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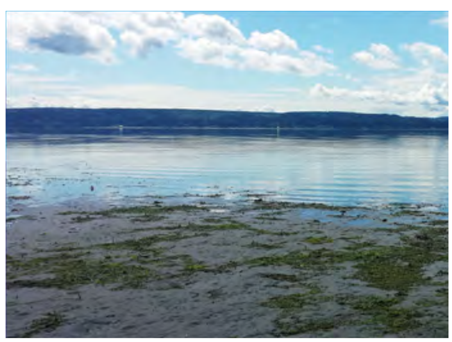
FINAL

ASSESSMENT OF INTERACTIONS BETWEEN SALMON HABITAT RESTORATION AND BIVALVE SHELLFISH RESOURCES

Prepared for:

Hood Canal Coordinating Council

September 2017



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ASSESSMENT OF INTERACTIONS BETWEEN SALMON HABITAT RESTORATION AND BIVALVE SHELLFISH RESOURCES

Prepared for:

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September 2017

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ACRONYMS

°C	degrees Celsius
ADCP	acoustic doppler current profiler
Corps	U.S. Army Corps of Engineers
DNR	Washington State Department of Natural Resources
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
ESNERR	Elkhorn Slough National Estuarine Restoration Project
FLUPSY	Floating Upweller System
GIS	geographic information system
HABs	harmful algal blooms
HCCC	Hood Canal Coordinating Council
HCSEG	Hood Canal Salmon Enhancement Group
LiDAR	Light Detection and Ranging
mg/L	milligrams per liter
MHHW	mean higher high water
MISM	Marine Invasive Species Volunteer Monitoring Program
MLLW	mean lower low water
mm	millimeter
NMFS	National Marine Fisheries Service
NOSC	North Olympic Salmon Coalition
OA	ocean acidification
PAH	polycyclic aromatic hydrocarbons
PCSGA	Pacific Coast Shellfish Growers Association
ppt	parts per thousand
PSI	Pacific Shellfish Institute
PSNERP	Puget Sound Nearshore Estuarine Restoration Project
PSRF	Puget Sound Restoration Fund
RTK	real time kinematic
SIP	Shellfish Interagency Permitting Team
State	Washington State
TPH	Total petroleum hydrocarbons
TSS	total suspended solids
USGS	US Geologic Survey
WDFW	Washington Department of Fish and Wildlife
WDOH	Washington Department of Health
WSI	Washington Shellfish Initiative

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1.0 INTRODUCTION

Declines in salmon populations led to Endangered Species Act (ESA) listings for multiple species in Hood Canal, including summer chum salmon (*Oncorhynchus keta*, listed 1999), Chinook salmon (*O. tshawytscha,* listed 1999), and steelhead (*O. mykiss*, listed 2007). Habitat restoration is a major component of the region's efforts to recover these populations, with projects being undertaken in freshwater, estuarine, and marine nearshore habitats. Meaningful progress has been made through habitat restoration, but there remains a substantial need to keep working to reduce modifications affecting salmon habitats and the ecological processes that create and sustain these habitats. Although habitat restoration projects involve removing modifications and returning a site closer to its historic and/or unmodified condition, those changes made to improve conditions for salmon can cause undesired changes for other species; in particular for this report bivalve shellfish[1].

The competing interests are particularly evident in river deltas and along the marine nearshore of Hood Canal where there are multiple interests reliant on the natural resources of the area. For salmon – and the restoration practitioners working to recover salmon populations – river estuaries and deltas are key habitats to restore and protect. Juvenile chum and Chinook salmon are highly dependent on estuarine and marine nearshore habitats for rearing and migration (Healey 1982, Simenstad et al. 1982). Therefore, providing high functioning estuarine and nearshore habitats is particularly important for these salmon species. However, bivalves are another key resource group that is highly dependent on river deltas and the marine nearshore. These shallow habitats provide favorable growing conditions for clams, oysters, and mussels, and the productivity of the habitats can be enhanced through modifications to increase the stability of growing conditions in these habitats. By extension, those dependent on shellfish resources for subsistence, cultural values, recreational enjoyment, and their livelihood have become highly reliant on productive growing conditions for bivalves, and in some cases on modifications to habitats that support productive growing conditions.

The potential conflicting interests between salmon habitat restoration and shellfish resources are further complicated by the benefits that each species can gain from the other. For example, one of the potential prey resources for salmon are benthic invertebrates and pelagic fish that accumulate in and around eelgrass and shellfish beds (Simenstad et al. 1980; Simenstad and Fresh 1995; Hosack 2003; Hosack et al. 2006; Cordell et al. 2007; Ferraro and Cole 2007, 2011, 2012; Allen et al. 2015). Similarly, shellfish beds can provide structured habitat that is used as nursery habitat for salmon and other fish. For example, a meta-analysis of 200 papers by Heck et al. (2003) reported that oyster reefs provide a similar amount of protection as seagrasses and salt marshes. Reducing or removing shellfish resources can be detrimental to the survival of salmonids in nearshore

[1] This report focusses on bivalve shellfish, and does not include other important shellfish species in Hood Canal, such as decapods (crabs). "Bivalves" and "shellfish" will be used interchangeably.

environments. Conversely, the benefits to shellfish resources from salmon restoration activities are the potential improvements to water quality, functioning habitat, and land that is dedicated to restoration rather than human development.

In Hood Canal, the overlap between salmon and shellfish interests has become increasingly apparent as salmon restoration project concepts have gotten progressively larger to address the widescale impairments to salmon habitats and because many of the smaller, less complex restoration actions have been completed. In recognition of this increasing intersection between salmon habitat restoration and shellfish resources, the Hood Canal Coordinating Council (HCCC) commissioned this assessment. HCCC is a council of governments with a regional focus intended to advance strategic priorities to recover and protect Hood Canal's environmental and economic health and wellbeing[2].

The goals of the project include:

- Assemble perspectives on the effects of salmon habitat restoration projects to shellfish resources and Olympia oyster restoration activities.
- Synthesize available information on any positive or negative effects of salmon habitat restoration projects to shellfish resources to understand linkages and interactions.
- Develop guidance for salmon restoration project teams to assess the potential for impacts to shellfish resources and Olympia oyster restoration actions, and develop steps to incorporate shellfish resource considerations into their proposed projects.
- Develop a checklist of pre-, during, and post-construction monitoring parameters that can help inform the types of changes to shellfish resources from a restoration project.

The geographic focus of this report is primarily Hood Canal, but also includes areas of importance to ESA listed summer chum salmon occurring in the Strait of Juan de Fuca, which are used as case studies in this report (Figure 1). The other exception to case studies in Hood Canal is Johns Creek in Oakland Bay, south Puget Sound, an area important for shellfish resources. The case studies illustrate both positive and negative interactions between salmon habitat restoration and shellfish resources, and highlight lessons learned and potential resolutions to land use conflicts (Appendix A).

It was not an objective of this report to assess habitat or ecological impacts of aquaculture activities. This type of analysis was beyond the scope of this report.

[2] More information about the HCCC can be found at www.hccc.wa.gov/.

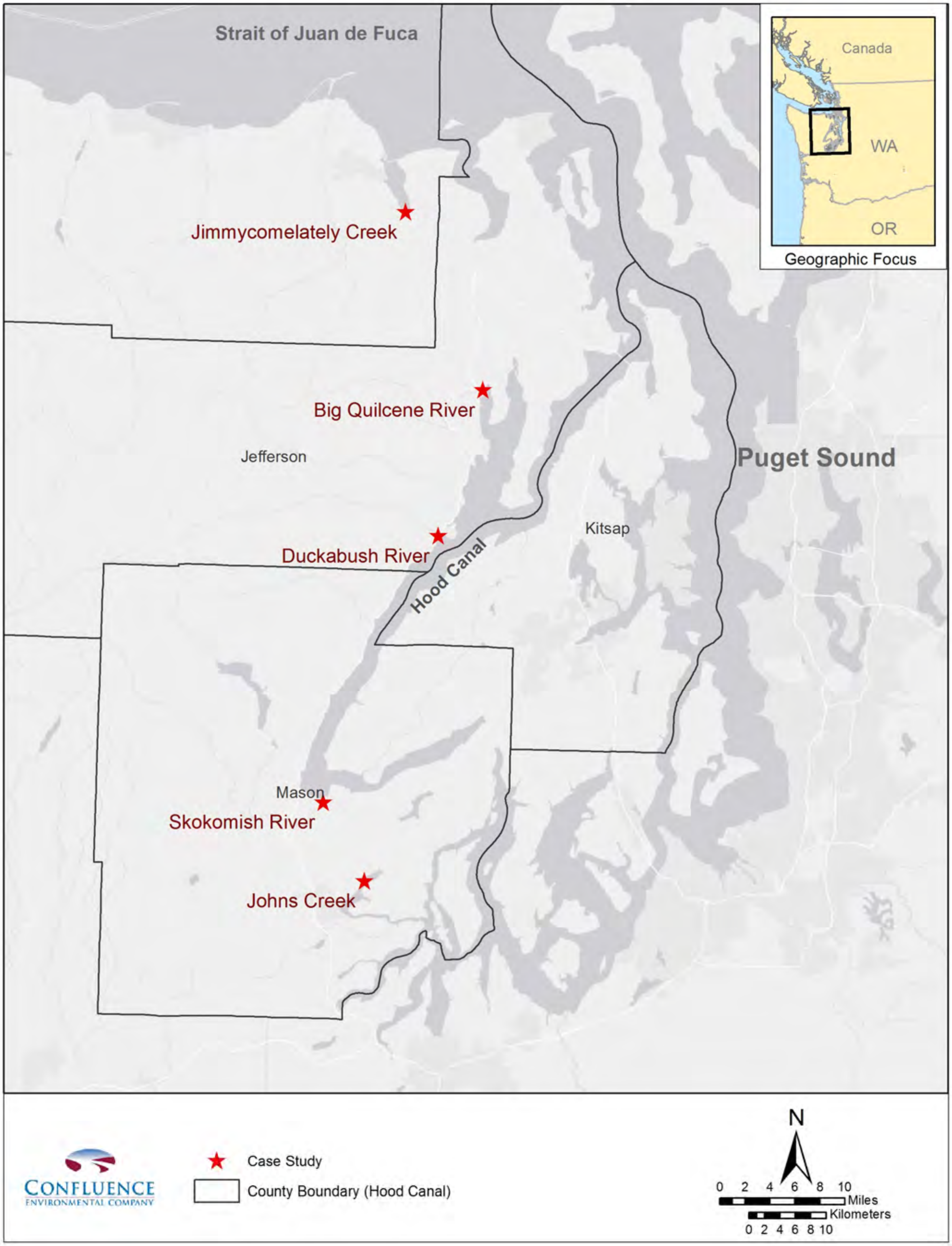

Figure 1. Hood Canal, Puget Sound, Washington, and Case Study Locations

1.1 Project Approach

It has largely been assumed that overall habitat conditions would improve in the long term from the implementation of habitat restoration projects, but this has been predominantly from the salmon habitat perspective. The impetus for this project was that there is a strong recognition of the importance of shellfish resources in Hood Canal, and that salmon habitat restoration projects are increasing in scope and scale with an increasing likelihood for interactions with shellfish resources. Shellfish resources support a diverse array of stakeholders, cultural resources, and economic resources for Washington State. The advantage of engagement with shellfish stakeholders is in gaining a more thorough understanding of their perspectives, as well as their knowledge of the habitat and bivalve resources of the site vicinity. If a project advances a true partnership between salmon restoration specialists and shellfish stakeholders that can acknowledge and understand multiple interests, then it is possible to work through potential impacts and find compromises on both sides. In this way, a project can still accommodate changes to the system but also avoid or minimize impacts to important existing resources.

The project approach included compiling available information on the potential interactions between shellfish resources and salmon habitat restoration actions. This was accomplished by using a combination of literature reviews and interviews with key individuals and organizations that have experience working in Hood Canal. This information was then used to develop recommended guidance for salmon habitat restoration projects to avoid, minimize, or address potential detrimental effects, or be designed in ways that can contribute positively to shellfish production.

1.1.1 Literature Review

Literature relevant to salmon habitat restoration and shellfish interactions were identified through interviews, research, and professional expertise. There was limited published documentation of how improved conditions to estuarine and nearshore habitats for salmon affect shellfish resources. The information gathered on this topic was mostly anecdotal in nature rather than monitoring data to quantify and compare changes. Therefore, the potential for interactions was assessed by linking the habitat requirements of shellfish with the conceptual changes to conditions due to habitat restoration activities.

A potential source of data that could be analyzed to assess changes to shellfish harvest biomass on public lands pre- and post-habitat restoration could be the information collected by tribes and the Washington Department of Fish and Wildlife (WDFW), who co-manage the shellfish resources on public tidelands. Tribal shellfish managers develop harvest management and enhancement plans, and collect harvest data that is shared with other tribes and WDFW. These records can sometimes extend over decades, and are one of the best resources for long-term data sets on shellfish resources. These data can be used to determine potential project impacts/benefits, sensitivities of the species present, and natural environmental variability. The main caution about this data set is that it is confounded by harvest events (e.g., removal of shellfish) and potentially supplementation events (e.g., seeding of shellfish). There are ongoing discussions, both within WDFW and the tribes, to attempt to collect more robust data sets that can be used during development of restoration projects, and as a learning tool to identify project impacts and recovery potential for shellfish resources following an impact.

The literature review provides information on tolerance by bivalve species and life stages to three habitat conditions identified as key environmental stressors to shellfish resources; salinity concentrations, sedimentation, and suspended sediments. In compiling available information on shellfish habitat requirements for survival and growth, one of the important resources used was a literature review prepared by the Pacific Shellfish Institute (PSI) for the Lower Big Quilcene estuary project (Suhrbier and Cheney 2015, Suhrbier et al. 2016). Additionally, a document compiling the habitat requirements for key native shellfish species by life history stage was prepared in support of the Puget Sound Nearshore Ecosystem Restoration Project (PSNERP) (Dethier 2006). Finally, the Elkhorn Slough National Estuarine Research Reserve (ESNERR) produced a guide to Olympia oyster restoration and conservation that identifies habitat requirements, environmental stressors, and the interactions between stressors (Wasson et al. 2015). These documents provide a good overview of bivalves, but do not represent all information that should be used to understand the interaction between habitat restoration and shellfish resources. The information developed in these documents is presented in this report in terms of species habitat requirements (Section 2.1) and environmental changes as a result of habitat restoration projects that are relevant to shellfish resources (Section 3.1).

1.1.2 Interviews

A total of 16 interviews were conducted with tribal and WDFW harvest and habitat managers, Washington State (State) agency representatives, commercial shellfish growers, and salmon and shellfish restoration specialists (Table 1). The purpose of these interviews was to gather information (observations and/or data) on how salmon habitat restoration actions have beneficially or detrimentally affected shellfish resources or other restoration activities (e.g., Olympia oyster restoration); review stakeholder outreach communications conducted as part of previous salmon habitat projects; and discuss ways in which the restoration project design, development, and construction could avoid or mitigate potential effects and/or find solutions to ameliorate effects. While not fully comprehensive, the list of interviewees represents a diverse group of individuals and opinions within the restoration and shellfish resource communities. Given that this report is intended as an initial phase identifying ways to approach salmon habitat restoration and shellfish resource interactions, the methods used for this process can be refined and expanded for future efforts.

Table 1. List of Interviews Performed for this Project by Group and Organization

Group Type	Organization	Contact
Agency	Office of Governor Jay Inslee	Julie Horowitz
Agency	Washington Department of Fish and Wildlife (shellfish group)	Rich Childers Philippa Kohn Brady Blake Camille Speck
Agency	Washington Department of Fish and Wildlife (habitat group) and Puget Sound Nearshore Ecosystem Restoration Project (PSNERP)	Doris Small Theresa Mitchell Chris Waldbillig
Agency	Washington State Department of Ecology	Perry Lund
PNW Tribe	Jamestown S'Klallam Tribe	Kelly Toy
PNW Tribe	Point No Point Treaty Council	Shannon Miller Cynthia Rossi
PNW Tribe	Port Gamble S'Klallam Tribe	Paul McCollum Tamara Gage Jason Haveman
PNW Tribe	Skokomish Tribe	Alex Gouley Chris Eardley Kris Miller Blair Paul
Restoration Specialist	Hood Canal Salmon Enhancement Group (HCSEG)	Mendy Harlow Michelle Myers Sarah Heerhartz
Restoration Specialist	North Olympic Salmon Coalition (NOSC)	Rebecca Benjamin
Restoration Specialist	Puget Sound Restoration Fund (PSRF)	Betsy Peabody Brian Allen
Shellfish Grower	Coast Seafoods Company	Chris Jones Lizzy Nelson
Shellfish Grower	Hama Hama Oyster Company	Adam James Tiffany Waters
Shellfish Grower	Rock Point Oyster Company	Dave Steele
Shellfish Grower	Taylor Shellfish Farms	Diane Cooper Gordon King
Shellfish Trade Organization	Pacific Coast Shellfish Growers Association (PCSGA)	Margaret Barrette Connie Smith

1.2 Report Organization

This report is divided into the following sections:

- **Section 2.0: Overview of Shellfish Resources** – this section includes a description of shellfish resources in Hood Canal; identification of the various shellfish-related stakeholders; information on habitat requirements for shellfish species found in Hood Canal, restrictions on shellfish harvest and growing conditions; and other existing challenges related to shellfish resources. **Appendix B** provides more detailed information on shellfish resources to supplement the overview provided in Section 2.0.

