia within the action area. We conclude that foreseeable effects to PCE #5 will not be measurable, and are therefore considered insignificant. Within the action area this PCE will retain its current level of function (fully functioning).

(8) *Sufficient water quality and quantity such that normal reproduction, growth, and survival are not inhibited.*

Water and sediment quality conditions are generally suitable and adequately functioning, though some portions of the action area exhibit mild or moderate impairment. Shellfish culturing and harvesting activities result in measurable, temporary impacts to water quality. Where these temporary impacts to water quality are concerned, our primary focus is on four biologically and behaviorally relevant water quality parameters: turbidity, DO, BOD, and nutrients (e.g., nitrogen and ammonium). ENVIRON International Corp. (2011, p. 41) has observed that water quality conditions typically reflect the pervasive influence of oceanic conditions, residence time, and other human activities in these same nearshore environments and watersheds. Forrest *et al.* (2009, p. 5) have observed, "…the potential for adverse water quality-related effects … is low, which is perhaps not surprising considering that intertidal farm sites are substantially or completely flushed on every tidal cycle." Shellfish activities result in temporary effects to water quality that are localized, limited in physical extent, and low intensity.

During 2008, the Service evaluated the effects of commercial geoduck harvest. That review indicated minor and small-scale effects resulting from elevated turbidity and sedimentation during harvest activities. The described impacts to designated bull trout critical habitat included temporary elevation of sediment levels (USFWS 2009b, p. 134).

Bivalves and other filter-feeding shellfish, whether occurring naturally or in farmed/cultured settings, provide important benefits in the form of ecosystem services. The Service expects that shellfish activities will generally, and in the majority of cases, provide long-term benefits in the form of improved water quality and sequestration of carbon and nutrients. These ecosystem services may be important as a means to control and prevent the effects of excess nutrient additions occurring elsewhere in the contributing watersheds and may lessen or counteract the potential for climate-induced ocean acidification and hypoxia.

Ecological carrying capacity is a useful concept for thinking about the possible erosion or loss of ecosystem services, and resulting consequences, under a scenario of pervasive and extremely high shellfish culturing densities. While we do not deny the role or significance of social carrying capacity and public acceptance, those aspects are beyond the scope of the Service's considerations, and therefore we limit our consideration of carrying capacity to the physical and ecological elements. Available information leads us to conclude it is unlikely that the projected 20-year future growth of the industry will approach or exceed ecological carrying capacity within the action area.

The Service concludes that the proposed action, consisting of the issuance of Corps permits and permit verifications for continuing and proposed, new shellfish activities and farms, will not degrade PCE #8. The proposed action will result in temporary impacts to water quality, but these effects will be limited in physical extent, intensity, and duration, and are not likely to measurably impair the current function of PCE #8. The proposed action will provide significant, measurable long-term benefits in the form of improved water quality and sequestration of carbon and nutrients. The Service expects no measurable adverse effects to the function of PCE #8. Within the action area this PCE will retain its current level of function (generally suitable and adequately functioning).

Summary

The proposed action will have measurable adverse effects to PCE #3 (*food base, including marine forage fish*) and PCE #4 (*complex marine shoreline aquatic environments and processes*). The Service expects that any permanent adverse effects to PCE #4 will be limited in scale. The Service concludes that the proposed action, consisting of the issuance of Corps permits and permit verifications for continuing and proposed, new shellfish activities and farms, will not prevent designated nearshore marine critical habitat from functioning as intended.

CUMULATIVE EFFECTS

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

Ongoing non-federal actions in the action area include implementation of State shellfish and angling regulations, State hatchery programs, and State, tribal, local, and private habitat restoration programs (i.e., those not supported by federal funds). Future local actions will include planned growth, development, and re-development consistent with land use and growth management plans. Future State and local actions may include implementation of TMDLs and watershed-scale water quality improvement programs. Taken as a whole, the foreseeable future State, tribal, local, and private actions may have both beneficial effects and adverse effects to the marbled murrelet, bull trout, and designated bull trout critical habitat.

The State's programs implementing shellfish and angling regulations provide for sustainable, fish- and wildlife-related recreational and commercial opportunities, while also ensuring long-term protection and enhancement of marine and estuarine resources. Related to these programs, the State administers more than two dozen marine protected areas in Puget Sound (conservation areas, marine preserves, and exclusion zones) for the protection and preservation of sensitive species and their habitats.

