FINAL REPORT TO THE HOOD CANAL COORDINATING COUNCIL ON:

ADVANCING A CUSTOM-FIT STRATEGY FOR RESTORATION OF OLYMPIA OYSTERS IN HOOD CANAL

AS PART OF THE HOOD CANAL SHELLFISH INITIATIVE

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Cover photos: Top - Quilcene Bay tidelands, looking north (credit: Jackelyn Garcia); bottom left – outplanted Olympia oyster on Pacific oyster shell (credit: PSRF); bottom right – students from Catalyst Public Schools at Klingel-Bryan-Beard Wildlife Refuge (credit: Great Peninsula Conservancy)

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EXECUTIVE SUMMARY

Our region's native oyster – the Olympia oyster, *Ostrea lurida* – once covered large swaths of portions of Puget Sound's intertidal shorelines, including several in Hood Canal. The oyster beds formed by clusters of these small oysters served as habitat for a host of species in the marine ecosystem, with the oysters themselves keeping water clean through filtration and serving as a food source for humans and other inhabitants. However, overharvest and impacts from pollution and urbanization took their toll on Olympia oyster populations, to the point of severe depletion. Nevertheless, these oysters are persistent and with boosts from restoration efforts throughout Puget Sound over the last 20+ years, populations in certain waterbodies are rebounding. And with oyster rebuilding efforts come opportunities to engage people in the region in restoration actions, appreciation of shellfish, and marine stewardship.

In Hood Canal, Washington Department of Fish and Wildlife (WDFW) identified two water bodies in which to focus Olympia oyster rebuilding efforts. These areas – 1) Quilcene Bay in the northern portion of the Canal, and 2) Union River/Big and Little Mission Creek(s) deltas (UR/MC) area in southern Hood Canal near Belfair – were historical hotspots for Olympia oysters, and places where investments in rebuilding are expected to be most effective. In addition to these two areas, WDFW recommends that restoration work in the southern portion of Hood Canal should consider including secondary restoration sites south of Ayock Point to enhance gene flow. The task, then, is to custom-fit restoration strategies and actions to those places to rebuild Olympia oyster populations and the structured habitat they provide in their developed and persistent assemblages.

In 2021, through funding made available in support of the Hood Canal Shellfish Initiative Action Plan (led by the Hood Canal Coordinating Council - HCCC), an opportunity arose to make substantial progress on Olympia oyster restoration in Hood Canal, while building support for restoration actions through education and outreach. Puget Sound Restoration Fund (PSRF), with support from the Great Peninsula Conservancy (GPC), the Skokomish Indian Tribe, and Washington Department of Fish and Wildlife (WDFW), was able to make substantial progress to develop and take initial steps towards implementation of a plan for Olympia oyster restoration in Hood Canal. As described in this report, the team has developed a stepwise, systematic approach for assessment of Olympia oyster restoration opportunities in the priority waterbodies and other locations in Hood Canal, compiled and synthesized several sources of existing knowledge and collected additional data, and created restoration recommendations for the priority waterbodies. In addition, the team – led by GPC – developed an education module on native oyster restoration, including a field component, and hosted a public event to showcase native oysters and the Hood Canal Shellfish Initiative.

The investment by HCCC in this project is key for development and implementation of a Hood Canal-specific Olympia oyster restoration plan (HCSI Action Plan Action 6.B.1). By identifying restoration actions that are custom-fit to priority sites, providing guidance for additional restoration, and performing education and outreach with partners, the team has laid critical groundwork for facilitating restoration of native Olympia oyster populations in Hood Canal (Action Plan Objective 6). Finally, restoring Olympia oysters and the habitat they provide, and connecting people to the oyster's story and its stewardship is at the core of the HCSI's goal, "to support and expand Hood Canal's thriving shellfish resources by identifying coordinated and mutually beneficial strategies and actions that honor tribal treaty rights, build resilience, pursue ecosystem protection and restoration, and support careful stewardship of commercial shellfish activities and recreational harvest now and into the future."