- **Section 3.0: Overview of Potential Interactions Between Salmon Habitat Restoration Projects and Shellfish Resources** – this section includes a description of the types of salmon habitat restoration projects in Hood Canal; the potential effects to shellfish resources that can result from salmon habitat restoration activities; and the location and timing (e.g., short- vs. long-term) of potential effects from different types of habitat actions. **Appendix A** presents five case studies of projects that include salmon habitat restoration actions and resulting changes to growing conditions for bivalves. **Appendix A** also provides lessons learned and potential resolutions for land use conflicts.
- **Section 4.0: Guidance and Recommendations** – this section includes a proposed approach that a salmon habitat restoration team can take to develop a communication and outreach plan for projects that potentially affect shellfish resources; and includes a series of checklists and resources that can be used as part of a communication plan. The detailed checklists are presented in **Appendix C**, but are introduced and summarized in Section 4.0.
- **Section 5.0: Monitoring** – this section includes a description of why monitoring is an essential component of restoration projects, and a checklist of potential monitoring parameters to be conducted pre-, during, and post-project activities related to interactions with bivalves. This section is intended to be an introduction to these methods and not a full review of successful monitoring plans.
- **Section 6.0: Summary and Next Steps** – this section includes a summary of the information presented in this document, and next steps for developing a more robust approach to incorporating shellfish resource considerations into a project design. Note that **Appendix A** includes a summary of the lessons learned from the various case studies, and includes the proposed Duckabush River project as an example of how those lessons learned can be used for a project still at the beginning planning stages.
- **Section 7.0: References** – this section includes the literature cited throughout the text used to understand the key issues associated with salmon habitat restoration and shellfish interactions.

2.0 OVERVIEW OF SHELLFISH RESOURCES

This section provides a brief overview of the shellfish resources in Hood Canal, the habitat requirements of shellfish species, and the shellfish user groups (i.e., stakeholders). The intent of this section is to inform salmon habitat restoration practitioners on the shellfish resources and user groups that rely on the same estuary and marine nearshore areas as the salmon populations that are the focus of recovery efforts. By understanding more about the shellfish resources and the stakeholders utilizing them, it is anticipated that salmon habitat restoration practitioners will increasingly recognize the need to engage these stakeholders during project development to work toward a shared vision for a project site that meets the salmon habitat objectives, while also providing for continued favorable growing conditions for bivalves. It is important for salmon habitat restoration projects to consider habitat requirements for shellfish within the restoration project site, and to consider the potential downstream or offsite impacts from a habitat restoration project.

Additional overview information on shellfish resources is provided in **Appendix B**.

2.1 Shellfish Species and Habitat Requirements

A well-designed project will consider the baseline resources surrounding the project, and include a range of distances in which impacts may occur away from the project site. Bivalves, depending on species and life stage, can demonstrate tremendous flexibility and tolerance of habitat conditions, but have key thresholds that, once exceeded, can result in broad-scale losses of the resource. Shellfish populations have been noted anecdotally to show signs of recovery within a 3- to 6-year timeframe for smaller projects and a 6- to 10-year (or longer) timeframe for larger projects, as long as there is a source population in the area to recolonize (assuming all other habitat conditions are available) or bivalve seed provided to establish a population. However, recovery is a relative term, and shifting baselines and changed environmental conditions are an important consideration for a project when trying to assess a recovery timeframe. In addition, even short-term impacts can result in a loss of shellfish resources, and should be considered during project design.

General locations (tidal elevation) and sensitivities of different bivalve species groups found in Hood Canal are provided in Table 2. The identified tidal elevation ranges are intended to represent the most common natural range for each species group. As noted in Table 2, the range can extend beyond these elevations if conditions are suitable for colonization. The distribution of commercial aquaculture areas and eelgrass habitat in Hood Canal, as presented by the U.S. Army Corps of Engineers (Corps; 2005) for shellfish aquaculture, recreational, and restoration activities throughout the State, is shown in Figure 2. Public shellfish harvest areas and beach closures are shown in maps by the Washington Department of Health (WDOH) and available at http://www.doh.wa.gov/CommunityandEnvironment/Shellfish/RecreationalShellfish. The WDOH website map shows the status of the shellfish harvest areas based on public health considerations; namely, the presence of biotoxins at harmful levels and overall classifications for water and sediment quality-driven parameters (e.g., pollution).

Table 2. General Guidelines for Tidal Elevation and Substrate Type of Key Bivalve Species

Shellfish Species	General Location/Conditions within the Habitat		
	Tidal Elevation* (MLLW)	Substrate Type	Sensitivity to Change
Native Oysters Olympia Oyster (*Ostrea lurida*)	-3 ft to +1 ft	Mud + coarse (shells or pebbles)	High
Naturalized** or Non-native Cultivated Oysters Pacific Oyster (*Crassostrea gigas*) Kumamoto Oyster (*C. sikamea*)	0 ft to MHHW	Mud/sand + coarse (gravel or cobbles)	Low
Mussels Bay Mussel (*Mytilus trossulus*) Mediterranean Mussel** (*M. galloprovincialis*)	0 ft to +4 ft	Hard surface	Medium
Native Burrowing Clams Geoduck (*Panopea generosa*) Horse Clam (*Tresus nuttallii* and *T. capax*)	Subtidal to MLLW	Sand with fines (<10%)	Medium
Native Hardshell Clams Littleneck Clam (*Leukoma staminea*) Butter Clam (*Saxidomus gigantea*)	-2 ft to +3 ft	Gravel-sand	Medium
Naturalized Clams Manila Clam (*Venerupis philippinarum*) Varnish Clam*** (*Nuttallia obscurata*)	0 ft to MHHW	Gravel/cobble-sand	Low

Sources: Kozloff 1993, Brooks 2001, Dethier 2006, Suhrbier and Cheney 2015, Wasson et al. 2015, Suhrbier et al. 2016, Valdez et al. 2016, WDFW 2017, Allen, pers. comm., 2017
MLLW = mean lower low water, MHHW = mean higher high water, ft = feet
*In general, species will exist outside of these elevation ranges, but require thermal conditions that mimic their normal distribution.
**Naturalized = an introduced species that is established in an environment to which it is not native.
***On the Marine Invasive Species Volunteer Monitoring Program (MISM) target species list (NNWS 2008)

Nearshore ecosystems are dynamic, and there are multiple environmental stressors to which bivalves have adapted, including (but not limited to): tidal elevation (i.e., amount of exposure to air during low tides), salinity concentrations, substrate conditions, food availability, and water quality (e.g., temperature, dissolved oxygen, nutrients). Other environmental conditions that affect the persistence and health of the shellfish include water velocity/flow rate, sediment quality, habitat stability, predation, competition, contaminants, and pathogens. As noted above, PSI, PSNERP, and ESNERR independently reported on shellfish tolerances and habitat requirements for key environmental parameters (Dethier 2006, Suhrbier and Cheney 2015, Wasson et al. 2015, Suhrbier et al. 2016). These reports, and other existing literature (see Table 2), provide general guidelines related to habitat requirements that can be used for identifying shellfish resources in Hood Canal.

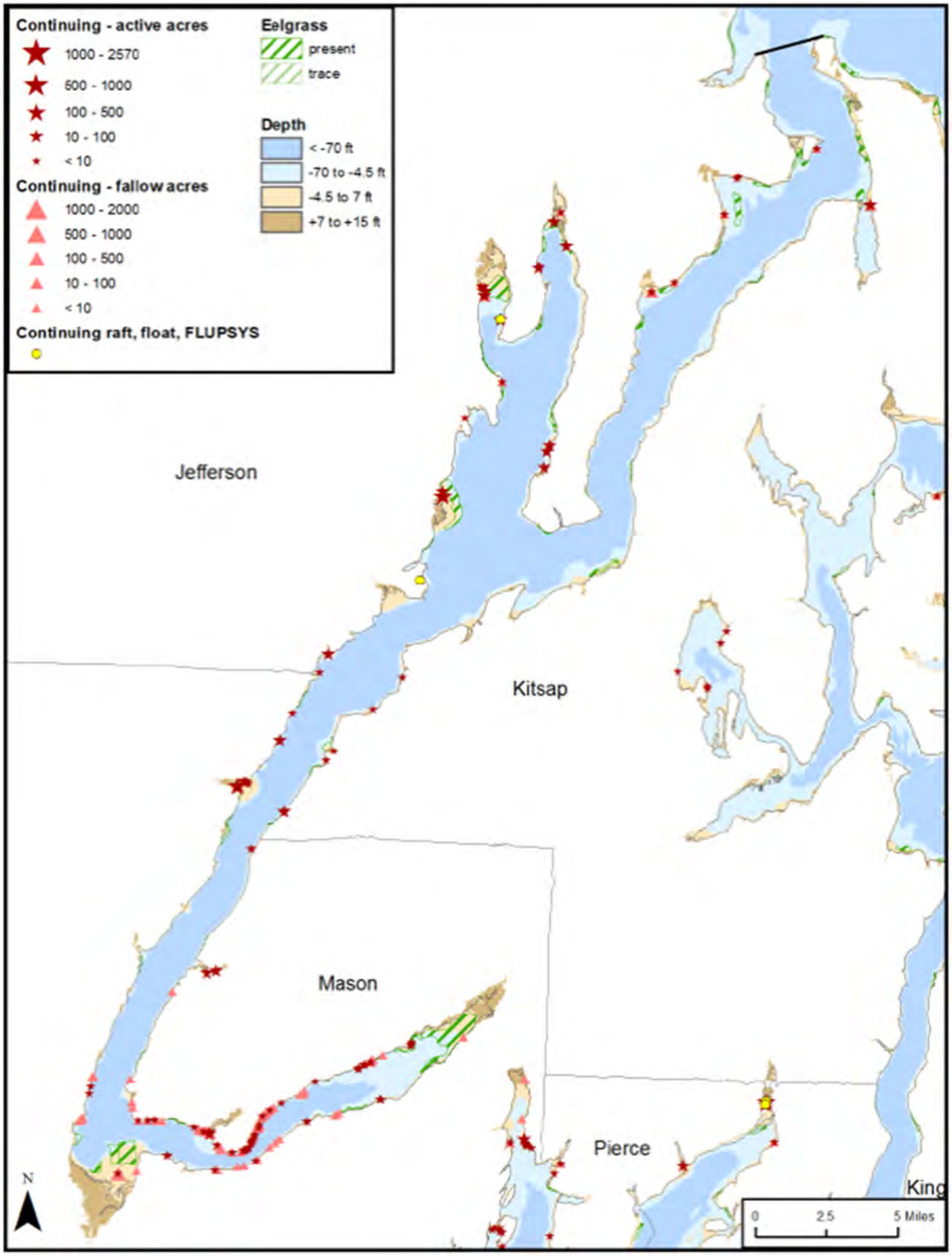

Figure 2. Distribution of Active Ground Culture, Fallow (Inactive) Ground Culture, and Floating Commercial Aquaculture Operations in Hood Canal

Source: Corps 2015

Note: The data in the figure does not represent a complete inventory, but is a representation of the best available science using data presented by the Corps during development of the Biological Assessment for shellfish aquaculture, recreational, and restoration activities throughout Washington State.

The bivalve species studied in the various reports by PSI, PSNERP, and ESNERR on habitat requirements include Olympia oysters, Pacific oysters, blue mussels, Manila clams, varnish clams, and other hardshell clams (Dethier 2006, Suhrbier and Cheney 2015, Wasson et al. 2015, Suhrbier et al. 2016). Although this research is not fully comprehensive for all species of shellfish in Hood Canal, they provide general guidelines that can be used as an initial understanding for habitat requirements. If a project exceeds these habitat requirements, there will almost certainly be an impact to shellfish resources that should be considered. A project that maintains these conditions does not necessarily avoid impacts, but will more readily support habitat requirements for bivalves. Similarly, a project may have shellfish species or life stages in the area that are more tolerant of extreme habitat conditions, and those cases would benefit from developing species-specific habitat requirements to inform potential impacts from project actions. Finally, there are other situations that do not fit into these general habitat requirements that should be dealt with on a case-by-case example, including subtidal or suspension culture and hatchery operational conditions.

General habitat requirements for bivalves include:

- **Salinity:** 27 to 32 parts per thousand (ppt) for larvae and >25 ppt for adults
  Note: adults can tolerate salinities as low as 20 ppt, but this is not optimal for growth
- **Temperature:** 10 to 15°C for larvae and <18°C for adults
  Note: this range is more closely associated with native oyster species; other oysters (e.g., the non-native cultured species: Pacific oysters) have a higher temperature tolerance of up to 22-25°C for larvae and 28°C for adults.
- **Suspended Sediment:** <20 milligrams per liter (mg/L)
  (post-set/early juveniles = low tolerance; adults = high tolerance)
- **Sediment Burial:** 10 to 70 millimeters (mm)
  (single oysters or post-set/juveniles = low tolerance; multiple oysters/cultch or adults of burrowing species = high tolerance)

One of the more sensitive species listed in Table 2 is the Olympia oyster. This is a native species to Washington State, and expansion of Olympia oyster restoration activities is promoted both through the Governor's Blue Ribbon Panel on ocean acidification (OA) and the Washington Shellfish Initiative (WSI). While Olympia oysters can be found sparsely at many locations in Hood Canal, core populations of Olympia oysters are severely depleted in the region and restoration is underway, proposed, or viable at several locations in Hood Canal (Cook et al. 1998, Dinnel et al. 2009, Blake and Bradbury 2012, Wasson et al. 2015). Awareness and consideration of existing Olympia oysters, as well as planned Olympia oyster restoration sites, is necessary when planning salmon habitat restoration projects that may affect the suitability of the area for the native shellfish.

In dense aggregations, Olympia oysters provide structured habitat, salmon food, and complexity to the nearshore system (Cordell et al. 2007, Allen et al. 2015). One Olympia oyster restoration practitioner shared, “It’s a bit like working from the opposite direction in terms of the logic model that is generally used for restoration” (Peabody, pers. comm., 2017). The action of restoring Olympia oysters provides a native species that builds habitat and restores natural processes. For salmon restoration projects, the action restores natural processes to build up the native species. Both approaches help to restore healthy marine ecosystems. In addition, Olympia oyster populations historically occurred at or near the heads of inlets of Puget Sound, in some of the same places where salmon-bearing streams meet the marine environment. This means that a priority location for salmon can overlap with a priority location for Olympia oysters, and a salmon restoration project can impact the ability for Olympia oysters to grow.

An important finding in the work by PSI, PSNERP, ESNERR, and others is the understanding that shellfish species (primarily naturalized or cultivated) are relatively tolerant of short-term environmental changes. However, most studies evaluating environmental thresholds do not address simultaneous exposure to multiple stressors. While shellfish may be tolerant of a range of environmental conditions when looked at independently or under laboratory conditions, the combination of stressors typically reduces the ability of the species to survive even short-term events. In addition, the species and life stage that is exposed to the stressor is an important consideration. According to Dethier (2006), “Larvae and juveniles of most marine organisms are more sensitive to physical conditions and to pollutants than are adults.” Therefore, it is important to consider short- and long-term effects of a project action, and the species and life stages exposed to the effects, to determine if multiple stressors and/or sensitive species and life stages exist, which might limit shellfish tolerances and survival.

2.2 Shellfish User Groups

Shellfish stakeholders represent a growing user group within the nearshore ecosystem. In Hood Canal, there are over 80 separate organizations associated with shellfish resources, including tribes, State agencies, shellfish aquaculture companies, research organizations, and restoration specialists. These diverse stakeholders are a result of the exceptional growing conditions that occur in Hood Canal providing a consistent resource of food and cultural value for millennia, and supported the growth of economic dependence on the health and stability of this resource for more than 120 years.

In terms of economic value, in 2013, Hood Canal represented over $11.5 million (13%) of the nearly $150 million total value of commercial bivalve shellfish production in the State[3] (Decker

[3] This value is largely recognized as an underestimate due to the limited quality of the reported shellfish production data. It is notable that this value only represents market value, and does not consider other economic and social aspects of the industry such as direct employment and supporting industries (e.g., distribution, restaurants).

2015). The contribution from shellfish aquaculture employment-related income throughout the State adds at least another $184 million (based on a 2010 value; Northern Economics 2013). There are over 70 commercial bivalve shellfish growers and/or harvesters in Hood Canal (WDOH 2017).

Aside from commercial operations, there is a significant amount of recreational harvest of bivalves in the State. Washington's public recreational harvest was valued at over $40 million in 2012 (NMFS 2016). Public shellfish resources are co-managed by WDFW and the tribes. This is a government-to-government relationship, similar to management of salmon and steelhead resources in the State. WDFW and tribes that have treaty harvest rights develop management strategies for shellfish harvest of naturally-occurring bivalves. Tribal and recreational harvest of shellfish supports local economies as well as public enjoyment of the resource.