The State's hatchery programs produce fish for harvest and support large and regionally important recreational fisheries. Hatchery programs also support wild stock research and conservation. The State is currently working with federal, tribal, and private managers and scientists to examine hatchery operations and determine what structural and operational changes are necessary to ensure that hatchery programs can continue to meet these dual objectives. Key issues include genetic introgression, competition, and disease transmission between hatchery-reared and wild stocks.

Ongoing non-federal actions also include State, tribal, local, and private habitat restoration programs. These programs are directed at protecting, enhancing, and restoring marine and estuarine habitats and the native fish and wildlife populations they support. Habitat restoration programs also provide for the advancement of marine and estuarine science, refinement of applied techniques, and public participation and education.

Future local actions will include planned growth, development, and re-development consistent with land use and growth management plans. Additional urban and suburban residential, commercial, and industrial development (or redevelopment) is certain to occur in the action area. Over the long-term, planned growth consistent with land use and growth management plans will result in additional effects to watershed conditions and functions, water and sediment quality, and nearshore marine and estuarine habitat conditions. However, with effective implementation of Shoreline Management Programs and Critical Area Ordinances, and in conjunction with State and local (city, county) environmental permit requirements (including those requirements established for the protection of wetlands and for the regulation of private and municipal stormwater discharges), effects to ecological functions should be reduced. Future State and local actions may also include implementation of TMDLs and watershed-scale water quality improvement programs.

Taken as a whole, the foreseeable future State, tribal, local, and private actions may have both beneficial effects and adverse effects to the marbled murrelet, bull trout, and designated bull trout critical habitat. Some of these actions (e.g., effective implementation of land use and growth management plans, TMDL clean-up plans, and habitat restoration programs) will be essential, and must be successful, to ensure that the action area will continue to provide for the conservation and recovery of the bull trout and marbled murrelet.

INTEGRATION AND SYNTHESIS OF EFFECTS (BULL TROUT)

The *Integration and Synthesis* section is the final step in assessing the risk posed to species and critical habitat as a result of implementing the proposed action. In this section, we add the effects of the action and cumulative effects to the status of the species and critical habitat, and the environmental baseline, to formulate our Opinion as to whether the proposed action is likely to: (1) appreciably reduce the likelihood of both survival and recovery of the species in the wild by reducing its numbers, reproduction, or distribution; or (2) reduce the value of designated critical habitat for the conservation of the species.

Shellfish culturing and harvesting activities result in measurable, temporary impacts to water quality. Where these temporary impacts to water quality are concerned, our primary focus is on four biologically and behaviorally relevant water quality parameters: turbidity, DO, BOD, and nutrients (e.g., nitrogen and ammonium). Shellfish activities result in temporary impacts that are localized, limited in physical extent, and low intensity.

Shellfish provide important benefits in the form of ecosystem services. The Service expects that shellfish activities will, in the majority of cases, provide significant long-term benefits in the form of improved water quality and sequestration of carbon and nutrients. These ecosystem services may be important as a means to control and prevent the effects of excess nutrient additions occurring elsewhere in the contributing watersheds. These ecosystem services may also lessen or counteract the potential for climate-induced ocean acidification and hypoxia.

Bull trout, their habitat, and prey resources will be exposed to shellfish activities, including foreseeable temporary and long-term impacts to water and sediment quality. However, with successful implementation of the included conservation measures, we conclude that shellfish activities will not have adverse effects to water or sediment quality, and related direct and indirect effects to bull trout and designated bull trout critical habitat will be insignificant, or measurable and beneficial.

Shellfish culturing and harvesting activities result in temporary impacts to the sound and visual environment. Most effects are temporal and limited in both physical extent and duration. Taking into consideration both the geographic setting (i.e., an open water marine environment), and the intensity and duration of exposures, we conclude that temporary impacts to the sound and visual environment will not significantly disrupt normal bull trout behaviors (i.e., the ability to successfully feed, move, and/or shelter), and are therefore considered insignificant.

Shellfish activities frequently involve or require placement of culturing equipment and materials on and over the bed (e.g., nets, bags, racks, stakes, longlines, and tubes). These materials are not generally an impediment to movement. To our knowledge, there have been no reported instances of bull trout becoming entrapped or entangled in shellfish culturing equipment. To our knowledge, there have been no reported instances of bull trout becoming stranded behind berms or dikes, or within pools impounded by or around shellfish culturing equipment.