Project Outcomes

The project has yielded the following outcomes, all of which are described fully in the body of the report:

- Developed a comprehensive approach to Olympia oyster restoration in Hood Canal created in collaboration with key stakeholders, taking the form of a revised and expanded Olympia Oyster Restoration Assessment Pathway;
- Summarized and compiled existing data and model results related to Olympia oysters in Hood Canal;
- Collected new data from Quilcene Bay and southern Hood Canal (Lynch Cove, including Union River/Big & Little Mission Creek) needed to guide in-water restoration actions, following Part 1 of the 3-part Assessment Pathway;
- Analyzed lessons learned from similar restoration projects;
- Crafted custom-fit recommendations for next steps for Olympia oyster restoration in Quilcene Bay and southern Hood Canal (Lynch Cove, including Union River/Big & Little Mission Creek);
- Showcased the Hood Canal Shellfish Initiative and the project at a GPC Hahobas Shoreline Walk and Talk given by PSRF Habitat Research Director Hilary Hayford;
- Led by GPC's Land Labs, formulated and implemented an Olympia oyster restoration education module and curriculum, including field component, with middle-school students from Catalyst Public Schools;
- Featured the project, with a focus on the education module and field trip, on an episode of KPTZ's Coastal Café, in blog posts, and on social media;
- Created a catalog of project photos to document field work and outreach/engagement activities; and
- Wrote the Quality Assurance Project Plan.

Findings and Recommended Actions

Olympia oysters have a contemporary presence in Hood Canal, with self-sustaining populations in several places, particularly sites in the central waterway north of Ayock Rock. However, in the two WDFW priority areas that were the focus of this project – Quilcene Bay and southern Hood Canal (Lynch Cove, including Union River/Big & Little Mission Creek) – most of the available habitat at sites of historical abundance remains unoccupied by Olympia oysters. Some current limitations to the development of self-sustaining populations are clear, such as lack of appropriate substrate, whereas others require further study, such as potential changes in circulation patterns compared to historic conditions. The recommendations below for the two WDFW priority rebuilding areas (and sites south of Ayock Point) include those that we consider suitable for immediate action, as well as in-depth studies critical to effective, targeted restoration of Olympia oysters in Hood Canal.

As a precursor to our place-based recommendations, we want to emphasize the importance of continued collaboration and communication among interested parties, community groups and non-profits (e.g., Great Peninsula Conservancy, Jefferson County Marine Resource Committee, Hood Canal Salmon Enhancement Group), resource managers (e.g., Tribes, WDFW), commercial shellfish growers, and the general public, such as on this project; these partnerships are paramount to successful Olympia oyster rebuilding efforts. Continued commitment to efforts such as recruitment index monitoring, environmental monitoring, and refinement of restoration strategies are all valuable contributions to long-term population and habitat recovery.

Southern Hood Canal (Lynch Cove, including Union River/Big & Little Mission Creek)

Olympia oysters are absent in the eastern Lynch Cove region – both adults and as larvae. Evidence suggests that while larvae are not present here, restricted movement of water between Lynch Cove and the rest of Hood Canal could help to entrain any larvae that did originate from that region.

To re-establish a persistent adult Olympia oyster population in the Lynch Cove area, we recommend recurring seeded cultch (conservation-hatchery produced seed settled on shell hash) enhancements over consecutive years. Iterative enhancements will build the oyster population while maintaining genetic diversity, and provide needed substrate at lower tidal elevations (below hummocks of Pacific oyster). The historic Clifton Oyster Reserve in Lynch Cove may make such a project eligible to propose for USDA funding. The following sequential actions should be taken:

1. Permit applications should be initiated both for 1) small-scale seeded cultch assays, and 2) to authorize population enhancements.
2. Seeded cultch assay plots should be established at several locations in the Lynch Cove vicinity.
3. Plots should be monitored for growth and survival of spat and retention of emergent shell over more than one winter season to inform final location of the enhancement site.
4. Coincident with seeded cultch assay monitoring, data collection on salinity, predator abundance, and oyster recruitment should occur, to help refine which test site is ultimately selected.
5. Upon final enhancement site selection, begin the first of five consecutive years of Olympia oyster seed production (following conservation genetics protocols as used at the Kenneth K. Chew Center for Shellfish Research and Restoration) to introduce Olympia oyster seeded cultch that will amount to, in total, 500,000 - 1,000,000 adult Olympia oysters.
6. Continue to monitor 1) Olympia oyster recruitment, and 2) development of the adult population both inside and outside of the enhancement area at reference locations with remnant populations (e.g., Twanoh State Park, Belair Cove, Tahuya) so as to facilitate comparison of control to treatment. This monitoring is essential so that restoration actions can be improved upon, boosting their efficacy.

To enhance gene flow at secondary restoration sites south of Ayock Point, we recommend 1) further assessment of the hydrodynamic regime and oyster resources; and 2) adult broodstock enhancement through conservation aquaculture (in regions east of Sister's Point only).

Further assessment of the hydrodynamic regime and oyster resources. This effort would be valuable to conduct for the entire lower canal, from Ayock Point to the Union River, to build on the information presented in this report. In particular, we suggest more robust assessment of the hydrodynamic connectivity, vectors and residence time from the main basin to the east arm, east of Sister's Point. For the Olympia oyster resource and demographics, we recommend continuing to identify and characterize additional source populations, larval distribution, and monitor recruitment at several stations along the east arm.

Adult broodstock enhancement through conservation aquaculture. We recommend exploration of the efficacy of broodstock enhancement via conservation aquaculture, whereby cultivated adult Olympia oysters are contributing to the larval pool for the years during which they are reproductive but before harvest. Two forms of conservation aquaculture for Hood Canal are 1) shellfish gardens, and 2) small-scale commercial Olympia oyster farming, specifically to support the Skokomish Tribe and potentially other Treaty Tribes in lower Hood Canal (Port Gamble S'Klallam, Jamestown S'Klallam, and Lower Elwha Klallam). While conservation aquaculture has been posited to contribute to population rebuilding, the idea has not yet been robustly tested. To truly test viability of conservation aquaculture, specific in-water activities must be paired with study of larval production and juvenile recruitment to the larger meta-population of lower Hood Canal. We recommend design and implementation of a study to detect the magnitude of positive impact of conservation aquaculture on stock rebuilding in lower Hood Canal between Annas Bay and Lynch Cove. WDFW has shown support for testing some forms of conservation aquaculture as a rebuilding strategy for the east arm of lower Hood Canal between Annas Bay and Lynch Cove. And the Skokomish Tribe has shown interest in coordinating outplant on their tidelands and with private tideland owners.

Quilcene Bay

Olympia oysters are present along much of the Quilcene Bay shoreline, but the biogenic oyster bed habitat that Olympia oysters form is not. Persistent populations of adults and high numbers of juvenile recruits are found near in the southern portion of the Bay, near to where it connects with the rest of the Canal. This, however, was not the historic location of Olympia oyster populations nearer to the head of the Bay. In the near-term, the top priority is to discern which stressors are preventing Olympia oyster recolonization. After gaining that understanding, targeted enhancement actions can be undertaken, as described further in the full report, and with greater confidence that they will contribute to population rebuilding. We have identified regions of interest where state and tribal resource managers would like to rebuild Olympia oyster habitat and efforts by PSRF, WDFW, the Jefferson County MRC to restore Olympia oysters in the Bay have been informative. The key missing piece is understanding to where larvae from adult broodstock are advected.

To increase likelihood of successful restoration of Olympia oyster habitat in Quilcene Bay, we recommend beginning with an analysis of circulation and hydrodynamic model outputs or collecting data de novo. These data should help address why, despite production of larvae by adult oysters at the mouth of the Bay, recruitment is very low at the head of the Bay especially in areas west of the Quilcene River with highly suitable habitat and very good substrate. If circulation models and recruitment index assays continue to suggest that larvae are not advected to the head of the bay, we recommend considering stock enhancement.