For many, the cultural aspect of shellfish is just as important as employment potential or contributions to the economy. Shellfish are used for subsistence farming and ceremonial practices of the tribes, and are a desired product from the State. Northern Economics (2009) studied the perceptions and values of shellfish stakeholders and reported that shellfish define communities, connect local people to the marine environment, and create a positive national image of the State. Several shellfish programs, including those led by the Puget Sound Restoration Fund (PSRF 2017), provide educational benefits, promote awareness of ecological linkages, and foster stewardship and husbandry for good water quality and the surrounding environment. The presence of shellfish is representative of the Pacific Northwest identity.

One of the best examples of shellfish stakeholder participation in a salmon restoration project, as indicated through multiple interviews, is the Lower Big Quilcene estuary restoration project (Case Study 1 in **Appendix A**) led by the Hood Canal Salmon Enhancement Group (HCSEG). This project will restore river and estuarine processes by removing and setting back levees. The project area is surrounded by shellfish aquaculture leases, a shellfish hatchery, public lands (co-managed by the tribes and WDFW), and engaged community members. Not all projects will have this level of engagement from shellfish stakeholders, but the sponsor's outreach to, and incorporation of, ideas from shellfish stakeholders have been instrumental in the large-scale restoration that is moving forward with a preferred alternative supported by the community and stakeholders.

2.3 Harvest Location Access Considerations

As noted above, shellfish resources on public tidelands are co-managed by the tribes and WDFW. For tribal and public harvest, the accessibility of a site is a key consideration for the co-managers. Anything that affects the harvest opportunities at a site is problematic because there are few areas that provide ready accessibility for harvesters. There are few public tideland locations in Hood Canal that have the appropriate conditions to make an area a priority harvest location, which includes:

- Dense and consistent shellfish populations,
- Suitable parking and basic facilities, and
- Accessibility by foot rather than by boat.

Combined, these factors make an area very hard to replace if they are impacted, given that the co-occurrence of all three factors is relatively limited. During interviews with the tribes and WDFW, it was noted that, while potential impacts to the resource itself need to be addressed, assessing activities that impact access to the resource is also important. Restoration projects that improve access can help increase support from the tribes and community members most interested in their ability to continue harvesting shellfish. The value of public and Tribal access to shellfish resources should be an important project design consideration.

2.4 Challenges Related to Shellfish Culture and Resources

This section is an introduction into some of the challenges related to shellfish resources that are important for a salmon restoration specialist to consider. Additional details for this information are provided in **Appendix B**. Neither this section nor **Appendix B** are intended to be comprehensive. The goal is to provide an understanding that there are both regulatory and environmental challenges facing groups that depend on shellfish resources. It is useful to understand that there is a commonality shared between salmon habitat restoration groups and shellfish user groups for some of these challenges, and ways in which the two groups can work together to address. Additionally, there are conditions that make an area less flexible to change because of the livelihoods that may already depend on the stability of shellfish resources present in an area.

2.4.1 Shellfish Aquaculture Permitting

The permitting process for shellfish aquaculture has been under increasing scrutiny over the last 20 years, and has progressively become more restrictive. The permitting process for shellfish aquaculture, and other shoreline activities, includes a significant review process by tribal governments and local, state, and federal entities (Ecology 2014). The Washington Department of Ecology (Ecology) was charged with streamlining the permitting process for shellfish aquaculture by the Washington State Legislature in 2007 (Ecology 2008). These streamlining efforts are still underway as part of the Shellfish Interagency Permitting Team (or SIP). Despite these efforts, permitting is still highlighted by many groups as a major restriction to the amount of flexibility shellfish growers have available to accommodate changes at a site. More information on the permitting process for shellfish aquaculture is provided in **Appendix B**.

2.4.2 Culture Methods

Understanding the culture methods present at a site can provide useful information on the species and life history stages present, and is required to be able to identify and understand potential habitat project interactions with cultured shellfish resources and aquaculture land use. The species of shellfish currently cultured in Hood Canal include Pacific oysters, Kumamoto oysters, Olympia oysters, Manila clams, geoducks, and mussels. The process starts with seed (i.e., the early life stage, or "seed," of oysters, clams, and geoducks) for culture operations and shellfish enhancement at public beaches being raised in hatcheries. Following hatchery production, seed are typically grown in Floating Upweller Systems (FLUPSYs) or nursery rafts to a suitable size to assist in early survival (e.g., about thumbnail sized) before being planted in the natural environment. Oysters, Manila clams, and littleneck clams are grown in intertidal habitats. Geoducks may be grown via ground culture in the intertidal or subtidal habitat. Mussels and oysters[4] are grown in the subtidal in either rafts or longlines. Additional information on the various culture methods used in Hood Canal is presented in **Appendix B**.

2.4.3 Other Challenges

There are other challenges to shellfish resources within the State. The main concerns include OA, degrading water and sediment quality conditions, and susceptibility to disease and parasites. The lower pH associated with OA increases dissolution rates of oyster shell or reduces the ability of larval oysters to lay down shell material (Waldbusser et al. 2011, Miller and Waldbusser 2016). The presence of eelgrass and shell material is mutually beneficial to water quality in the ability to provide buffering capacity from corrosive waters to live shellfish, especially juveniles. The co-occurrence of shellfish plots and eelgrass may provide a certain amount of benefit for both organisms, although most benefit is likely being provided to the shellfish themselves. Given the importance of OA effects to shellfish resources, this may be an area of future collaboration for salmon habitat restoration and shellfish interests.

Maintaining acceptable water and sediment quality to support shellfish populations and allow for harvest activities is an ongoing challenge, especially with the continued growth of shoreline communities. Related to habitat quality changes is the susceptibility to disease and parasites. Changes in habitat conditions can cause physiological stress, which make them more susceptible to ever-present threats (Dethier 2006). Good habitat quality is a shared goal for both salmon restoration and shellfish resource interests, and may be a valuable approach for future collaboration.

Additional information on these challenges is provided in **Appendix B**.

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[4]Note that oysters grown in subtidal habitat is an emerging culture method for Washington, and there is no subtidal oyster culture currently in Hood Canal. The first raft culture experiments began in 1952 in Ladysmith Harbour, British Columbia, Canada, which were modeled after culture from Japan and Norway (Quayle 1971).

3.0 OVERVIEW OF POTENTIAL INTERACTIONS BETWEEN SALMON HABITAT RESTORATION PROJECTS AND SHELLFISH RESOURCES

As introduced in Section 2.0, there are valued shellfish resources in the river deltas and marine nearshore habitats that need to be considered in planning salmon habitat restoration projects. Restoring habitats in these areas is also essential to the recovery of salmon populations, as juvenile chum and Chinook salmon are highly dependent on estuarine and marine nearshore habitats for rearing and migration (Healey 1982, Simenstad et al. 1982). Given the importance of these areas for both salmon and shellfish, it is necessary to understand how proposed salmon habitat restoration projects may affect growing conditions for shellfish. It is also necessary to apply this knowledge to develop constructible projects that meet habitat objectives, while limiting detrimental effects to shellfish resources. This section describes the linkages between salmon restoration projects and the growing conditions for bivalves.

3.1 Types of Salmon Restoration Projects

For the purposes of this assessment, the term “habitat restoration” refers to all actions intended to improve ecological conditions, including projects focused on habitat enhancement and creation, as well as projects constructed as mitigation. Further, while this assessment is primarily focused on salmon restoration projects, the findings are applicable to any projects that may affect habitat conditions in the estuarine and nearshore areas, regardless of target species or impetus for the project.

There are a wide range of habitat restoration actions that can be undertaken to improve conditions for salmon and/or their prey. A single habitat restoration project may include one or more individual actions. PSNERP called the individual actions “management measures” and identified a list of management measures that were included in their proposed projects to improve estuarine and nearshore habitat conditions (Clancy et al. 2009). Although the PSNERP project was focused on estuarine and nearshore habitats, the management measures include several that could be expanded to apply to freshwater settings. A modified list of the PSNERP management measures is provided in Table 3 as examples of the type of activities considered in this report as habitat restoration. The PSNERP list was modified to include management measures addressing restoration actions and to broaden the description to be more applicable to freshwater areas as well. The list includes freshwater projects because the offsite changes derived from freshwater projects can extend downstream to the estuary either during or after construction.

Table 3. Summary of Habitat Actions Often included in Salmon Habitat Restoration Projects

Habitat Action	Description
Armor Removal or Modification	Removal, modification, or relocation of shoreline or bank protection structures, such as rock revetments, bulkheads, and concrete walls, in either the marine or freshwater environment.
Beach Nourishment	Placement of sand and/or gravel on the upper portion of a beach where historic supplies have been eliminated or reduced.
Channel Restoration or Creation	Restoration or creation of channels in a tidal estuary (e.g., distributary channels) or river (e.g., side channels) to change water flow, provide habitat, and improve ecosystem function.
Contaminant Removal and Remediation	Removal or remediation of unnatural or natural substances (e.g., heavy metals, organic compounds) harmful to the integrity or resilience of the ecosystem. Includes dredging.
Culvert or Tide Gate Removal or Modification	Removal or modification of culverts or tide gates to remove restrictions to fish passage and/or the natural delivery of water, sediment, and organic matter past the site.
Debris Removal	Removal of solid waste (including wood waste), debris, and derelict or otherwise abandoned items (e.g., derelict piling) from the nearshore or banks of the river.
Groin Removal or Modification	Removal or modification of groins and similar nearshore structures.
Levee/Dike Removal or Setback	Removal or modification of levees or other structures along river to restore floodplain connectivity.
Log Jam Placement	Installation of large wood (large tree trunks with root wads, sometimes referred to as large woody debris) in contact with water to increase aquatic productivity and habitat complexity. In river settings, this will include installation of engineered log jams.
Overwater Structure Removal or Modification	Removal or modification of overwater structures such as piers, floats and docks to reduce shading.
Revegetation	Site preparation, planting, and maintenance to manipulate soils and vascular plant populations to supplement the natural development of native vegetation.
Wetland or Marsh Restoration – Tidal or Freshwater	Improvement of tidal or freshwater wetland function or expansion of wetland area through removal of structures or fill and excavation to suitable elevations to support wetland vegetation.

3.2 Potential Interactions between Salmon Restoration and Shellfish Resources

In many cases, the modifications that have been constructed in our estuaries and lower rivers function both for their main purposes (e.g., levees to reduce flooding or bridges to facilitate travel), as well as in providing more stable, consistent growing conditions for shellfish. The modifications often serve to restrict the natural dynamics of the estuary, such as distributary and tidal channels that dynamically shift alignments over time, and in doing so expose shellfish resources to more predictable conditions, especially as it relates to salinity, sedimentation, and minimization of disturbance events. In this way, shellfish stakeholders are accustomed to, and invested in, the continuation of growing conditions at a site even if the conditions are a result of modifications.

Depending on the type of action and the magnitude of its effects, the actions included in a habitat restoration project can lead to changes at the project site, in surrounding areas, and potentially even miles away (e.g., downstream transport of sediment to estuary areas). Increasingly, the emphasis in habitat restoration has been to restore not only the habitat conditions at a given site, but to do so in a way, and at a scale, to restore the underlying processes which shape, form, and sustain the natural habitat structures and biological functions (e.g., Clancy et al. 2009, Beechie et al. 2010). This “process-based restoration” aims to remove manmade stressors (e.g., levee, fill, armoring) to return to undisturbed conditions at a scale to allow natural processes to be reestablished. Successful restoration of processes at the appropriate scale is intended to enable the area to adjust over time and be more sustainable over the long-term with less maintenance required. The effects of process-based restoration often extend beyond the specific site of the construction action. In this way, the benefits to aquatic habitats and the species dependent upon those habitats, such as salmon and forage fish, are provided over a larger area and are self-sustained following project completion. An example of process-based restoration is the removal of levees in the upper estuary of a river delta. This action enables the river and distributary channels to flow freely across the delta and change flow paths and patterns over time. As a result, the restored processes create and maintain habitat (structure) in newly inundated areas, which in turn provides re-established aquatic functions for species.

The changes resulting from habitat restoration actions, especially those affecting ecological processes beyond the project site, can affect the suitability of habitat conditions for bivalves. As described above, shellfish species require specific habitat conditions for survival and optimal growth, even though there is a range of tolerance to changing environmental conditions. The environmental requirements vary among species and among life stages of individual species. For example, excessive fine sediments can prevent shellfish larvae from settling or surviving (Dethier 2006). However, the potential effects are not always detrimental, as beneficial effects can also be realized. For example, restoration that changes the delivery of coarse sand and gravel can improve substrate size suitability for shellfish (Dethier 2006). In some instances, there may be a mix of detrimental and beneficial effects and the mix may change over time.

> *“While the species… are diverse in their life histories, feeding modes, and exact habitat requirements, they share several susceptibilities to human impacts. Many of these impacts could be directly or indirectly reduced by restoration actions.”* Dethier (2006)

Overall, the actions taken during restoration will affect the resulting type(s), location, and timing of habitat changes. Each of these changes is discussed below. It is not unusual for the changes to vary over time in terms of type and location of changes as the habitats adjust to the restored conditions. Although restoration actions provide identifiable events that can be pointed to as causing changes to conditions that affect resources, it must be acknowledged that the estuary and marine nearshore are naturally dynamic areas where natural disturbances and processes also affect the suitability of areas for shellfish survival and growth.

3.2.1 Types of Change Potentially Affecting Shellfish

There are multiple types of changes that are favorable for restoration of salmon habitat and natural ecological processes, but are not necessarily favorable changes for bivalve populations that have developed – either naturally or with human assistance – within the existing conditions of a site. The type of change refers to how the action(s) is expected to alter the habitat conditions in the water and/or the riparian corridor. Example types of changes include altering how the river is connected to its floodplain, and the resulting changes to water flow and sediment transport; altering habitat complexity to promote pool formation and sediment sorting; and reconnecting coastal bluff sediment sources to the marine nearshore.

The types of change that are particularly relevant for shellfish include:

- **Channel alignment in delta** – the alignment of distributary and tidal channels across a delta. This change can affect the suitability of areas for shellfish growth and survival because bivalves require stable substrate throughout their life cycle. Shifting channel alignments can affect salinity, hydraulic forces, water quality, and sediment deposition.
- **Water quality** – increases in total suspended solids (TSS) and decreases in salinity are the primary parameters affected by restoration. TSS results from increases in silts and clays being transported to the estuary. Salinity reductions change depending on changes in channel alignments in the delta. Temperature and pH can also be affected by restoration. These changes can affect shellfish growth and survival.
- **Sediment supply, transport, and deposition** – related to water flow routes because the channels deliver water and sediment. Refers to how much sediment is moved and deposited, and whether the sediment is delivered steadily over time or episodically in larger events. Sediment scour can also occur and affect shellfish resources
- **Sediment size** – changes to sediment deposition patterns and how a restoration action may change energy conditions acting on a site. The size of sediment may be coarsened or made finer, depending on the action, which can affect shellfish resources.
- **Contaminants or toxins** – in restoration, this is primarily associated with removal of contaminated materials (e.g., sediments, creosote materials, or septic systems), which can unintentionally disperse contaminants or pollutants and/or trigger toxic cyst germination (e.g., toxin causing paralytic shellfish poisoning) through re-entrainment into the water column. Examples of cyst re-entrainment are discussed in **Appendix B**; there are many factors needed to go from cyst re-entrainment to a harmful algal bloom.

Contaminants and toxins affect both the bivalves themselves and the quality of the product for human consumption.

- **Freshwater flow rates** – delivery of freshwater to the estuary and nearshore from precipitation events and snowmelt. Related to connectivity of river systems to the floodplain and wetlands that influence storage and infiltration.

The types of effects and potential magnitude of changes to shellfish growing conditions are described in Table 4. The magnitude of change will vary depending on project size and setting, but, for informational purposes, is generally estimated for each type of action. Please note that, aside from contaminant removal and remediation, this table is not intended to show construction impacts, but rather the potential long-term effect. In addition, Table 4 is not intended to indicate whether this change is positive or negative, but rather compares the potential magnitude of effects on shellfish growing conditions to guide the effort of assessing the impacts from the project.

Table 4. Types and Potential Magnitude of Effect of Habitat Actions on Shellfish Growing Conditions

Habitat Action	Potential Magnitude of Effect on Shellfish Growing Conditions ● = major effect; ○ = moderate or minor effect; blank = no effect					
	Channel Migration in Delta	Water Quality (e.g., TSS, Salinity)	Sediment Supply, Transport, and Deposition	Sediment Size	Contaminants or Toxins	Freshwater Flow Rates
Armor Removal or Modification	○		●	●	○	
Beach Nourishment			○	●		
Channel Restoration or Creation – Tidal	●	●	●	○	○	
Channel Restoration or Creation – Riverine	○		○	○		○
Contaminant Removal and Remediation					●	
Culvert or Tide Gate Removal or Modification	●	●	●	○		○
Debris Removal			○		●	
Groin Removal or Modification	●	●	●			
Levee/Dike Removal or Setback	●		●	○		●
Log Jam Placement	○		○	○		
Overwater Structure Removal or Modification		○			○	

Table continues on next page

Habitat Action	Potential Magnitude of Effect on Shellfish Growing Conditions ● = major effect; ○ = moderate or minor effect; blank = no effect					
	Channel Migration in Delta	Water Quality (e.g., TSS, Salinity)	Sediment Supply, Transport, and Deposition	Sediment Size	Contaminants or Toxins	Freshwater Flow Rates
Revegetation		○	○		○	○
Wetland or Marsh Restoration – Tidal		○	○	○	○	
Wetland or Marsh Restoration – Freshwater		○	○	○	○	○

The potential changes described in Table 4 do not mean that all changes will noticeably modify site suitability for bivalves, nor that the effects will necessarily be detrimental. Salmon restoration projects can result in changes that also benefit shellfish resources. An example of a restoration project that beneficially affected shellfish resources over time is the Jimmycomelately Creek Restoration Project in Sequim Bay (Case Study 2 in **Appendix A**). This project restored the lower creek and estuarine habitats by removing obstructions and returning the creek to its historic alignment. The removal of obstructions restored sediment transport processes from the creek, and in doing so, led to a gradual improvement in the suitability of estuarine sediment sizes to support oysters where they had not grown in recent decades due to excessive silt.