Considering the size and mobility of subadult and adult anadromous bull trout, the Service believes that the incidence rate of entanglement, entrapment, and/or stranding must be very low across the whole of the industry. However, shellfish farms occupy tens of thousands of nearshore marine acres in Washington State, and overlap significantly with habitats that are regularly used by anadromous bull trout (e.g., approximately 12,000 acres of designated bull trout critical habitat). Therefore, the Service concludes with reasonable certainty that there will be limited instances of individual bull trout injury or mortality over the 20-year term of the programmatic (2016 to 2036). We expect that instances of bull trout injury or mortality will occur more frequently in the north Puget Sound, where anadromous bull trout are relatively more abundant, and will occur less frequently in the other four geographic sub-areas (Willapa Bay, Grays Harbor, Hood Canal, and south Puget Sound). The Service expects that a maximum of six (6) subadult or adult bull trout will be injured or killed in the north Puget Sound over the 20-year term of the programmatic. We expect that a maximum of two (2) subadult or adult bull trout will be injured or killed in each of the other four geographic sub-areas (Willapa Bay, Grays Harbor, Hood Canal, and south Puget Sound) over the 20-year term of the programmatic (2016 to 2036).

Shellfish culturing and harvesting activities have direct and indirect effects to nearshore marine habitat structure, function, and productivity. These effects may have significance for how well these habitats support the essential behaviors and needs of listed species, including bull trout that forage in the marine environment. The Service expects there will be measurable losses of native eelgrass and rooted kelp production. We expect that there will be measurable losses of associated ecosystem services, including habitat functions and prey production that are important to bull trout. The Service expects there will be measurable, temporal losses of marine forage fish spawning habitat and production.

However, the Service also expects that most of these impacts and measurable losses will be temporary. In most cases, and in most settings, we expect that much of the lost production and function will be recovered over time. The weight of available evidence suggests and leads the Service to conclude that permanent losses of submerged aquatic vegetation, production, and function will not be typical of most outcomes.

The weight of available evidence suggests and leads the Service to conclude that permanent losses of marine forage fish spawning habitat and production will be uncommon, and not typical of most outcomes. The Service does not expect that permanent losses attributable to shellfish activities will be measurable at the scale of the five geographic sub-areas (Willapa Bay, Grays Harbor, Hood Canal, south and north Puget Sound), at the scale of any whole waterbody (e.g., Willapa Bay), or sub-basin (e.g., Totten Inlet, Samish Bay). We expect that these temporal losses will rarely, if ever, occur at a scale, or with a duration or severity, sufficient to measurably reduce the quality or availability of bull trout prey resources in any portion of the action area.

Ecological carrying capacity is a useful concept for thinking about the possible erosion or loss of ecosystem services, and resulting consequences, under a scenario of pervasive and extremely high shellfish culturing densities. While we do not deny the role or significance of social carrying capacity and public acceptance, those aspects are beyond the scope of the Service's considerations. Available information leads us to conclude it is unlikely that the projected 20-year future growth of the industry will approach or exceed ecological carrying capacity within the action area.

Bull trout will be exposed to the measurable, persistent and long-term effects of regulated shellfish activities. The Service expects that persistent and long-term stressors and exposures resulting directly and indirectly from continuing and proposed, new shellfish activities and farms will in some instances have adverse effects to bull trout. However, we are not able to demonstrate that exposures are reasonably certain to result in a significant disruption of normal bull trout behaviors (i.e., the ability to successfully feed, move, and/or shelter). The best available information is currently insuffcient to demonstrate that persistent and long-term stressors and exposures are reasonably certain to result in measurable adverse effects to energetics, growth, fitness, or long-term survival (injury or mortality).

The Service concludes that the proposed action, consisting of the issuance of Corps permits and permit verifications for continuing and proposed, new shellfish activities and farms, will not appreciably reduce or diminish the current, known distribution of anadromous bull trout in Washington's inland marine waters, and will not appreciably reduce or diminish bull trout numbers (abundance) or reproduction (productivity) at the scale of the local populations, core areas, or coterminous range. The anticipated direct and indirect effects of the action, combined with the effects of interrelated and interdependent actions, and the cumulative effects associated with future State, tribal, local, and private actions will not appreciably reduce the likelihood of survival and recovery of the species. The anticipated direct and indirect effects of the action (permanent and temporary) will not measurably reduce bull trout reproduction, numbers, or distribution at the scale of the core areas or Coastal Recovery Unit. The anticipated direct and indirect effects of the action will not alter the status of the bull trout at the scale of the Coastal Recovery Unit or coterminous range.