Background & context

The Olympia oyster, its decline, and efforts to restore

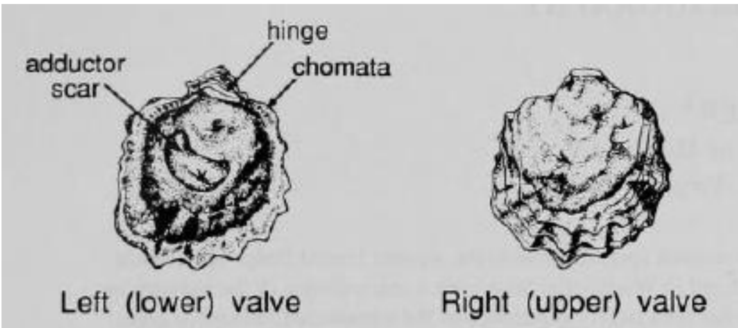

Figure 1. Illustration of the Olympia oyster, *Ostrea lurida*, from Baker 1995

The Olympia oyster, *Ostrea lurida*, is the only oyster native to Washington. Found along the Eastern Pacific from Baja California, Mexico to British Columbia, Canada. The Olympia oyster is a relatively small oyster, with the maximum size of adults near 6 cm in shell height (the greatest distance across the shell from hinge to shell margin), that is typically elliptical or circular in shape and not deeply cupped (Fig. 1, Baker 1995). Developed populations of Olympia oysters can form multiple year-class clusters in unconsolidated assemblages, which form low-relief reefs (a.k.a. beds) that add three dimensional structure to intertidal shorelines.

The Olympia oyster is monoecious with each individual producing both sperm and eggs sequentially alternating throughout the animal's life, though only one type of gamete is spawned at any point in time. It has a meroplanktonic life history; after fertilized embryos are brooded in the mantle cavity for 1-2 weeks, larvae spend several days to several weeks in the water column before settling on benthic shorelines (see overviews in Baker 1995, Wasson et al. 2014). A small percent of larvae survive to settlement and fewer still to adulthood - estimated at 3% alive at 6 months of age (Baker 1995). This life history has important implications for oyster populations. First, larvae arriving onshore may have been produced locally or may have traveled for multiple weeks, therefore currents play a large role in both population growth and genetic mixing, and it's possible for sites lacking an Olympia oyster population to receive sufficient larval input from source populations outside the immediate vicinity. Additionally, without separate sexes, reproductive capability of the population is not affected by settlement in specific sex ratios. Providing the right environment for larvae to naturally settle on shore is therefore a smart approach to restoration and comprises a large proportion of current actions.

Historic Olympia oyster beds occupy areas within water bodies that host a suite of characteristics that include protracted water residence, a low disturbance exposure, a lower littoral bench with a low slope/grade and are often associated with a low to moderate volume of terrestrial inputs [creek/river] that maintain the alluvial tideland. These can be large spaces where the oyster bed distribution included elevations near MLLW and extending to near ELW, in the lower and fringe littoral tideland. These historic oyster beds were an unconsolidated complex of relic shells, incorporated with the benthos, and a veneer population composed of multiple year-classes numbering in the millions. These populations were resilient in their numbers; weathering mortality events but facilitated by gregarious settlement on abundant settlement substrate.

Several compounding stressors led to a dramatic decline in abundance in Puget Sound, beginning with early commercial oyster fisheries in the mid-1800s, and including impacts of pulp mills, urbanization, and the alternate use of tidelands once Olympia oysters had been removed (Blake & Bradbury 2012). Once populations and associated settlement structures decline, Olympia oyster beds are unlikely to reestablish on their own in historic locations as larvae must be delivered from adjacent source populations. Absent the developed oyster bed, and the population that maintains it, there is no source for larvae or settlement substrate to receive it. In the absence of the Olympia oyster bed, these spaces return to unstructured tidal flats, or can also be occupied by eelgrass (*Zostera marina*) encroaching from a lower existing distribution. Changes to the watershed and shorelines that alter sedimentation and channel stream flows also affect the characteristics of tidelands that we encounter today.