Another example of a salmon restoration project benefitting shellfish resources is in the Skokomish River delta (Case Study 3 in **Appendix A**). The multi-phase project entailed removal of dikes to improve tidal connectivity. Although monitoring has been limited, there appears to be improvement to substrate conditions for shellfish, including areas with reduced burrowing shrimp activity due to increased sediment grain size.

3.2.2 Location of Change

The location of change refers to whether the changes will occur only on the site of the action or if they will extend to offsite locations. Certain actions in rivers can affect habitat conditions throughout all downstream areas, including the estuary and river delta, through changes to water flow and sediment transport conditions. An example of an action that causes only onsite change is removal of a shoreline bulkhead that is not in an area where longshore drift of sediment occurs (i.e., a "no appreciable" drift portion of a drift cell). An example of an action that causes both onsite and offsite (downstream or downdrift) changes is a levee setback project, which will reconnect the river to its floodplain and change water quality, water flow, water velocities, sediment transport, and sediment deposition patterns. Depending on the size and location of the project, the changes may extend all the way to the estuary and marine nearshore.

The potential area affected by each type of salmon habitat restoration action is described in Table 5. Please note that this table provides a general description of potential extent to guide the assessment of impacts for a project.

Table 5. Potential Spatial Extent of Effects from Habitat Actions on Shellfish Growing Conditions

Habitat Action	Extent of Potential Effects
Armor Removal or Modification and associated Fill Removal	Generally results in localized effects on shoreline except for those actions that reconnect feeder bluff sediment sources that supply sediments. Sediment associated with feeder bluffs can be transported along drift cells that may extend several miles. However, the reconnection of feeder bluffs would not be expected to deliver sediment beyond the project site in quantities that cause burial concerns for shellfish. Comparatively, the suspended sediments in the water column caused by erosion of feeder bluffs can change conditions beyond the site and potentially have detrimental effects to shellfish. While this erosion is a natural process, the erosion rates can be higher at sites where armoring had been in place for several decades and the site will readjust to natural slopes and orientation.
Beach Nourishment	Effectively functioning as a substitute for reconnecting natural sediment supplies, beach nourishment projects add sand and gravel to the beach system. These projects will have localized effects initially, then over time sediments will be transported along drift cells that may extend several miles. The volume of beach nourishment material placed can have an impact on shellfish beds if the quantity of sediment that is delivered is beyond the project site's ability to appropriately disperse. Sediment in excess quantities can cause burial concerns for shellfish or result in chronic impacts to a shellfish bed. Suspended sediments at and beyond the site may occur during construction and during high wave energy events following sediment placement.
Channel Restoration or Creation – Tidal	Dependent on the location and size of the project, channel restoration or creation can potentially affect conditions throughout the entire delta and surrounding nearshore areas. Effectively, these projects will cause changes beyond the project site. Suspended and bedload sediments at and beyond the site may occur during construction and during high flow events following construction.
Channel Restoration or Creation – Riverine	Dependent on the location and size of the project, channel restoration or creation can potentially affect conditions in the delta even if located several miles upstream. Effectively, these projects will cause changes beyond the project site. Suspended and bedload sediments at and beyond the site may occur during construction and during high flow events following construction.
Contaminant Removal and Remediation	Best management practices during construction are intended to limit impacts to the project site. Post-construction, the benefits to sediment and water quality will extend beyond the project site, depending on sediment transport conditions and water circulation processes.

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Habitat Action	Extent of Potential Effects
Culvert or Tide Gate Removal or Modification	Dependent on the location and size of the project area, culvert or tide gate removal/modification can affect large areas downstream and the connectivity benefits to upstream areas. As with channel restoration, these projects can change water flow and sediment transport patterns in the delta and adjacent nearshore areas.
Debris Removal	Debris removal generally results in localized effects. These projects can restore sediment transport processes that impact a larger area, but unlikely at a magnitude that affects shellfish resources beyond the site. If debris is contaminated, then the contaminant removal and remediation description also applies.
Groin Removal or Modification	Groins associated with houses along marine nearshore habitats will tend to impact the site and downdrift areas benefiting from the removal of obstructions to sediment transport. Effects from these actions will generally not be of a magnitude to impact shellfish resources beyond the site. Groins in river deltas are often in place to improve shellfish growing conditions by restricting water flow and sediment delivery. Removal or modification of these structures will potentially impact the entire delta and surrounding nearshore areas.
Levee/Dike Removal or Setback	Dependent on the location and size of the project, a levee/dike removal or setback can potentially impact conditions throughout the entire delta and surrounding nearshore areas. Effectively, these projects will cause changes beyond the project site. Suspended sediments at and beyond the site may occur during construction and during high flow events following sediment placement. This action may also reconnect floodplains and provide more space for water and sediment during high flows to lower the risk of sedimentation in the delta/nearshore in the long term.
Log Jam Placement	Generally results in localized effect, although often undertaken with other actions that will have effects across a larger area.
Overwater Structure Removal or Modification	Generally results in localized effect.
Revegetation	Generally results in localized effect.
Wetland or Marsh Restoration – Tidal	Dependent on the location and size of the project, wetland or marsh restoration can potentially impact conditions throughout the entire delta and surrounding nearshore areas. Effectively, these projects will cause changes beyond the project site. Suspended sediments at and beyond the site may occur during construction and during high flow events following construction. This action may also reconnect floodplains and provide more space for water and sediment during high flows to lower the risk of sedimentation in the delta/nearshore in the long term.
Wetland or Marsh Restoration – Freshwater	Dependent on the location and size of the project, wetland or marsh restoration can potentially affect conditions in the delta, even if the project is located upstream. Suspended sediments at and beyond the site may occur during construction and during high flow events following construction. This action may also reconnect floodplains and provide more space for water and sediment during high flows to lower the risk of sedimentation in the delta/nearshore in the long term.

3.2.3 Timing of Change

The timing of change refers to whether the change is immediate or delayed and whether it is short term or long term. In considering duration, there are effects that may occur during construction, immediately following construction as a site adjusts, and lasting over the long term. Some of the effects are anticipated – particularly those that directly align with the project goals – while others may be unanticipated and unintended given the project goals.

In many cases, the timing of the effect is also related to the natural environmental conditions that occur during or after project construction. For example, at Belfair State Park soon after restoration was constructed to expand the estuary and improve fish passage to Big Mission Creek, an exceptionally strong winter storm impacted the site. Substantial quantities of sediment were delivered from the creek to the delta and adjacent shorelines. The sediment smothered all shellfish in a large area, which resulted in total mortality of the existing shellfish population within the impact area. It cannot be determined whether the impacts would have occurred even if the restoration had not been completed, but the restoration is assumed to have allowed for increased sediment transport and partially contributed to the impacts on shellfish resources.

It can be anticipated that effects from actions will vary over time. For projects that aim to restore natural processes, some equilibrating adjustment should be expected following construction as the restored processes act on an area. These adjustments may alter how a project action affects conditions for shellfish over space and time.

Many individuals interviewed reported that shellfish populations that were initially depleted due to a salmon restoration project would show signs of recovery on a time scale of approximately 6 to 10 years after restoration project construction. However, in each of the examples discussed, a source population of shellfish remained in the impact area which enabled the relatively rapid reestablishment of the population. Other reports described a total loss of bivalves in a project area with no observed recovery in the first decade. It is important to understand that shellfish populations can recover, but also that a project needs to consider the potential long-term effects that may be unintended. Shellfish stakeholders can be a valuable resource in understanding these unintended responses.

Finally, almost all project examples discussed during the interview portion of this work were deficient in pre-, during, and post-monitoring activities that could have provided detailed or quantitative information to effectively answer the question of shellfish effects and recovery potential. This deficiency was not a lack of interest or effort on the part of the project sponsors but the lack of funding for project monitoring. Consideration of both the potential short-term (<5 years) and long-term (>5 years) effects of a project is a key topic of discussions with shellfish stakeholders.

4.0 GUIDANCE AND RECOMMENDATIONS

A consistent theme of the interviews was the importance of early communication by those proposing salmon habitat restoration projects with those involved with bivalve shellfish management, restoration, harvest, or aquaculture. It should be noted that early communication is also beneficial from shellfish stakeholders to salmon restoration organizations when new or expanded shellfish operations are proposed. The guidance and recommendations presented here are aimed towards helping salmon habitat project teams assess the potential for interactions with shellfish resources, identify shellfish representatives to facilitate communication, and develop a plan for communication to continue through the remainder of the proposed project.

The guidance and recommendations from this synthesis report are primarily based on the information presented above, and can be summarized into four main steps (Figure 3). The end goal of this guidance is to create an effective communication and outreach plan that is tailored to the proposed restoration project to incorporate shellfish stakeholders into the project planning process. The following sections describe each of these steps in more detail, and potential resources to use or develop within each of these steps.

Figure 3. Steps to Identifying Recommended Communication Plan for Shellfish Stakeholders

4.1 Step 1: Identify the Potential for Project Effects on Shellfish

The first step is to identify the potential for a proposed salmon restoration project to affect estuary and nearshore habitats supporting shellfish resources, or areas identified as priorities for shellfish restoration. The general types of questions to ask include:

- Does the project have the potential to affect estuary and nearshore habitats? This question is primarily for projects in the freshwater to consider, since projects in the estuary and nearshore will certainly affect those habitats.
- Are there shellfish resources in, or near, those habitats?
- Are the shellfish resources harvested by tribes, the public, or as part of commercial aquaculture operations?
- Will access to harvest be impacted and/or harvest pressure be shifted to a new location?

- Are the shellfish resources part of a restoration effort for native Olympia oysters? This question is to ensure the salmon habitat project does not inadvertently impact Olympia oyster restoration efforts.

The map in Figure 2 shows the distribution of commercial shellfish growing areas in Hood Canal based on information provided by the Corps (2015). In addition, public harvest areas are shown in maps at http://www.doh.wa.gov/CommunityandEnvironment/Shellfish.

The types of salmon habitat restoration projects and potential interactions with shellfish resources were identified above in Tables 4 and 5. Key pieces of information to consider when looking at project effects include:

- Boundaries of the action area (defined below),
- Baseline, variability, and potential future habitat conditions, and
- Shellfish species and life stages present in the action area.

The "action area" for a project is the farthest extent of any project action that will result in effects to shellfish resources (e.g., suspended sediments, sediment transport, drainage patterns). It is important to note that many salmon habitat restoration projects occur near river mouths, or farther upstream, and the project team may need to identify shellfish resources downstream in the estuary as a potential impact risk. Salmon habitat restoration proponents need to think beyond the direct project impacts, and about how the system and habitat processes will change in response to project actions.

A more detailed checklist of questions and information needs for Step 1 of the guidance process to identify project effects is presented in **Appendix C**.

4.2 Step 2: Identify Magnitude and Timeframe of Potential Project Effects

Nearshore ecosystems are dynamic. There are changes that occur on an hourly basis (e.g., tides, wind/waves), seasonal basis (e.g., storms, mass-wasting events), and over long time periods (e.g., coastal geomorphic processes). Changes to these systems, especially when larger salmon habitat restoration projects are involved, can have a variety of impacts on wide spatial and temporal scales. Given the dynamic nature of these systems, predicting the new equilibrium state can have a lot of uncertainty that is challenging to communicate effectively. Although the dynamics of the nearshore make it difficult to predict effects and/or recovery with certainty, Step 2 focuses on gathering information to help understand the likely magnitude and timeframe of effects.

To help salmon habitat restoration project teams understand the potential shellfish interactions that could result from a restoration project – and therefore would benefit the restoration project to know and plan for at the outset – salmon habitat restoration project teams are advised in Step 2 to refer to Tables 4 and 5 to help identify the potential magnitude of project effects on shellfish resources and the potential spatial extent of those changes. In considering potential effects, salmon project teams are encouraged to think conservatively (i.e., err on the side of overestimating) for the purposes of being more inclusive with the stakeholder group than risk leaving out potential effects or adjacent stakeholders. This conservative approach is recommended to help identify potential challenges to implementation earlier in the process, rather than later.

A checklist of questions and recommended information needs for Step 2 of the guidance process to identify the potential extent of effects and timing/recovery is presented in **Appendix C**.

4.3 Step 3: Identify Shellfish Stakeholders

As described above, there are over 80 separate organizations in the Hood Canal area associated with shellfish resources including tribes, agencies, shellfish aquaculture companies, research organizations, and restoration specialists. Identifying the correct organizations, and individuals within those organizations, can be a difficult process. The first step is to identify what shellfish species are present at the site or within the action area and which stakeholder(s) has the potential to be affected (e.g., tribal, recreational, commercial, restoration). The web links listed in **Appendix C** can be used to identify an initial list of shellfish stakeholders. **Appendix C** also provides the three county parcel assessor websites within Hood Canal, as well as Washington Department of Natural Resources (DNR) resources, for identifying property owners and parcel information[5]. Identifying the property owners for the project site, and adjacent parcel owners, can assist with identifying shellfish stakeholders. Determining tideland ownership can be very complicated, and tideland ownership information provided on county websites varies. DNR is an excellent source to utilize for determining tideland ownership (private or public); they may be able to provide a deed for private tidelands or a tideland lease on public tidelands. DNR can also provide information on aquaculture leases. It may be necessary to utilize a title company to conduct a title search to determine tideland ownership.

It is also recommended that projects are more inclusive in identifying shellfish stakeholders. One of the lessons learned from the Lower Big Quilcene estuary project (see Case Study 1 in

[5] Note that the county assessor websites may or may not include tideland ownership boundaries. Other sources that can be used include DNR tideland parcel ownership information (DNR Aquatics) or surveyor reports. Open source geographic information system (GIS) data from DNR can be found at: http://data-wadnr.opendata.arcgis.com/ Caution should be used in interpreting field boundaries from GIS data due to error in location of boundary lines and aerial photos.

Note that the DNR database provides information on DNR-owned lands, and identifies other parcels as privately owned. More information on private lands may be possible by contacting the DNR Aquatics land managers (http://www.dnr.wa.gov/publications/aqr_land_manager_map.pdf).

Appendix A) was that all shellfish stakeholders would have liked to have been included from the beginning of the process.

As described below in Section 5.0 (Monitoring), it is advised that salmon project proponents conduct a site walk with one or more shellfish stakeholders to discuss shellfish resources in the area and the potential salmon habitat restoration work at the site.

4.4 Step 4: Create a Communication and Outreach Plan

The final step in the guidance and recommendations is to create a communication and outreach plan. The goal of this step is to promote sustainable decisions that recognize and communicate the needs and interests of all participants, including salmon restoration specialists and shellfish stakeholders.

The following tips are general guidelines for communication that were heard during the interviews with stakeholders during this project:

- Communication should be meaningful, but strategic. Be sure to understand/be clear about the level of engagement being requested. Don't ask if you have no intention to include that input or follow up on it.
- Get the word out and get focused on a targeted outreach effort (i.e., more than just a general mailing), and prepare the stakeholder for participation. Include project information related to the location, and concept sheets that provide the basics of the project. Providing information is important for stakeholders to be able to access and comment on a project.
- Make sure to understand what the public or affected party expects. Asking for specific information and setting reasonable expectations will improve communications.
- For projects with multiple stakeholders that have multiple purposes, make sure that multiple individuals are targeted.
- Follow-up with those who are expected to be key or particularly interested individuals to ensure they received the initial communication. Additional effort to ensure there is project awareness and to receive input is encouraged.
- Initial discussions with individual stakeholders who are expected to be hesitant or even resistant to the proposed project are recommended to be conducted separately. Taking the time to meet individually will allow for full exchange of information and to ensure the stakeholder knows their comments have been heard. Meeting individually also provides the opportunity to initiate a one-on-one relationship with key stakeholders.
- Seek input early, before design decisions are made. Communication is key before an alternative is selected.
- Communicate the anticipated effects of the restoration project and the ways in which it will be designed to lessen undesired effects on other resources. This communication can

decrease the likelihood of repetitive design revisions, lead to realistic project designs, avoid permitting delays, and minimize stakeholder resistance.