The proposed action will have measurable direct and indirect effects to the PCEs of designated bull trout critical habitat. The proposed action will have measurable, temporary adverse effects to PCE #3 (*food base, including marine forage fish*) and PCE #4 (*complex marine shoreline aquatic environments and processes*). The Service does not expect permanent adverse effects to any of the PCEs. The Service concludes that the proposed action, consisting of the issuance of Corps permits and permit verifications for continuing and proposed, new shellfish activities and farms, will not prevent designated nearshore marine critical habitat from functioning as intended.

Within the action area, the PCEs of designated bull trout critical habitat will remain functional, and designated critical habitat will continue to serve its intended conservation role. The anticipated direct and indirect effects of the action, combined with the effects of interrelated and interdependent actions, and the cumulative effects associated with future State, tribal, local, and private actions will not prevent the PCEs of critical habitat from being maintained, and will not degrade the current ability to establish functioning PCEs at the scale of the action area. Critical habitat within the action area will continue to serve the intended conservation role for the species at the scale of the core areas, Coastal Recovery Unit, and coterminous range.

INTEGRATION AND SYNTHESIS OF EFFECTS (MARBLED MURRELET)

The *Integration and Synthesis* section is the final step in assessing the risk posed to species and critical habitat as a result of implementing the proposed action. In this section, we add the effects of the action and cumulative effects to the status of the species and critical habitat, and the environmental baseline, to formulate our Opinion as to whether the proposed action is likely to: (1) appreciably reduce the likelihood of both survival and recovery of the species in the wild by reducing its numbers, reproduction, or distribution; or (2) reduce the value of designated critical habitat for the conservation of the species.

Shellfish culturing and harvesting activities result in measurable, temporary impacts to water quality. Where these temporary impacts to water quality are concerned, our primary focus is on four biologically and behaviorally relevant water quality parameters: turbidity, DO, BOD, and nutrients (e.g., nitrogen and ammonium). Shellfish activities result in temporary impacts that are localized, limited in physical extent, and low intensity.

Shellfish provide important benefits in the form of ecosystem services. The Service expects that shellfish activities will, in the majority of cases, provide significant long-term benefits in the form of improved water quality and sequestration of carbon and nutrients. These ecosystem services may be important as a means to control and prevent the effects of excess nutrient additions occurring elsewhere in the contributing watersheds. These ecosystem services may also lessen or counteract the potential for climate-induced ocean acidification and hypoxia.

Marbled murrelets, their habitat, and prey resources will be exposed to shellfish activities, including foreseeable temporary and long-term impacts to water and sediment quality. However, with successful implementation of the included conservation measures, we conclude that shellfish activities will not have adverse effects to water or sediment quality, and related direct and indirect effects to marbled murrelets will be insignificant, or measurable and beneficial.

Shellfish culturing and harvesting activities result in impacts to the sound and visual environment. Most effects are temporal and limited in both physical extent and duration. Taking into consideration both the geographic setting (i.e., an open water marine environment), and the intensity and duration of exposures, temporary sound and visual disturbance resulting from shellfish activities is unlikely to significantly disrupt normal marbled murrelet behaviors (i.e., the ability to successfully feed, move, and/or shelter). The Service concludes that these temporary exposures will not result in direct injury or mortality, a significant disruption of normal behaviors (i.e., the ability to successfully feed, move, and/or shelter), or measurable adverse effects to energetics, growth, fitness, or long-term survival. However, these general conclusions regarding shellfish activities do not extend to the practice of intentionally hazing wildlife. Growers and farm operators who engage in intentional wildlife hazing should educate themselves and understand their liabilities under the Migratory Bird Treaty Act, Bald and Golden Eagle Protection Act, and ESA (see *Temporary Stressors, Resulting Exposures, and Effects, Intentional Hazing of Wildlife*).

Shellfish activities frequently involve or require placement of culturing equipment and materials on and over the bed (e.g., nets, bags, racks, stakes, longlines, and tubes). These materials are not generally an impediment to movement. To our knowledge, there have been no reported instances of marbled murrelets becoming entrapped or entangled in shellfish culturing equipment. Available information suggests that exposure of marbled murrelets is likely to occur very infrequently, if at all. We conclude that exposures are not discountable ("extremely unlikely"). However, the Service is not able to demonstrate that potential exposures are reasonably certain to result in a significant disruption of normal marbled murrelet behaviors (i.e., the ability to successfully feed, move, and/or shelter) or instances of direct injury or mortality.