Olympia oyster restoration efforts in the U.S. and Canada began in 1999 with actions taken by Puget Sound Restoration Fund (PSRF). PSRF's approach is to rebuild dense, breeding populations in historical areas of abundance, to restore structured oyster bed habitat and ecosystem services that dense accumulations of living oysters provide. We use historic locations as a guide based on conditions unique to those locales. We study these and assess limiting factors and address those through our manipulations, follow evidence and monitor outcomes to improve our practice. The goal is ultimately to recover an imperiled habitat form to ecologically-relevant scales. We work closely with the Washington Department of Fish and Wildlife (WDFW), frequently following their priorities for Olympia oyster restoration: (1) to achieve natural-like Olympia oyster habitat in self-sustaining populations; and (2) where strictly necessary, to increase larval supply; and (3) selection of priority water bodies (Blake & Bradbury 2012).

As with restoration of other oyster species globally, contemporary focus is on the design of projects that are likely to be successful now and into a future impacted by climate change, as well as developing systematic approaches to assessment and long-term monitoring so that project designs can be continually improved (Baggett et al. 2014, Wasson et al. 2014, Howie & Bishop 2021, Ridlon et al. 2021). As Olympia oyster restoration practice has developed, estimating likelihood of success at specific sites has focused on quality of environment, population size, and reliability of recruitment (Wasson et al. 2014). Effective restoration of Olympia oysters and the habitat they form requires careful consideration of site suitability, evaluation of available biological resources (e.g., amount of naturally-produced larvae), and project coordination that takes other human uses into account. By taking such care, the restoration actions are more likely to lead to successful persistence and development of the native oysters and the biogenic habitat they form.

Restoration actions typically include increasing the amount of high-quality substrate for larval oysters to recruit to and/or seeding shorelines with wild-transferred or hatchery-reared oysters. Enhancing the substrate can be successful if there is sufficient larval supply in the water column. This also avoids any genetic risk associated with hatchery production (Zacherl et al. 2015). In some cases, stock must be rebuilt through introduction of hatchery-reared oysters, typically as seeded cultch (juveniles settled to relic shell, commonly Pacific oyster shell). Careful matching of broodstock to water body or sub-basin and repeated introductions of oyster seed produced through unique broodstock collections in different years are good practices to mitigate risks of reduced genetic diversity or selection when hatchery-reared oysters are prescribed (Brady Blake, *personal communication* 2020).

Hood Canal

Hood Canal is an inland marine water body within the southern Salish Sea and is considered one of the four main basins of Puget Sound in Washington state. Hood Canal is a unique water body with several physical features that contribute to distinctive oceanographic and biological phenomena within its waters and shorelines. The canal is a fjord formed in the late Pleistocene. It's long, narrow shape creates an extended residence time for waters further inland, especially in bays and coves. An underwater sill just south of the Hood Canal bridge limits mixing between regions of the basin and between depth strata (Fig. 2). In places where the residence time is long, there are several notable impacts including, higher water temperature, higher risk of hypoxic or anoxic events, and the entrainment of plankton, including invertebrate larvae. This low rate of ocean flushing and water mixing can also lead to a larger impact of substances entering the water body from terrestrial sources. For example, freshwater from terrestrial outflows can lead to seasonal freshening, especially in the backwaters. Similarly, pollutants may linger, including nutrients that lead to eutrophication. Additionally, the shape of the fjord provides