- If the size of the project or project impacts warrants it, utilize technical experts to present project design and/or technical assessments. These technical experts will need to be able to convey the information to a non-technical audience.
- Provide hard-copy results for stakeholders to review and comment on (open sharing of information to obtain informed input).
- Be sure to follow up on comments, document how input has been applied, and/or how the analysis was revised to incorporate comments.
- Communicate willingness to be flexible in addressing questions and comments (fact-finding analysis). This approach respects the stakeholder process and builds trust.
- Budget and schedule accordingly when developing grants, which provides an understanding of the benefits of early stakeholder involvement and potentially leads to less time required for getting stakeholders up to speed later in the process. Consider including funding for contracted meeting facilitation, should your organization not have sufficient expertise or capacity.
- Find an approach that is structured, but also organic enough to modify based on site-specific information.

A checklist of questions and information needs for Step 4 of the guidance process to provide guidance for communication and outreach is presented in **Appendix C**. The Duckabush Estuary Restoration, presented as Case Study 4 in **Appendix A**, presents an opportunity to apply these recommendations. This Case Study is in the beginning stages of the project development process and provides an opportunity to demonstrate how the project could benefit from the lessons learned from other examples of habitat restoration efforts within Hood Canal/Puget Sound.

5.0 MONITORING

Monitoring and adaptive management is a necessary step to understand whether restoration goals are achieved, what habitat change responses occurred, and how long those changes persisted, and to adjust the project, where necessary, if goals are not achieved or if unintended responses occur. Monitoring includes pre-project (baseline monitoring), during construction (implementation monitoring), and post-project (performance monitoring) activities. Monitoring can inform restoration design to help alleviate concerns, define design criteria to avoid or minimize impacts to shellfish resources, or differentiate post-project responses from natural population changes or impacts (such as storm events).

Lack of monitoring of projects is a major data gap for past restoration efforts. Multiple interviewees indicated that, without monitoring, there can be no understanding of how long project responses persist, how they change over time, and what benefits the project is providing. This was also a source of frustration in the Jimmycomelately Creek project – see Shreffler (2008) quote – and expressed by Ecology in terms of the value of learning from past projects. Monitoring is the primary way to assess performance criteria and goals of the project and to inform future project actions and designs.

> *"The science of ecosystem restoration will only advance if grant agencies are willing to consistently devote money to monitoring the successes and failures of restoration projects like the Jimmy Project."* Shreffler (2008)

Baseline monitoring of current habitat conditions within the action area should be performed for any project. However, understanding the variability in baseline conditions, and potential future habitat conditions, should be scaled to the size, effects, and duration of the project. A variety of resources can be used to understand habitat conditions that go beyond site surveys, including interviews with local experts, data from tribes and WDFW, past reports and studies, and data collected by resources agencies (e.g., WDOH, NMFS, WDFW, Ecology). As noted during multiple interviews, some of the most knowledgeable individuals are the people that work the tides on a regular basis. Even if harvesters or growers are not incorporated into the final project design team, walking a site with someone that has been in the area for years can add valuable information to a project compared to site observations collected once or twice for a project. This process was emphasized in the PSI effort (Suhrbier and Cheney 2015, Suhrbier et al. 2016). Ideally, the site walk would also include salmon ecologists or coastal engineers from the salmon habitat project team so there can be an onsite exchange of salmon and shellfish perspectives of the area and the potential changes to the area.

The monitoring checklist provided in Table 6 is a list of potential approaches for guiding and planning needs for monitoring, but is not a structured monitoring plan. Proposed habitat project and location variability will require site-specific or project-specific information to develop a monitoring plan. In addition, monitoring approaches should follow agency-approved methodologies, as appropriate.

Table 6. Monitoring Approaches for Salmon Habitat Restoration Projects

Project Effect	Description of Potential Approach
Sediment Transport	
Aggradation and Scouring	▪ Establish channel cross sections at different stations to provide an indication of changes in bed elevations, sediment depth, availability of hard substrates, and channel gradients, widths, and slopes. ▪ Perform pebble counts and sample suspended sediment loads. ▪ Use Real Time Kinematic (RTK) positioning techniques, or other land survey methods, to track changes in sediment profiles. ▪ Deploy sediment plates in various locations of the channel.
Tidal Channel Formation and Tidal Elevation	▪ Review available data on historical changes to estuaries. ▪ Use drone technology (low altitude aerial photography), other aerial photography, or LiDAR to track changes in channel formation and sediment transport in the estuary.
Sediment Composition	▪ Collect sediment samples to track changes in sediment composition. ▪ Identify the size and structure of sediment source material. ▪ Take photographs at multiple locations (photo point data).
Hydrology	
Channel Flow Capacity	▪ Deploy an Acoustic Doppler Current Profiler (ADCP) or other flow meter at multiple locations.
Flood Intensity	▪ Review monitoring data from USGS stream gages. ▪ Use land survey methods to track changes to high water marks.
Water and Sediment Quality	
Metals, Organics, total petroleum hydrocarbons, Polycyclic aromatic hydrocarbons	▪ Collect sediment samples and analyze for desired constituents using an EPA-approved laboratory.
Salinity, Temperature, Dissolved Oxygen, Suspended Sediments, Fecal Coliform, pH	▪ Review available data from DOH or Ecology. ▪ Collect water samples and analyze for desired constituents. ▪ Deploy water quality meters/data loggers (sondes) at multiple locations.
Toxic Algae	▪ Collect water/sediment samples and analyze for Harmful Algae Blooms (HABs) by identifying the amount of paralytic shellfish poisoning or amnesic shellfish poisoning toxins. ▪ Expose mussels, or other sentinel species, to the site and determine marine toxin levels in tissue samples.
Biological	
Shellfish Resources	▪ Interview the tribes and WDFW on available data from shellfish harvest management areas. ▪ Perform site surveys using common survey methods for abundance and species identification.

Table continues on next page

Project Effect	Description of Potential Approach
Eelgrass Habitat	▪ Review available data from the DNR nearshore habitat eelgrass monitoring program (e.g., Christiaen et al. 2016). ▪ Perform site surveys using underwater video cameras, aerial photography, low altitude aerial drones, side scan sonar, or other methods.
Other Organisms	▪ Review available data for the site (e.g., WDFW, University of Washington, Ecology). ▪ Perform site surveys using field transects, taking cores, counting in quadrats, beach seining, and other observation methods for benthic invertebrates, birds, fish (especially forage fish), or other organisms using common survey methods. ▪ Take photographs at multiple locations (photo point data).
Predation Pressure	▪ Characterize species and abundance using field transects/quadrats. ▪ Perform caged vs. uncaged oysters or other sentinel species experiments.
Food Resources	▪ Measure abundance of chlorophyll *a* during seasonal shifts. ▪ Characterize species and abundance using field transects, quadrats, and benthic cores.
Access Conditions	
Roads and Access Points	▪ Review available data on historical changes to roads. ▪ Review aerial photography data, county data, or parks and recreation data on access points (e.g., boat launches, parks, parking lots).
Private Properties	▪ Review available data on private property changes using county parcel data and DNR data. ▪ Review available aerial photography (e.g., GoogleEarth) to look at land development.
Sources: Bradbury et al. 2005, Dethier and Schoch 2005, Dowty 2005, Todd et al. 2006, Shreffler 2008, Grossman et al. 2015, Wasson et al. 2015, Dethier et al. 2016, Valdez et al. 2016	

As described in the Johns Creek example (Case Study 5 in **Appendix A**), the length of time dedicated to monitoring, and commitment to an adaptive management strategy, are critical components to monitoring plans. This project committed to monitoring 5 years post construction and an adaptive management strategy. Project changes were made to account for underperformance of sediment management efforts. In many cases, a monitoring plan that extends 2 years is not sufficient to address an assessment of changes and recovery potential. This was also confirmed by comments from WDFW, indicating insufficient monitoring has resulted in past project issues, resulting in time and money dedicated to fixing failing project components.

6.0 SUMMARY AND NEXT STEPS

Salmon and bivalves are important resources in Hood Canal. Given the low numbers of salmon in several Hood Canal populations, and the ESA listing of three species, there is a pressing need to restore habitats for salmon. The ability to make the large-scale habitat improvements needed for salmon requires working with diverse stakeholder interests to find opportunities to address salmon habitat needs in ways that works with the other interests of the area. Shellfish stakeholders, including tribes, WDFW, restoration specialists, and commercial shellfish aquaculture growers, are also highly reliant on the river deltas and marine nearshore areas of Hood Canal. As such, engaging with shellfish stakeholders early and consistently during the development of salmon habitat restoration projects will facilitate finding a constructible project direction that balances the habitat objectives with the shellfish stakeholder needs for the area.

The literature review revealed that there are no published studies documenting how salmon habitat restoration projects interact with shellfish resources. However, using available information on the habitat requirements of the bivalve species present in Hood Canal, information developed through interviews with individuals with experience in Hood Canal, and an understanding of anticipated changes to an area through salmon habitat restoration actions, the conceptual linkages of the interactions were identified. This included the type of changes that may interact with shellfish resources, and whether the effects may extend beyond the project site.

A four-step guidance was developed as a framework for identifying the potential for interactions, and establishing a communication and outreach approach for engaging shellfish stakeholders early and consistently in the project development process. This includes a series of checklists that can be used to understand what questions a restoration practitioner should be asking during project development.

The case studies presented in **Appendix A** were developed based on information from the interviews and available project documentation. The case studies highlight five project examples where there were interactions between planned or completed salmon restoration (or sediment management) actions and shellfish resources. The case studies provide valuable insights on lessons learned for working in these shared areas. The common themes from the case studies include:

- The importance of respectful, early, and consistent communication.
- The value of long-term monitoring and adaptive management.
- The need to be creative about solutions, realizing that an idea may change the scope of a restoration project, but more closely align with user groups in the area.

- Finding shared goals among multiple stakeholders, including improvements to water, sediment, and habitat quality, and restrictions on upland development.

Because salmon and bivalves are such important resources in Hood Canal, and for the State in general, having a full understanding of how a salmon habitat restoration project may affect shellfish resources and shellfish stakeholders should be a major focus of a restoration project plan and design. To accomplish this funding for project monitoring and communications/outreach is required. Shellfish stakeholders represent important potential partners because the goals of improved water quality and habitat conditions are well aligned with supporting both economic and cultural resources dependent on shellfish.

This project represents the first step in identifying a process for incorporating shellfish resources and stakeholders into restoration projects. Several next steps can be taken to further these efforts, including:

- Work with the Governor's Salmon Recovery Office and other restoration funding sources to create a robust approach to assessing and addressing potential impacts to shellfish resources from salmon habitat restoration projects. Addressing impacts may include developing strategies for mitigation if impacts to shellfish resources are identified, especially when long-term benefits greatly outweigh short-term impacts.
- Incorporate consideration of the potential for impacts to shellfish resources into grant applications and/or lead entity project ranking decisions for state salmon recovery grants. Doing so would help leverage the importance of the checklists and guidance provided in this assessment. It would also inform the granting entities evaluation of the project sponsor's understanding and readiness to address the potential challenges of a project.
- Discuss funding for monitoring and adaptive management included in State and federal funding sources.
- Create monitoring criteria/protocols through WDFW and tribal governments that will aid in understanding salmon habitat restoration interactions with shellfish resources.
- Identify a "shellfish liaison" who can be a resource to salmon habitat restoration practitioners to gain information on the shellfish resource issues that a proposed project concept might encounter. The shellfish liaison may also be able to serve as a valuable communicator to help the exchange of information and perspectives between salmon restoration project teams and shellfish stakeholders. Such a position could also have a formal role in the grant review or ranking process for Hood Canal.
- Conduct further research into timeframe of disturbance and recovery potential for shellfish under different habitat action scenarios.

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Appendix A

Case Studies of Projects with Interactions between Salmon Habitat Restoration and Shellfish Resources

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CASE STUDIES OF PROJECTS WITH INTERACTIONS BETWEEN SALMON HABITAT RESTORATION AND SHELLFISH RESOURCES

The case studies presented here were developed based on information from the interviews and available project documentation. The case studies highlight five project examples in which there were interactions between planned or completed salmon restoration activities and shellfish resources, which provided valuable insights on lessons learned for working in these shared areas.

Case Study 1: Lower Big Quilcene River – this project represents the importance of early and sincere outreach to affected shellfish stakeholders. It emphasizes the positive relationships that can be developed through consistent feedback, incorporation of shellfish interests, and active communication. The design that is in development includes some creative solutions and some restoration compromises to avoid impacts to shellfish resources.

Case Study 2: Jimmycomelately Creek – this project represents improved habitat conditions, but also the need to include more communication between partners, including multiple branches of the same organization. Shellfish stakeholders were not engaged in this process, but the recognition that this would have been valuable was stated during the interview process.

Case Study 3: Skokomish River – this project represents improved habitat conditions, including restored water quality and expansion of eelgrass, but also a need to communicate with shellfish biologists during project planning and implementation. Shellfish stakeholders were not engaged in this process, but the recognition that this would have been valuable was stated during the interview process.

Case Study 4: Duckabush River – this project represents a failing nearshore system in terms of water quality and habitat conditions for salmon, but an extremely important area for shellfish resources. This project could be a robust partnership between tribal and State interests if managed appropriately. Note that this project is not even in the design phase, but could benefit from the information generated in this assessment report.

Case Study 5: Johns Creek – this project represents successful monitoring and adaptive management of the project site. The project committed to monitoring 5 years after the site was constructed, and provided design modifications if conditions did not meet the established performance criteria. Creative solutions to avoid impacts to shellfish resources included re-alignment of the channel and adding a levee that could allow the drainage to perform normally on one side, but protect shellfish habitat on the other side.

CASE STUDY 1 | Lower Big Quilcene River (Quilcene Bay)

ABOUT THE PROJECT | The Lower Big Quilcene estuary is the site of a large-scale restoration of the lower river, estuary, and delta to restore floodplain and estuary habitat and reduce flood risk for the community (PSNERP 2012). The project is in the design phase, and is being conducted by the Hood Canal Salmon Enhancement Group (HCSEG). The upcoming phase is the third phase of restoration in the estuary and is by far the largest. The project area is the lower one mile of the Big Quilcene River. The lower river currently consists of levees, road structures, and bridges that limit the river from its historic channel migration zone. The lower Big Quilcene River is a high priority for restoration to recover ESA-listed summer chum salmon, steelhead, and Chinook salmon.

HABITAT OBJECTIVES | Reconnect river to floodplain and delta; remove constraints to dynamic estuarine flow paths and processes.

POTENTIAL SHELLFISH INTERACTIONS | Channel migration in delta; water quality; sediment supply, transport, and deposition

PROJECT HIGHLIGHTS

- ✓ Positive stakeholder outreach
- ✓ Improved habitat conditions
- ✓ Reduced flood hazards to homes, roads, and utilities
- ✓ Restored water quality
- ✓ Monitoring and adaptive management

WHAT WORKED | HCSEG is undertaking a wide-reaching stakeholder outreach effort to ensure input from salmon habitat specialists, shellfish growers/harvesters, the affected community, and recreational interests. The outreach and stakeholder effort for the project has been highly successful, to date, based on the numerous people interviewed as part of this assessment. Stakeholders have been involved to help shape the restoration alternatives evaluated in a feasibility study and the associated hydrodynamic modeling completed to help understand how water and sediment transport patterns could change with the project. HCSEG has actively sought and incorporated stakeholder input. Stakeholders interviewed as part of this assessment were satisfied with the alternative selected and that their input was valued.

The engagement of shellfish interests was conducted in a manner consistent with the guidance recommendations provided in this assessment. HCSEG recognized that the project could affect nearby shellfish resources, identified the appropriate stakeholder representatives, and implemented an effective communication and outreach approach.

LESSONS LEARNED | Previous phases of restoration on the Big Quilcene River pointed out the importance of early and sincere outreach to affected stakeholders. This lesson was learned from earlier phases of the project, including starting construction activities without notifying neighbors or stakeholders that would potentially be affected. In the current phase of the project, some stakeholders joined the planning efforts mid-way through the process and/or missed key meetings in the sequence. While their input was welcomed, it created some inefficiencies because meeting time needed to be spent revisiting topics that were discussed at earlier meetings and left less time to address new topics.

CASE STUDY 2 | Jimmycomelately Creek (Sequim Bay)

Before (1999)

After (Virtual: 2005)

WHAT WORKED | The JCL ecosystem restoration focused on improving conditions for salmon, and the project has functioned as intended. For shellfish resources, the estuarine conditions improved as the delivery of sediment from the creek firmed up the substrate to better support shellfish. About 5-years post-construction, substrate was suitable to support oysters for the first time in decades. Therefore, the site has evolved to being better for shellfish resources in more recent years without having been identified as a major shellfish harvest area prior to restoration efforts.

LESSONS LEARNED | Some of the more challenging elements of the project included creosote pile removal, acquiring private properties within the project area, and construction of the Olympic Discovery Trail. One of the main identified lessons learned by the project team (Shreffler 2008), was not enough communication between the partners, even to the point of making sure that multiple branches of the same organization are involved. This is a theme expressed by many of the individuals interviewed, providing the understanding that shellfish resources are becoming more prominent for any action within estuaries.

A key component was monitoring. The project plan included a suggested pre-, during, and post-project monitoring that included adaptive management. Due to lack of funding, monitoring for only a few of the essential tasks was funded and no corrective actions were taken for elements that did not achieve the performance criteria (Shreffler 2012). There was no monitoring for shellfish resources.