Shellfish culturing and harvesting activities have direct and indirect effects to nearshore marine habitat structure, function, and productivity. These effects may have significance for how well these habitats support the essential behaviors and needs of listed species, including marbled murrelets. The Service expects there will be measurable losses of native eelgrass and rooted kelp production. We expect that there will be measurable losses of associated ecosystem services, including habitat functions and prey production that are important to bull trout. The Service expects there will be measurable, temporal losses of marine forage fish spawning habitat and production.

However, the Service also expects that most of these impacts and measurable losses will be temporary. In most cases, and in most settings, we expect that much of the lost production and function will be recovered over time. The weight of available evidence suggests and leads the Service to conclude that permanent losses of submerged aquatic vegetation, production, and function will not be typical of most outcomes.

The weight of available evidence suggests and leads the Service to conclude that permanent losses of marine forage fish spawning habitat and production will be uncommon, and not typical of most outcomes. The Service does not expect that permanent losses attributable to shellfish activities will be measurable at the scale of the five geographic sub-areas (Willapa Bay, Grays Harbor, Hood Canal, south and north Puget Sound), at the scale of any whole waterbody (e.g., Willapa Bay), or sub-basin (e.g., Totten Inlet, Samish Bay). We expect that these temporal losses will rarely, if ever, occur at a scale, or with a duration or severity, sufficient to measurably reduce the quality or availability of marbled murrelet prey resources in any portion of the action area.

Ecological carrying capacity is a useful concept for thinking about the possible erosion or loss of ecosystem services, and resulting consequences, under a scenario of pervasive and extremely high shellfish culturing densities. While we do not deny the role or significance of social carrying capacity and public acceptance, those aspects are beyond the scope of the Service's considerations. Available information leads us to conclude it is unlikely that the projected 20-year future growth of the industry will approach or exceed ecological carrying capacity within the action area.

Marbled murrelets will be exposed to the measurable, persistent and long-term effects of regulated shellfish activities. The Service expects that persistent and long-term stressors and exposures resulting directly and indirectly from continuing and proposed, new shellfish activities and farms will in some instances have adverse effects to marbled murrelets. However, we are not able to demonstrate that exposures are reasonably certain to result in a significant disruption of normal marbled murrelet behaviors (i.e., the ability to successfully feed, move, and/or shelter). The best available information is currently insufficient to demonstrate that persistent and long-term stressors and exposures are reasonably certain to result in measurable adverse effects to energetics, growth, fitness, or long-term survival (injury or mortality).

The Service concludes that the proposed action, consisting of the issuance of Corps permits and permit verifications for continuing and proposed, new shellfish activities and farms, will not appreciably reduce or diminish the current, known distribution of the marbled murrelet in Washington's inland marine waters, and will not appreciably reduce or diminish marbled murrelet numbers (abundance) or reproduction (productivity) at the scale of the action area, Conservation Zones 1 (Puget Sound) and 2 (Western Washington Coast Range), or rangewide. The anticipated direct and indirect effects of the action, combined with the effects of interrelated and interdependent actions, and the cumulative effects associated with future State, tribal, local, and private actions will not appreciably reduce the likelihood of survival and recovery of the species. The anticipated direct and indirect effects of the action (permanent and temporary) will not measurably reduce marbled murrelet reproduction, numbers, or distribution at the scale of action area, Conservation Zone 1, or Conservation Zone 2. The anticipated direct and indirect effects of the action will not alter the status of the marbled murrelet at the scale of Conservation Zone 1, Conservation Zone 2, or rangewide.

CONCLUSION (BULL TROUT AND DESIGNATED CRITICAL HABITAT)

The Service has reviewed the current rangewide status of the bull trout, the environmental baseline for the action area, the direct and indirect effects of the proposed action, the effects of interrelated and interdependent actions, and the cumulative effects that are reasonably certain to occur in the action area. It is the Service's Biological Opinion that the action, as proposed, will not appreciably reduce the likelihood of survival and recovery of the bull trout in the wild. The action, as proposed, is not likely to jeopardize the continued existence of the bull trout. It is the Service's Biological Opinion that the action, as proposed, will not destroy or adversely modify designated bull trout critical habitat.