ABOUT THE PROJECT | The Jimmycomelately Creek (JCL) Ecosystem Restoration Project included redesigning the configuration of the lower creek and estuarine habitat. The project is located on land owned by the Jamestown S'Klallam Tribe, and although they were the primary project sponsor, this effort represents a significant collaboration between multiple entities. JCL is the major tributary flowing into Sequim Bay, and the habitat was considered isolated and fragmented from logging and settlement activities that resulted in reduction in ecological function, a declining fish population, and increased flooding. Restoration included channel realignment (2002-2003), estuary restoration/fill removal (2003-2005), bridge replacement (2004), and diversion of existing creek flow (2004). The restoration effort took 10 years (from conception to construction) and restored habitat for fish, shellfish, eelgrass, migratory water fowl, and other wildlife. More detailed information on this project can be found in Shreffler (2008).

HABITAT OBJECTIVES | Restored and enlarged lower creek and estuary habitats, removal of contaminants, restored riparian corridor.

POTENTIAL SHELLFISH INTERACTIONS | Channel migration in delta; water quality; sediment supply, transport, and deposition; sediment size; freshwater flow rates; contaminants and toxins; freshwater flow rate

PROJECT HIGHLIGHTS

- ✓ Improved habitat conditions
- ✓ Reduced flood hazards to homes, roads, and utilities
- ✓ Restored water quality
- ✓ Open and respectful communications
- ✓ Community involvement
- ✓ Monitoring

CASE STUDY 3 | Skokomish River (Hood Canal)

ABOUT THE PROJECT | The Skokomish River has a long history of large-scale habitat restoration activities led by the Skokomish Tribe to improve habitat conditions for salmon, decrease flood risk, and increase connectivity between habitats and physical processes to reduce the effects of historic land use activities. Habitat restoration has included multiple projects in the estuary and lower river. Phase 1 was constructed in 2007 and entailed dike removal. Phase 2 (2010-2011) activities included recovery of fluvial and tidal connectivity to approximately 215 acres of the former Nalley Island farmland (Grossman et al. 2015). Future planned restoration activities include increasing the channel capacity and sediment movement, which will also improve habitat conditions for salmon by providing more floodplain to control water during flooding events.

HABITAT OBJECTIVES | Remove constraints to dynamic estuarine flow paths and processes.

POTENTIAL SHELLFISH INTERACTIONS | Channel migration in delta; water quality; sediment supply, transport, and deposition; freshwater flow rates; contaminants and toxins

PROJECT HIGHLIGHTS

- ✓ Improved habitat conditions
- ✓ Reduced flood hazards to homes, roads, and utilities
- ✓ Restored water quality
- ✓ Compensatory mitigation
- ✓ Monitoring and adaptive management

WHAT WORKED | Although monitoring funding was not available through the original funding partner (Mason County Conservation District), the Tribe was recently able to secure monitoring funding through the USGS to inform restoration success and future activities (Grossman et al. 2015). Additional surveys in the area also support the notion of improved habitat conditions, such as increased eelgrass habitat within the estuary observed between 2005 and 2014 (Christiaen et al. 2016). In general, there appears to be improvements in substrate conditions that are more suitable for shellfish along the west beach, including areas that have seen reductions in burrowing shrimp activity due to increased sediment grain size. The Tribe is also collecting biomass data, temperature data, and sediment data within the estuary to inform future actions (Eardley, pers. comm., 2017). In general, the observations by the Tribe has been that restoration actions result in short-term impacts to shellfish resources but may have long-term benefits to water and sediment quality.

LESSONS LEARNED | Although the long-term benefits to shellfish are anticipated from the completed restoration actions in the Skokomish River estuary, there was no communication with shellfish biologists during restoration planning and implementation. The Tribe recognizes its own need to improve internal communications within different disciplines (e.g., salmon and shellfish). It was also noted that a well-developed monitoring plan should have been part of this project early on, including shellfish/habitat impacts. Finally, future restoration actions will also consider ways to incorporate mitigation from the temporary loss of shellfish resources.

CASE STUDY 4 | Duckabush River (Hood Canal)

ABOUT THE PROJECT | There is a proposed restoration action for the Duckabush River that would potentially include re-engagement of the river delta through the removal of obstructions (PSNERP 2012). The main action would be to place Highway 101 on a long bridge rather than the current road and short bridges across the river mouth. The proposed restoration would reconnect the river to its floodplain and intertidal wetlands and promote more natural tidal exchange, sediment transport, and estuary/delta development.

The Duckabush River delta provides productive and easily accessible shellfish harvest opportunities for recreational users and Tribes. This area is considered at risk of being closed for harvest by DOH due to high levels of fecal coliform contamination from the upper watershed.

The restoration effort would potentially create a more dynamic river and result in conditions that are less stable for shellfish. This will result in a net loss of shellfish resources compared to current conditions. Over time restored sediment delivery may provide better habitat conditions for water and sediment quality in the long-term after recovery and equilibration of changes.

HABITAT OBJECTIVES | Remove constraints to dynamic estuarine flow paths and processes.

POTENTIAL SHELLFISH INTERACTIONS | Channel migration in delta; water quality; sediment supply, transport, and deposition; freshwater flow rates

WHAT COULD WORK | The shellfish resources in the Duckabush River estuary represent more than just the harvestable area. This is a location that is highly utilized by the public and tribes because it is accessible by foot and has a high concentration of shellfish biomass in a large area. There are ways to offset short-term impacts and plan for long-term recovery, but this will involve direct and early coordination with the Tribes and WDFW shellfish biologists. The Tribes can be a significant partner in terms of monitoring, planning, and designing the project. The Tribes have long-term data for the Duckabush River estuary, and are actively collecting baseline information. The data that are being collected will be valuable for this project, and can be used to create a monitoring and adaptive management plan. This project will also require robust modeling of sediment transport and freshwater flow paths to promote effective communication and inform design alternatives. The project provides an excellent opportunity to apply the guidance recommendations provided in this assessment. In particular, the development and completion of a communications and outreach plan will help the project team engage with key stakeholders and identify a restoration alternative.

PROJECT HIGHLIGHTS

- ✓ Partnership between Tribal and State interests
- ✓ Robust modeling and stakeholder feedback
- ✓ Restored water quality
- ✓ Compensatory mitigation actions
- ✓ Monitoring and adaptive management

CASE STUDY 5 | Johns Creek (Oakland Bay)

ABOUT THE PROJECT | The lower Johns Creek sediment management project (constructed 2000) in south Puget Sound was initiated because of impacts in the watershed from gravel mining operations and a levee breach near the property line of the tidelands owned by Taylor Shellfish Farms and the State. Sediment associated with multiple slide events, followed by winter storms, deposited sediment onto clam beds in Oakland Bay and resulted in a levee failure. Taylor Shellfish Farms engaged WDFW, the Squaxin Island Tribe, local non-profit organizations, and habitat restoration consultants to design a sediment management plan that included channel realignment and levee repairs in the lowermost portion of the creek as it drained into the intertidal zone (ATEC 1996). The primary goals of the project were to protect the clam beds and benefit salmonid habitat connectivity. The restoration design included removing a berm on one side of the tidal channel to allow the creek to meander and realigning the berm on the other side to protect the clam beds.

HABITAT OBJECTIVES | Reduce constraints to stream mouth to allow improved channel dynamics and habitat connectivity.

POTENTIAL SHELLFISH INTERACTIONS | Channel migration in delta; sediment supply, transport, and deposition

PROJECT HIGHLIGHTS

- ✓ Protection of shellfish habitat
- ✓ Early engagement of all stakeholders
- ✓ Respect for a diversity of opinions
- ✓ Collaborative solutions
- ✓ Monitoring and adaptive management

WHAT WORKED | The project engaged stakeholders right from the beginning and resolved issues during the planning process. Stakeholders were treated with respect and listened to during planning meetings. The project also provided monitoring that informed adaptive management, and mitigation for recreational/Tribal impacts. The adaptive management process was a key aspect of this project because it included commitments for monitoring and recognition among all parties that future project adjustments would be made if the site was not performing as intended. Monitoring demonstrated the need for corrective action 5 years after the site was constructed. The design adjustment entailed pulling back part of the berm and removing sediment that had been deposited.

LESSONS LEARNED | Communication and an agreed to monitoring and adaptive management process were key aspects of this project. In-person meetings worked better than email/phone conversations, and personalities at the table made a difference in terms of the productive quality of the meetings. Communicating significant impacts of water and sediment load, and making sure that the stakeholders are on board with solutions is the basic challenge of any large-scale effort. The collective agreement for adaptive management of the site through adjustments to the site configuration on an as-needed basis determined through post-construction monitoring was instrumental to the project being implemented. Through the project, it was learned adaptive management agreement worked as planned.

Appendix B

Additional Shellfish Resource Information, Including Permitting Process, Culture Methods, and Existing Challenges

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1.0 INTRODUCTION

This appendix supplements the overview of bivalve[1] shellfish resources included in the main text of the assessment. The intent of providing this additional information is to inform salmon habitat restoration practitioners on the shellfish resources and user groups that rely on the same estuary and marine nearshore areas as the salmon populations that are the focus of recovery efforts. By understanding more about the shellfish resources, and the stakeholders utilizing them, it is anticipated that salmon habitat restoration practitioners will increasingly recognize the need to engage these stakeholders during project development to work towards a shared vision for a project site that meets the salmon habitat objectives, while also providing for continued favorable growing conditions for shellfish. It should be noted that many of the reasons that shellfish are important (e.g., cultural, commercial, recreational) are similar to why salmon are important in this region. However, the focus of this work is to provide more understanding to salmon restoration practitioners of shellfish resources. As a first step towards this, it is important for salmon habitat restoration projects to consider habitat requirements for bivalves within the restoration project site, and to consider the potential downstream (downdrift) or offsite impacts from a habitat restoration project.

The environmental factors that are desirable to support shellfish resources, and dependence upon these resources in Hood Canal, include wide stretches of tide flats, protection from wave and wind fluctuations, relative ease of access (e.g., low banks), and abundant availability of food and nutrients. These are all factors that are consistent with Bush and Callow Act[2] lands identified in 1895 as valuable for developing into shellfish aquaculture sites (DNR 2016). As an example of shellfish resources in Hood Canal, a subset of relevant data was mapped to show the broad extent of these resources throughout the region (Figure B1). The Bush Act and Callow Act lands presented in Figure B1 have largely been altered by human development. As discussed in Dethier (2006), lands changed from human development may no longer provide valuable shellfish habitat due to direct loss of habitat, alteration of substrate type, pollution or other alterations in nearshore water characteristics, alteration of runoff from land and beach porewater, changes in nearshore plankton, introduced species (e.g., oyster drills), and increased susceptibility to predators and parasites. Conversely, there are areas that may be beneficial to shellfish due to habitat changes that have allowed shellfish to colonize.

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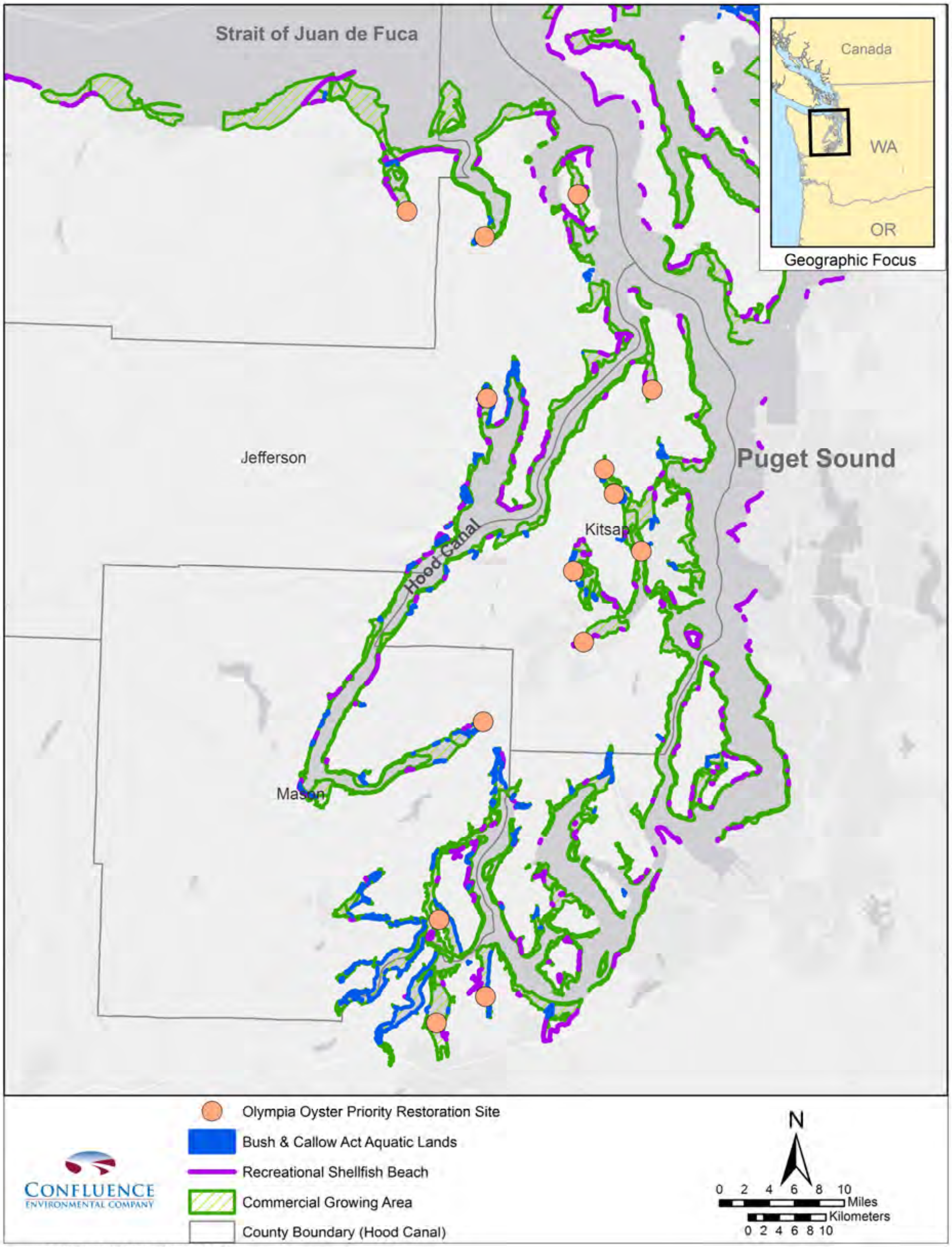
[1]This report focusses on bivalve shellfish, and does not include other important shellfish species in Hood Canal, such as decapods (crabs). “Bivalves” and “shellfish” will be used interchangeably.

[2]The Bush and Callow acts were passed in 1895 to encourage and facilitate growth of the oyster industry in Washington State (DNR 2016). The acts allowed for the sale of State-owned aquatic land into private ownership to qualified individuals for oyster planting and cultivation. There were multiple revisions to these acts, including repeals, but in 2002, House Bill 2819 (RCW 79.135.010) “grand fathered” these lands to be used for shellfish cultivation and propagation, and allowed the continued cultivation in subtidal areas if active cultivation was initiated prior to December 31, 2001.



Source: ESRI 2016, WA DOH 2017, PSRF 2017

Figure B1. Olympia Oyster Restoration Sites, Recreational Harvest Areas, Commercial Growing Areas, and Bush/Callow Act Lands in Hood Canal

Note: Data on Olympia oyster priority restoration sites was provided by PSRF, an NGO that conducts native oyster restoration projects with guidance from the Blake and Bradbury (2012) plan for rebuilding Olympia oyster populations.

In addition to providing important food and cultural values for millennia, the consistency of shellfish as a major resource in Hood Canal has resulted in the growth of economic dependence on the health and stability of this resource for more than 120 years. For example, combined, the tribes and shellfish aquaculture companies represent a significant number of employment opportunities in Mason, Jefferson, and Kitsap counties (i.e., the counties in the Hood Canal region). Shellfish also provide significant recreational and commercial opportunities in Hood Canal.

Public shellfish resources are co-managed by the Washington Department of Fish and Wildlife (WDFW) and the tribes. This is a government-to-government relationship, similar to management of salmon and steelhead resources in Washington State (the State). WDFW and the tribes that have treaty harvest rights develop management strategies for shellfish harvest on public lands.

Treaty harvest rights were provided to the tribes under the five treaties with Indian Tribes of the Western Washington Territory in 1854 and 1855 (United States v. State of Washington 1998). When the State sold their tidelands in the 1850s to private land owners, the treaty rights followed with the sale of the lands. The Rafeedie Decision of 1994 included the ruling that the tribes have "reserved harvest rights to half of all shellfish from all of the usual and accustomed places, except those places 'staked or cultivated' by citizens – or those that were specifically set aside for non-Indian shellfish cultivation purposes" (NWIFC 2017). Treaty harvest includes agreements between land owners and tribes on the density of the shellfish population, harvest times and locations, and other potential management considerations. Tribal shellfish managers develop harvest management and supplementation plans, and collect harvest data that is shared with other tribes and WDFW.