CONCLUSION (MARBLED MURRELET)

The Service has reviewed the current rangewide status of the marbled murrelet, the environmental baseline for the action area, the direct and indirect effects of the proposed action, the effects of interrelated and interdependent actions, and the cumulative effects that are reasonably certain to occur in the action area. It is the Service's Biological Opinion that the action, as proposed, will not appreciably reduce the likelihood of survival and recovery of the marbled murrelet in the wild. The action, as proposed, is not likely to jeopardize the continued existence of the marbled murrelet.

INCIDENTAL TAKE STATEMENT

Section 9 of the ESA and federal regulation pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct. *Harm* is defined by the Service as an act which actually kills or injures wildlife. Such an act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavior patterns, including breeding, feeding, or sheltering (50 CFR 17.3). *Harass* is defined by the Service as an intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering (50 CFR 17.3). Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the ESA provided that such taking is in compliance with the terms and conditions of this Incidental Take Statement.

The measures described below are non-discretionary, and must be undertaken by the Corps so that they become binding conditions of any grant or permit issued to Corps permit applicants, as appropriate, for the exemption in section 7(o)(2) to apply. The Corps has a continuing duty to regulate the activity covered by this Incidental Take Statement. If the agency 1) fails to assume and implement the terms and conditions, or 2) fails to require applicants to adhere to the terms and conditions of the Incidental Take Statement through enforceable terms that are added to the permit or grant document, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impact of incidental take, the Corps must report the progress of the action and its impact on the species as specified in this Incidental Take Statement [50 CFR 402.14(i)(3)].

The Service does not anticipate that the proposed action will incidentally take marbled murrelets. The Service must provide a reasoned basis for a likelihood of take in order to anticipate and exempt it. Since no marbled murrelet take is anticipated or exempted, no related reasonable and prudent measures or terms and conditions are provided below. If take of marbled murrelets is detected during implementation of the proposed action, reinitiation of formal consultation should be requested, and any operations causing such take must cease pending the outcome of the reinitiated consultation.

AMOUNT OR EXTENT OF TAKE

The Service expects that take of anadromous subadult and adult bull trout, in the form of harm, will result from the proposed action. The Service expects take in each of the five geographic sub-areas (Willapa Bay, Grays Harbor, Hood Canal, south and north Puget Sound). Anadromous bull trout from any of the Puget Sound and coastal Washington core areas may be taken (Puget Sound: Nooksack, Lower Skagit, Stillaguamish, Snohomish-Skykomish, Puyallup, Skokomish, Dungeness, and Elwha River bull trout core areas; Coastal Washington: Hoh, Queets, and Quinault River bull trout core areas).

The Service expects that incidental take of bull trout will be difficult to detect or quantify for the following reasons: 1) the low likelihood of finding dead or injured adults or subadults; 2) delayed mortality; and, 3) losses may be masked by seasonal fluctuations in numbers.

1. Incidental take of subadult and adult bull trout, in the form of harm (injury or mortality), as a direct effect of entrapment or entanglement in shellfish culturing equipment, stranding behind berms or dikes, and/or stranding within pools impounded by or around shellfish culturing equipment.

    a. A maximum of six (6) subadult or adult bull trout will be harmed in the north Puget Sound geographic sub-area over the 20-year term of the programmatic (2016 to 2036).

    b. A maximum of two (2) subadult or adult bull trout will be harmed in each of the other four geographic sub-areas (Willapa Bay, Grays Harbor, Hood Canal, and south Puget Sound) over the 20-year term of the programmatic (2016 to 2036); a total of eight (8) subadult or adult bull trout.

EFFECT OF THE TAKE

In the accompanying Opinion, the Service determined that the level of anticipated take is not likely to result in jeopardy to the species (bull trout) or destruction or adverse modification of critical habitat (designated bull trout critical habitat).

REASONABLE AND PRUDENT MEASURES

1. Minimize and monitor incidental take caused by entrapment or entanglement in shellfish culturing equipment, stranding behind berms or dikes, and/or stranding within pools impounded by or around shellfish culturing equipment.

The proposed action incorporates conservation measures which we expect will avoid and minimize the direct loss of bull trout individuals. We expect that the Corps will fully implement the conservation measures, and therefore they have not been identified as terms and conditions.

TERMS AND CONDITIONS

1. The Corps shall include permit language requiring that all growers/farm operators, when performing other activities on-site, shall inspect for and document any salmonids that are entrapped or entangled in shellfish culturing equipment, stranded behind berms or dikes, or stranded within pools impounded by or around shellfish culturing equipment. The permit language shall provide for immediate notification (within 24 hours) to the Corps, NMFS, and the Service. The permit language shall require a written and photographic record of the event, including dates, species identification, number of individuals, and final disposition.

2. The Corps shall compile information annually and submit a report to the Service (Washington Fish and Wildlife Office, Consultation and Conservation Planning Division, Attn: Federal Activities Branch Manager) by March 1 each year.

3. The Corps shall obtain, compile, and submit to the Service by March 1, 2017, information to describe the ongoing use and prevalence of berms or dikes on the upper intertidal bed: number of current, authorized berms or dikes; permittee, grower or farm operator, name and location; position, length, and current condition of the berm(s) or dike(s). Alternatively, the Corps shall collect this information from applicants during pending permit reauthorizations and shall provide this information in a report to the Service (Washington Fish and Wildlife Office, Consultation and Conservation Planning Division, Attn: Federal Activities Branch Manager) by March 1 each year.

The Service is to be notified within 24 hours upon locating a dead, injured, or sick endangered or threatened species specimen. Initial notification must be made to the nearest U.S. Fish and Wildlife Service Law Enforcement Office. Notification must include the date, time, precise location of the injured animal or carcass, and any other pertinent information. Care should be taken in handling sick or injured specimens to preserve biological materials in the best possible state for later analysis of cause of death, if that occurs. In conjunction with the care of sick or injured endangered or threatened species or preservation of biological materials from a dead animal, the finder has the responsibility to ensure that evidence associated with the specimen is not unnecessarily disturbed. Contact the U.S. Fish and Wildlife Service Law Enforcement Office at (425) 883-8122, or the Service's Washington Fish and Wildlife Office at (360) 753-9440.

CONSERVATION RECOMMENDATIONS

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

The Corps has included conservation measures as elements of their proposed action (Corps 2015, pp. 49-53). Permits and permit verifications issued by the Corps will incorporate these conservation measures as enforceable permit conditions. Permits and permit verifications issued by the Corps will include permit conditions addressing security of culturing equipment used on the tidelands, spill prevention and containment, avoidance of native eelgrass and rooted kelp, performance of marine forage fish spawn surveys, and other related restrictions designed to protect fish and wildlife, aquatic resources, and water quality.

If a Corps permit applicant or group of applicants cannot or will not commit to fully implementing the conservation measures, the issuance of that permit or permit verification cannot be covered under the programmatic consultation, and case-by-case consideration and individual section 7 ESA consultations will be required. Growers and farm operators who seek coverage under the programmatic consultation, but who also fail to fully comply with these conservation measures (where applicable), will not satisfy the requirements of their Corps permit and are potentially liable under provisions of the ESA.

The Corps has excluded 14 specific activities from programmatic coverage (Corps 2015, p. 39). The Corps has indicated that the following activity is specifically excluded from coverage under the programmatic consultation (Corps 2015, p. 39): Any form of chemical application to control undesired species (e.g., non-native eelgrass, *Zostera japonica*; ghost shrimp, *Neotrypaea californiensis*; mud shrimp, *Upogebia pugettensis*).

Service Comment and/or Recommendation – The Service assumes and expects that the Corps will actively solicit information from their applicants about all of the excluded activities, including chemical applications, prior to approving coverage under the programmatic consultation, and before issuing permits or permit verifications. Growers and farm operators who seek coverage under the programmatic consultation, but who also engage in any of the excluded activities (including chemical application to control undesired species), will not satisfy the requirements of their Corps permit and are potentially liable under the provisions of the ESA.

In the event that a Corps applicant or group of applicants has been issued a valid State permit(s) to engage in application of herbicides or pesticides to the bed or waters, the Service expects that the Corps will confirm compliance with the procedural requirements of the ESA before issuing a permit or permit verification under this programmatic. We recommend that the Corps include relevant language to collect this information in the Programmatic ESA Consultation Specific Project Information Form. The Corps has a continuing obligation to implement the programmatic and will only do so successfully if the Corps acts on good information to effectively exclude each and all of the prohibited activities.

REINITIATION NOTICE

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

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