In terms of economic value, in 2013, Hood Canal represented over $11.5 million (13%) of the nearly $150 million total value of commercial bivalve shellfish production in the State (Decker 2015). This value is largely recognized as an underestimate due to the limited quality of the reported shellfish production data. It is also notable that this value only represents market value, and does not consider other economic and social aspects of the industry such as direct employment and supporting industries (e.g., distribution, restaurants). The contribution from shellfish aquaculture employment-related income throughout the State adds at least another $184 million (based on a 2010 value; Northern Economics 2013). Finally, Washington's wild harvest fishery for bivalve shellfish was valued at over $40 million in 2012 (NMFS 2016). This results in a combined total of nearly $375 million contributed to the Washington State economy that can be attributed to shellfish resources.

2.0 PERMITTING

The permitting process for shellfish aquaculture, and other shoreline activities, includes a significant review process by tribal governments and local, State, and federal entities (Ecology

2014). Due to the restrictions placed on shellfish aquaculture through the permitting process, operators at a particular site may not have the flexibility within their permits to alter locations or culture methods to help accommodate anticipated changes associated with salmon habitat restoration projects.

The federal process includes a Department of Army permit issued by the U.S. Army Corps of Engineers (Corps) and an analysis for Endangered Species Act (ESA) listed species and essential fish habitat with the National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS). Most shellfish aquaculture in the State falls under the Nationwide Permit 48 (NWP 48), which is a federal program administered by the Corps.

Activities authorized by a nationwide permit must be similar in nature, and cause only minimal adverse environmental effects on the aquatic environment when performed separately or cumulatively (33 CFR § 322.2[f]). The Corps, during its ESA consultation on NWP 48 for the State with NMFS and USFWS, recently updated the terms and conditions[3] for shellfish aquaculture operations (Corps 2015, NMFS 2016, USFWS 2016). The ESA consultation estimated growth for shellfish activities of approximately 67% (34,798 acres) over the next 20 years, although most of this growth is in subtidal wildstock geoduck harvest activities and not in aquaculture operations (Table B1). The projected growth values presented in Table B1 include commercial aquaculture, tribal harvest, recreational harvest, and shellfish restoration activities throughout the State. It is notable that projected growth within Hood Canal is estimated at 32% for commercial shellfish aquaculture and 123% for subtidal wildstock geoduck harvest.

Table B1. Projected Growth in Shellfish Activities (in acres) in Washington State over the Next 20 Years

Type of Activity	Grays Harbor	Willapa Bay	Hood Canal	South Puget Sound	North Puget Sound	Total
Continuing Shellfish Activity*						
Commercial Aquaculture	2,965	25,865	1,351	3,131	3,687	36,999
Subtidal Geoduck Harvest**	0	0	3,010	6,025	6,015	15,050
Recreation	NR	NR	NR	NR	NR	0
Restoration	NR	NR	NR	NR	NR	0
TOTAL	2,965	25,865	4,361	9,156	9,702	52,049
Projected Shellfish Activity (over 20 years)						
Commercial Aquaculture	3,065	25,965	1,789	3,578	4,002	38,399
Subtidal Geoduck Harvest**	0	0	6,703	22,676	18,754	48,133
Recreation	0	0	74	41	45	160
Restoration	0	0	24	126	5	155
TOTAL	3,065	25,965	8,590	26,421	22,806	86,847

Source: Corps 2015; NR = not reported
*Continuing activities include active and fallow acres, and commercial shellfish activities include both floating and ground-based.
**Subtidal geoduck harvest = harvest of native "wildstock" resources in Puget Sound. This does not include aquaculture operations.

[3]Terms and Conditions are required actions described in an ESA consultation to ensure that an action does not jeopardize the persistence of a listed species or critical habitat.

3.0 SHELLFISH AQUACULTURE CULTURE METHODS

The species of shellfish currently cultured in Hood Canal include Pacific oysters, Kumamoto oysters, Olympia oysters, Manila clams, geoducks, and mussels. Seed for culture operations, and some enhancement within public beaches, are raised in hatcheries. Following hatchery production, the early life stage, or "seed," of oysters, clams, and geoduck may be grown in Floating Upweller Systems (FLUPSYs) or nursery rafts before being planted. Oysters, Manila clams, and littleneck clams are grown in the intertidal (Table B2). Geoduck may be grown via ground culture in the intertidal or subtidal habitat. Mussels and oysters[4] are grown in the subtidal in either rafts or longlines.

Table B2. Culture Methods for Typical Shellfish Aquaculture Species.

Species Cultured	Culture Method					
	Intertidal		Subtidal			
	Ground	Staked/Flipbag	Ground	FLUPSY*	Raft**	Longlines
Native Oysters Olympia Oyster (*Ostrea lurida*)	X	X		X		
Naturalized or Non-Native Cultivated Oysters Pacific Oyster (*Crassostrea gigas*) Kumamoto Oyster (*C. sikamea*)	X	X		X	X	X
Mussels Bay Mussel (*Mytilus trossulus*) Mediterranean Mussel (*M. galloprovincialis*)					X	X
Native Clams Geoduck (*Panopea generosa*)	X		X	X		
Naturalized Clams Manila Clam (*Venerupis philippinarum*)	X			X		

*FLUPSYs are Floating Upweller Systems used to grow shellfish "seed," or the early life stage of each species. The seed are then planted for growth until appropriate size for harvest.
**Species may be cultured in trays or from "droppers," i.e., various types of grow-out support structure (e.g., ropes, strips of mesh, socks or socking, tapes of flat material, or plastic tubes)

Figure B2 includes representative photographs of culture methods used in the State. The following sections provide more details on intertidal and subtidal culture methods.

[4] Note that oysters grown in subtidal habitat is an emerging culture method for Washington, and there is no subtidal oyster culture currently in Hood Canal. The first raft culture experiments began in 1952 in Ladysmith Harbour, British Columbia, Canada, which were modeled after culture from Japan and Norway (Quayle 1971).

Figure B2. Photos of Typical Shellfish Aquaculture Culture Methods

3.1 Shellfish Hatcheries

Washington State is the largest producer of farmed shellfish in the United States that is supported by shellfish hatcheries, accounting for 25% of the total domestic production by weight (PSI 2017). A shellfish hatchery is an upland facility used for spawning, feeding, and growing juvenile shellfish "seed" to a size suitable for transfer to FLUPSYs or floating nurseries. There are five main components related to the production of shellfish seed: (1) broodstock and larvae, (2) seed setting, (3) seed washing, (4) intake and discharge, and (5) microalgae production for larval food.

Broodstock are mature shellfish used for breeding larvae. Hatchery managers are typically participants in the disease prevention program, Shellfish High Health Program, sponsored by the Pacific Coast Shellfish Growers Association (PCSGA). Disease examination of all species cultured annually in the hatchery is conducted by a U.S. Department of Agriculture (USDA) certified Shellfish Pathologist. All import of bivalve larvae and seed are done under a permit issued by the WDFW, and exports are permitted by cooperating state or foreign governments. All species cultured are mono-culture, with their origin at a certified hatchery that cultures only species that are licensed by the state of origin.

Seed setting is when free-swimming larvae attach themselves to a surface, either a small piece of shell (single-set) or half shell (cultch). Once the seed are settled, they are called "spat." A seed washing system will prepare seed for shipment. Water is drawn through an intake from the adjacent water body where the hatchery is located. The water is passed through a filtration system for controlling suspended sediments, heated, and then passed through bins containing the larvae and shell. Once passed through these bins, the water is brought back down to ambient temperature and discharged into the water body where the intake is located. If needed, algae from the greenhouse may be added to the water as food for the larvae and spat. Since bivalve larvae are filter feeders, the water being discharged typically contains lower amounts of organic material and other detritus than the water taken into the facility.

Water quality conditions at the intakes (i.e., dissolved oxygen, suspended sediments, salinity, pH, aragonite saturation state[5]) can restrict hatchery operations. There are methods to manage some water quality issues (e.g., filtration), but it depends on the capacity of the system and the technology available.

[5]When carbonate ion concentration is high, aragonite saturation (Ω) is high; when carbonate ion concentration is low enough that Ω drops below the threshold level of 1, the biominerals begin to dissolve. Seawater with $\Omega_{aragonite} < 1$ is termed "corrosive" because it can dissolve the aragonite shells of marine organisms. This is an important consideration for hatcheries.

3.2 Shellfish Seed in FLUPSYs or Nurseries

Clam, oyster, and geoduck seed may be grown in trays suspended in FLUPSYs or placed in nurseries, prior to out-planting. The FLUPSY is an integral part of many companies' seed production systems, and is a highly efficient method for growing seed out to a larger size. This system takes advantage of the natural algae in marine water to feed and grow the seed.

A FLUPSY is an in-water, raft-like structure generally constructed of aluminum with poly-encapsulated floats for buoyancy designed to upwell nutrient-rich water through shellfish seed bins to provide a consistent source of nutrients to growing shellfish. It has a submerged trough at both ends containing a paddle wheel or small electric pump. Along the length of the FLUPSY, there are open wells containing upwelling bins where the shellfish seed is placed. The paddle wheel or pump turns and moves water out of the trough. For the trough to refill, water must pass through the upwelling bins. The bottom of the upwelling bins has 0.05 to 0.08 inches (1.2 to 1.8 mm) mesh screens, which allows water to come up through the upwelling bin and exit the bin through the troughs.

Seed is typically placed in a FLUPSY when it is approximately 0.02 to 0.08 inches (0.4 to 2.0 millimeters [mm]) in size from the hatchery, and removed when it reaches 0.2 to 0.8 inches (4.0 to 18.0 mm) to be planted in intertidal or subtidal habitats. This process takes approximately 2 to 6 months, depending on the season, local growing conditions, and species of shellfish cultured.

Intertidal nurseries are sometimes used in a process called beach hardening, which can be needed to allow the seed to gain size and strength prior to out-planting for further growth. An intertidal nursery is either cultch or single-set oysters that are placed on the ground or in bags and stacked on pallets to prevent the bottom of the stack from becoming silted in, which suffocates the seed. Seed is typically placed in nurseries to beach harden for 3 to 8 months, depending on time of year, growth, and condition of the seed.

Typical restrictions to FLUPYs and nurseries are also water quality-related, although because these are exposed to the surrounding environment without the ability to alter conditions, they are more highly dependent on consistent water quality compared to a hatchery. However, the seed is also larger and more resistant to environmental changes in a FLUPSY than a nursery.

3.3 Intertidal Oyster Culture Methods

Cultured oysters are typically planted at tidal elevations ranging from approximately extreme low tide (ELT) to +5.0 feet (ft) mean lower low water (MLLW). The oysters can be planted in any substrate type using a variety of different methods. Larger gravels will typically have on-ground culture while smaller substrate types (e.g., sand or small gravel) will have bags. Oyster seed is placed in 0.08- to 0.3-inch (2- to 8-mm) mesh bags or on-bottom without bags and without predator protection netting. When bags are used, they are strung together and staked to the ground or raised above the sediment surface on longlines.

Oysters typically remain in bags during the nursery phase (usually 1 year) until they reach about 3 inches in size. Depending on growth rate, oysters may be removed from the bags and spread directly onto the tidelands and allowed to mature and harden. Oysters may also remain in grow-out bags until ready to harvest. Removing the oysters from the bags and placing them on the ground typically occurs weekly until all oysters are placed on the ground.

Once the oysters are mature, they are handpicked during low tide either by forking oysters into tubs or pulling bags and removing them from the site by boat. Oysters take approximately 6 to 36 months to grow, depending on the size required, the grow-out system utilized, and the season the animal is placed on the farm. Harvesting occurs throughout the year.

Typical habitat requirements for the oysters used in intertidal operations are discussed in Section 2.1 of the main report. Sub-adult and adult oysters are more resistant to environmental changes compared to earlier life stages, but there are thresholds related to the ability of these species to tolerate changes. In general, intertidal oyster operations are sensitive to changes in salinity concentrations, sediment burial, suspended sediment concentrations, and water quality conditions.

3.4 Intertidal Clam (Cultured) Culture Methods

Clams are typically planted at tidal elevations ranging from approximately ELT to +5.0 ft MLLW. Clams are generally planted in areas with small or pea-sized gravel. Clam seed is spread directly onto the tidelands. Commercial clam beds are covered by securely staked predator exclusion nets, which are placed directly on the sediment surface (i.e., no vertical relief) and secured every 8 to 10 ft along the perimeter with U- or J-shaped stakes. Clams take approximately 24 to 36 months to grow, depending on the intended market size and growing conditions. Harvesting occurs throughout the year.

Typical habitat requirements for the clams used in intertidal operations are discussed in Section 2.1 of the main report. Similar considerations as for oysters hold true for Manila clams in terms of sensitivities to habitat changes.

3.5 Intertidal Geoduck Culture Methods

Intertidal geoducks are typically planted at tidal elevations ranging from approximately ELT to +3.0 ft MLLW, although there are some farms planted up to +5.0 ft MLLW with lower survival. Geoducks are generally planted in sandy substrate with minor fractions of silt. Geoduck seed are highly vulnerable to predation because they are not of a size or at a depth in the sediment that would provide adequate protection. No active predator removal is performed. Predator control is achieved through exclusion by planting geoduck seed into culture tubes. The ability to have a variety of predator exclusion options (e.g., different culture tube designs) available allows the grower to adapt to site-specific conditions.

There are two types of culture tubes currently available: polyvinyl chloride (PVC) tubes and flexible mesh tubes (made of high-density polyethylene – HDPE). Culture tubes range from 4 to 6 inches in diameter, and extend approximately 3 to 5 inches from the sediment surface. If PVC tubes are used, either an individual predator net is affixed to the top of the tube with a rubber band designed for marine application or a predator exclusion net is affixed over the entire plot. Flexible mesh tubes are shaped like a diamond, which allows the grower to install the tubes into the prevailing direction of sediment transport. Predator exclusion nets are not used when flexible mesh tubes are present. Flexible mesh tubes are maintained for 3 years. Alternatives to culture tubes also exist, but are not very prevalent as a current culture method. One example is net tunnels made from 4-ft-wide rolls of polyethylene net placed over a rebar frame (Figure B3). Net tunnels are also in place for approximately 2 to 3 years of a 5- to 7-year culture cycle. When tubes and nets are removed, there is no gear present in the culture plot, and it may not be obvious that there is a shellfish operation present other than high-density geoduck present in the intertidal habitat. Harvest occurs after the 5- to 7-year grow-out cycle, and can occur in any month depending on market conditions.

Figure B3. Geoduck Tunnel Net over Rebar Frame
Source: Dewey 2013 (*as cited in* Corps 2015)

Typical habitat requirements for the geoducks used in culture operations are discussed in Section 2.1 of the main report. Because geoducks burrow up to approximately 36 inches in the sediment, they are more resistant to burial and can use their burrowing ability to survive short-term environmental changes. However, they are extremely sensitive to changes in salinity, which can affect both survival and quality of the product.

3.6 Subtidal Geoduck Culture Methods and Wildstock Harvest

Subtidal geoduck aquaculture uses similar predator protection methods to intertidal geoduck aquaculture (see above). The main difference is that subtidal culture methods typically use only individual predator nets affixed to the top of the subtidal tube with a rubber band designed for marine application. Comparatively, intertidal culture methods will use either individual nets or a predator protection net that covers a large area of tubes in the intertidal. There are also wildstock geoduck resources within subtidal habitats (also called geoduck tracts) which can be harvested between -18 ft and -70 ft MLLW. There are some exceptions to these harvest depths, including avoidance of eelgrass habitat and Pacific herring habitat (WDFW 2017). Harvest and planting are performed by divers, and follow the timing associated with intertidal geoduck culture methods.

Typical habitat requirements for geoducks used in subtidal geoduck operations or the wildstock population that is harvested are discussed in Section 2.1 of the main report. Similar sensitives would be relevant for subtidal operations as for intertidal. However, subtidal habitat is harder to change from upland or nearshore activities, although these resources can still be sensitive to major habitat shifts.

3.7 Subtidal Mussel Culture Methods

Mussels are typically grown on two different overwater structures: rafts and longlines. Raft platforms are typically constructed of lumber, galvanized steel, aluminum, and plywood. Flotation is generally made from reclaimed polyurethane food-grade barrels, or coated or vinyl-wrapped polystyrene foam. Raft structures and longlines are anchored in place, frequently with concrete anchors attached with nylon or polypropylene line. Rafts are not a solid surface, but rather mostly open on top with cross beams that create "wells" from which lines suspend. Rafts may be periodically wrapped with nets to exclude predators.

Surface longlines are typically made of heavy polypropylene or nylon rope suspended by floats or buoys attached at intervals along the lines and anchored in place at each end. Anchors are frequently made of concrete, and floats are either foam filled or recycled food-grade containers. Mussels take approximately 16 months to grow, depending on the intended market size. Harvesting occurs throughout the year.

Typical habitat requirements for the mussels used in culture operations are discussed in Section 2.1 of the main report. Water quality, temperature, and salinity concentrations are the main habitat requirements for subtidal mussel operations. Mussels are especially sensitive to changes in temperature.

3.8 Subtidal Oyster Culture Methods

Raft-grown oysters are primarily destined for the half-shell market. Rafts are typically constructed of lumber beams or aluminum of three different sizes to accommodate stacks of trays (Figure B4). Rows of flotation structures sit underneath the length of each raft, and a fir or aluminum walkway sits on top of the floats. The entire system is anchored to the bottom, much like a mussel raft. Seed trays are in stacks of about 7 to 15 trays, depending on the type of tray used, and held together with "drop line" so that the stack can be pulled out of the well by a crane. Growth, harvesting, and restrictions are discussed above. Water quality, temperature, and salinity concentrations are the main habitat requirements for subtidal oyster operations.

Figure B4. Representative Oyster Raft Seed Trays in a Stack
Source: BCSGA 2015
Notes: Employee is standing on a walkway board and guiding a stack of oyster trays (i.e., drop line) out of a tray well.

4.0 EXISTING CHALLENGES TO SHELLFISH RESOURCES

There are other emerging challenges to shellfish resources within the State. The main concerns include ocean acidification (OA), as well as degrading water and sediment quality conditions.

4.1 Ocean Acidification (OA)

OA is a progressive increase in the acidity (or decrease in pH) of the ocean over an extended period caused primarily by the uptake of CO_2 from the atmosphere by the ocean (WSBRP 2012). Current research indicates that some species, such as Pacific oysters, are more sensitive to OA compared to species such as Olympia oysters (Waldbusser et al. 2016). Lower pH increases dissolution rates of oyster shell or reduces the ability of oysters to lay down shell material (Waldbusser et al. 2011a, 2016). In extreme cases, OA results in total loss of the shell and mortality of organisms, primarily at the earliest life stages when shell is just being formed. For shell-building species, such as shellfish, loss of shell material can be catastrophic to the population as well as to entities that depend on shellfish resources.

According to Waldbusser et al. (2011b), "estuarine waters are more susceptible to acidification because they are subject to multiple acid sources and are less buffered than marine waters." Seagrasses have been shown to raise pH values and provide some buffering capacity to the surrounding waters (Beer et al. 2006, Horwith 2015). New research out of San Quintín Bay indicates that eelgrass, in association with oyster aquaculture, appears to be able to incorporate more ammonium (NH_4^+) into the shoots compared to shoots from meadows without aquaculture (Sandoval-Gil et al. 2015, 2016). In these small study plots, this has resulted in higher vegetative production, biofiltration of oyster biodeposition, and buffering capacity for OA. This research indicates that the combination of eelgrass and oysters appears to be mutually beneficial.

The presence of eelgrass and shell material is mutually beneficial to water quality in the ability to provide buffering capacity from corrosive waters to live shellfish, especially juveniles. The co-occurrence of shellfish plots and eelgrass may provide a certain amount of benefit for both organisms, although most benefit is likely being provided to the shellfish themselves. Given the importance of OA effects to shellfish resources, this may be an area of future collaboration for salmon habitat restoration and shellfish interests.

4.2 Degrading Water and Sediment Quality Conditions

Water and sediment quality is influenced by the surrounding habitat as well as historical uses, and numerous factors can affect the overall quality. Some of the more common sources of poor water or sediment quality include failing on-site septic systems, elevated average rainfall and stormwater runoff that includes contaminant and nutrients, presence of livestock and upland farming, timber harvest, increased impermeable surfaces and other urban development, and mining/gravel operations (Dethier 2006). Poor water or sediment quality conditions can affect all water-dependent activities, including cultural, recreational, and commercial shellfish harvest. Due to the recognized value of shellfish in Washington, there are many examples throughout the State where poor environmental conditions for shellfish harvest have created opportunities and funding mechanisms to improve the main sources of degraded conditions (e.g., Port Gamble Bay, Dungeness Bay, Burley Lagoon). In this way, both salmon habitat restoration and shellfish activities are well aligned in terms of the overall goals for the habitat.

4.2.1 Water Quality

There are at least two authorities that classify water quality in the State: (1) Ecology under the federal Clean Water Act and through its 303(d) list, and (2) the Washington Department of Health (WDOH) Shellfish Growing Area Program. The Ecology 303(d) assessment measures several factors such as temperature, dissolved oxygen, bacteria, and heavy metals. The WDOH water quality assessment focuses on fecal coliform. Regular updates on the 303(d) list are provided through Ecology (2017a) and updates on the classification of shellfish growing areas are provided through WDOH (2017).

WDOH has five classifications for Commercial Growing Areas: Approved, Conditionally Approved, Restricted, Prohibited, and Unclassified. Prohibited is defined as, "when the sanitary survey indicates that fecal material, pathogenic microorganisms, or poisonous or harmful substances may be present in concentrations that pose a health risk to shellfish consumers. Growing areas adjacent to sewage treatment plant outfalls, marinas, and other persistent or unpredictable pollution sources are classified as Prohibited. Commercial shellfish harvests are not allowed from Prohibited areas" (WDOH 2017). It is notable that the WDOH classification of Prohibited does not exclude all types of shellfish aquaculture. Since the WDOH prohibition is only in relation to harvest, shellfish "seed" can be raised in nursery systems (e.g., FLUPSYs) in areas that are classified as Prohibited by DOH because juvenile shellfish can be transferred and later harvested in Approved areas because bacteria do not persist in shellfish once they are transferred to areas with good water quality.

Shellfish activities are inherently reliant on the maintenance of good water quality conditions to ensure the safety and survival of the shellfish products. As stated above, projects that address water quality conditions are naturally aligned with shellfish resources.

4.2.2 Sediment Quality

There are also programs to assess sediment quality, including the Puget Sound Ambient Monitoring Program (PSAMP) run by Ecology and the National Oceanic and Atmospheric Administration (NOAA). Based on sampling for toxicity, chemical contamination, and infaunal assemblages, sediments are classified as Unimpacted, Likely Unimpacted, Possibly Impacted, Likely Impacted, Clearly Impacted, and Inconclusive (Ecology 2017b). Both Ecology and the Environmental Protection Agency (EPA) are involved in tracking and controlling toxic cleanup sites. There are three Superfund or major cleanup sites listed in the Hood Canal area: Port Gamble Bay, Port Hadlock, and Bangor (Ecology 2016, EPA 2017). There are other Brownfields Properties listed by EPA (2017), which also include cleanup activities.

Projects that disrupt sediment can result in exposure of shellfish to toxicity, chemical contamination, or changes to substrate conditions. There are two examples, and potential solutions, that can be used to highlight these concerns: Port Gamble Bay and Johns Creek.

Port Gamble Bay is a site that requires maintenance dredging to allow for boat access, and is also the site of a major sediment cleanup from legacy contamination at a former sawmill site (Ecology 2016). In October 2003, dredging activities were conducted and coincident with this timing was a paralytic shellfish poisoning (PSP) outbreak[6] that exceeded 3,000 µg/100g of PSP toxins. Dredging activities occurred again in 2004 and 2006 during cleanup activities, and again there were PSP outbreaks. According to Tamara Gage (pers. comm., 2017), the shellfish manager for the Port Gamble S'Klallam Tribe, dredging was the only activity in the bay that was coincident with the PSP outbreaks. While it is hard to establish a direct link between sediment disturbing activities and PSP outbreaks, enough doubt was raised based on local observations to change the timing of dredging operations. Dredging operations were moved to winter months to avoid the two key factors known to lead to PSP outbreaks: temperature and nutrients (Ebbesmeyer et al. 1991, Anderson 1997, Joyce 2003). Other concerns related to PSP have been raised for Quilcene Bay and elsewhere in Hood Canal (see Suhrbier and Cheney 2015). Although it is hard to identify a root cause for any individual PSP outbreaks, including shellfish experts and individuals with local knowledge of these systems during the early stages of project development can benefit projects by avoiding or minimizing risk.

4.2.3 Susceptibility to Disease and Parasites

Maintaining acceptable water and sediment quality to support shellfish populations and allow for harvest activities is an ongoing challenge, especially with the continued growth of shoreline communities. Related to habitat quality changes is the susceptibility to disease and parasites. Changes in habitat conditions can cause physiological stress, which make them more susceptible to ever present threats (Dethier 2006). Good habitat quality is a shared goal for both salmon restoration and shellfish resource interests, and may be a valuable approach for future collaboration.

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[6]A PSP outbreak is a harmful algal bloom that contains a biotoxin called saxitoxin, which is what is measured during a PSP outbreak. The organisms that produce biotoxins that cause PSP can concentrate in filter-feeding shellfish, and then humans that eat the contaminated shellfish get infected. The causative agent of PSP in Puget Sound is assumed to be *Alexandrium catenella*; although, there are five other *Alexandrium* species that occur within West Coast estuaries, which have an unknown influence on PSP occurrence (Horner et al. 1997). The phase specifically related to PSP outbreaks is when cysts germinate to a vegetative (motile) stage (Anderson 1997, Joyce 2003, Hubert et al. 2007). Cysts remain dormant in bottom sediments until conditions are right for germination and growth of the vegetative stage. There are many environmental factors that have to work in conjunction to trigger cyst germination and toxic blooms, these include: (1) resuspension of cysts, (2) warming water temperatures, (3) increases in nutrients, (4) decreases in salinity, (5) increases in sunlight, and (6) oxygenation (Anderson 1997, Joyce 2003). The two most important factors in PSP outbreak are temperature and nutrients.

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Appendix C
Guidance and Recommendation Checklists

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GUIDANCE AND RECOMMENDATION CHECKLISTS

The following checklists of questions are based on the 5-step process described in Section 4.0 of the Synthesis Report:

Step 1: Identify Project Effects

Salmon Project Questions	Answer/Checklist			
	Yes	No	Don't Know	Note/Comment
Will the proposed type of action(s) lead to changes that alter conditions in the estuary (delta) or marine nearshore?				
If so, will the proposed type of action(s) potentially change any of the following conditions in the river estuary (delta) or marine nearshore? Refer to Tables 4, 5, and 6 for information.				
Channel Migration in Delta				
Water Quality (e.g., Salinity, Turbidity)				
Sediment Supply, Transport, and Deposition				
Sediment Size				
Contaminants or Toxins				
Freshwater Flow Rates				
Is there known or observable shellfish, or shellfish aquaculture gear, in the estuary or surrounding marine nearshore? Note: Shellfish aquaculture gear may include bags, stakes, PVC pipes, floating rafts, or known water intake for aquaculture in the area. See Appendix B for pictures of some of these gear types.				
In estuary (delta)				
In surrounding nearshore				
If yes, which of the following types of shellfish resources or harvest activities occur in the estuary and surrounding marine nearshore?				
Natural populations, unknown if any harvest occurs				
Public				
Tribal				
Commercial				
If there are public shellfish resources, will access to harvest areas be impacted or will the action shift harvest pressure to a new location?				
Are there any other restoration activities in the area, or known plans for activities (e.g., salmon habitat or Olympia oyster habitat)?				
Based on the answers above, does the proposed project potentially affect shellfish resources in the estuary and marine nearshore?				

Step 2: Identify the Magnitude and Timing of Potential Effects

Salmon Project Questions	Answer/Checklist			
	Yes	No	Don't Know	Note/Comment
Is the estuary or surrounding marine nearshore open for harvest according to DOH? https://fortress.wa.gov/doh/eh/maps/biotoxin/biotoxin.html				
If yes, what is the quality of shellfish habitat based on DOH criteria?				
Approved				
Conditionally Approved				
Restricted				
Prohibited				
Are any of the following shellfish species present in the estuary or surrounding marine nearshore?				
Olympia oysters				
Naturalized or cultured oysters (e.g., Pacific, Kumamoto)				
Other oyster species/unidentified species				
Mussels				
Geoducks				
Non-native clams (e.g., Manila, purple varnish)				
Native clams (e.g., littlenecks, butter clams, cockles)				
Other clam species/unidentified species				
Salmon Project Questions	**Positive for Bivalves**	**Negative for Bivalves**	**Don't Know**	**Note/Comment**
Of the project effects identified above, what is the expected short-term (<5 years) effect?				
Channel Migration in Delta				
Water Quality (e.g., Salinity, Turbidity)				
Sediment Supply, Transport, and Deposition				
Sediment Size				
Contaminants or Toxins				
Freshwater Flow Rates				
Of the project effects identified above, what is the expected long-term (>5 years) effect?				
Channel Migration in Delta				
Water Quality (e.g., Salinity, Turbidity)				
Sediment Supply, Transport, and Deposition				
Sediment Size				
Contaminants or Toxins				
Freshwater Flow Rates				
Of the shellfish species identified above, what is the expected short-term (<5 years) effect?				
Olympia oysters				
Naturalized or Cultured oysters (e.g., Pacific, Kumamoto)				
Other oyster species/unidentified species				
Mussels (e.g., bay, Mediterranean, blue mussel)				
Geoducks				
Non-native clams (e.g., Manila, purple varnish)				
Native clams (e.g., littlenecks, butter clams, cockles)				
Other clam species/unidentified species				

Salmon Project Questions	Answer/Checklist			
	Yes	No	Don't Know	Note/Comment
Of the shellfish species identified above, what is the expected long-term (>5 years) effect?				
Olympia oysters				
Naturalized or cultured oysters (e.g., Pacific, Kumamoto)				
Other oyster species/unidentified species				
Mussels (e.g., bay, Mediterranean, blue mussel)				
Geoducks				
Non-native clams (e.g., Manila, purple varnish)				
Native clams (e.g., littlenecks, butter clams, cockles)				
Other clam species/unidentified species				

Step 3: Identify Shellfish Stakeholders

Stakeholder Group	Organization	Contact Information Website*
County	Mason County	http://property.co.mason.wa.us/Taxsifter/Search/Results.aspx
County	Jefferson County	http://www.co.jefferson.wa.us/assessors/parcel/ParcelSearch.asp
County	Kitsap County	https://psearch.kitsapgov.com/pdetails/default.aspx
Agency	Office of Governor Jay Inslee (Washington Shellfish Initiative)	http://www.governor.wa.gov/issues/issues/energy-environment/shellfish
Agency	Washington Department of Fish and Wildlife (WDFW)	http://wdfw.wa.gov/about/contact/edirectory/
Agency	Washington State Department of Ecology (Ecology)	http://www.ecy.wa.gov/programs/sea/sma/contacts/regional.html
Agency	Washington State Department of Natural Resources (DNR)	http://www.dnr.wa.gov/contact-us
Growers	Pacific Coast Shellfish Growers Association (PCSGA)	http://pcsga.org/contact/
Growers	Washington Department of Health (DOH) Shellfish Growers	http://www.doh.wa.gov/CommunityandEnvironment/Shellfish/CommercialShellfish
Tribe	Jamestown S'Klallam Tribe	http://www.jamestowntribe.org/programs/nrs/nrs_staff.htm
Tribe	Point No Point Treaty Council	http://www.pnptc.org/Staff_Directory.html
Tribe	Port Gamble S'Klallam Tribe	https://www.pgst.nsn.us/tribal-programs/tribal-services/natural-resources/contact-natural-resources
Tribe	Skokomish Tribe	http://www.skokomish.org/natural-resources/
Tribe	Suquamish Tribe	https://suquamish.nsn.us/home/departments/natural-resources/
Research	Pacific Shellfish Institute (PSI)	http://pacshell.org/about-us.asp
Research	Washington Sea Grant	https://wsg.washington.edu/about-wsg/contact-us-2/
Restoration	Puget Sound Restoration Fund	http://www.restorationfund.org/about/staff
*This information may shift with time, and the HCCC can serve as a valuable resource for up-to-date information.		

Step 4: Communication and Outreach

Salmon Project Questions	Answer/Checklist			
	Yes	No	Don't Know	Note/Comment
Is the parcel number and owner name known for the site? If yes, add the number(s) and name(s) in the notes/comment section.				
If the land owners and adjacent land owners were notified of the project, was there a response? If yes, add the name(s) in the notes/comment section.				
Does the land owner, or adjacent land owner, want to be involved? If yes, add the method for contacting and desired frequency in the notes/comment section.				
Are there public lands present in the action area that are co-managed by the tribes and WDFW?				
If yes, is it known which tribes have treaty rights? If yes, add the name(s) in the notes/comment section.				
If a tribe/WDFW was contacted, was there a response provided by a shellfish biologist on the project? If yes, add the name(s) in the notes/comment section.				
Does the shellfish biologist want to be involved? If yes, add the method for contacting and desired frequency in the notes/comment section.				
Are there commercial aquaculture activities in the action area?				
If yes, is it known what company or companies are active in the area? If yes, add the name(s) in the notes/comment section.				
If a grower was contacted, was there a response by the grower on the project? If yes, add the name(s) in the notes/comment section.				
Does the grower want to be involved?				
If yes, add the method for contacting in the notes/comment section and desired frequency.				
If no, but an alternative grower was suggested, add the method for contacting in the notes/comment section and desired frequency.				
Are there shellfish restoration activities in the action area?				
If yes, was WDFW notified of the project?				
If yes, is it known what organization or organizations are active in the area? If yes, add the name(s) in the notes/comment section.				
Does the restoration specialist want to be involved? If yes, add the method for contacting in the notes/comment section and desired frequency.				
Are there things that the shellfish stakeholders would like to know about the restoration project? If yes, list them in the notes/comments section.				

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