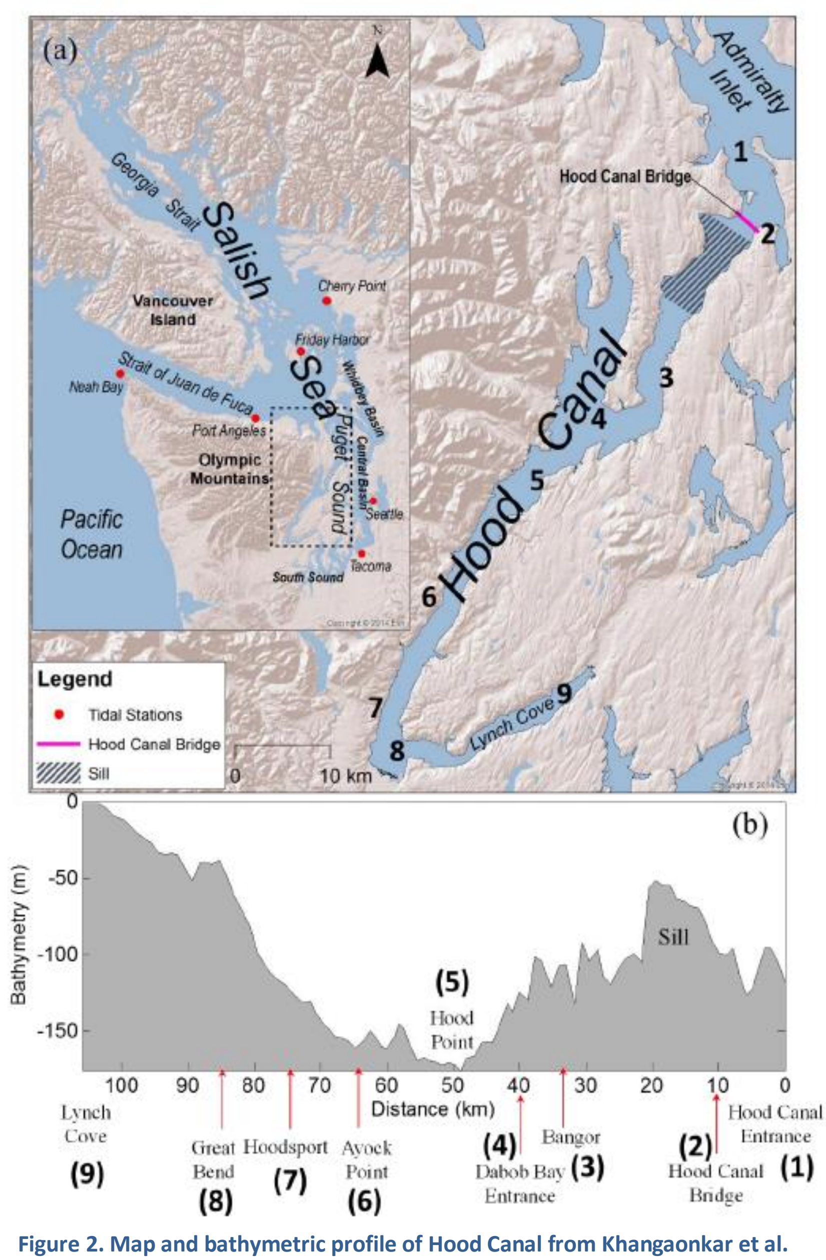

Figure 2. Map and bathymetric profile of Hood Canal from Khangaonkar et al. 2018.

for a long fetch distance through the central canal that can result in high winds. Shorelines that are exposed to this wind energy are more likely to experience associated wind waves and therefore be dominated by wave-tolerant or wave-loving species.

Hood Canal is home to thousands of people. The lands, waters, and wildlife have been stewarded by the Coast Salish people of the Skokomish Tribe (Twana people), Port Gamble S'Klallam, Jamestown S'Klallam, Lower Elwha Klallam, and Suquamish Tribes since time immemorial. Currently, portions of Hood Canal are in three counties: Mason, Kitsap, and Jefferson. These federally-recognized Treaty Tribes and Washington state are co-managers of fish and wildlife resources. Resource managers, community groups such as Great Peninsula Conservancy (GPC), the Jefferson County Marine Resource Committee (MRC), and the Hood Canal Salmon Enhancement Group (HCSEG), commercial shellfish growers, and the general public, are among the groups closely involved in conservation and restoration development in Hood Canal. (See Appendix E for a summary of regulatory agencies and other stakeholders.)

The indigenous people of Hood Canal have maintained a cultural and spiritual connection to shellfish and other natural resources for thousands of years. For example, the Natural Resources Department of the Skokomish Tribe works towards a healthy natural environment with abundant resources in order to sustain the cultural and spiritual identity of the tribal community and provide economic security to present and future generations. Today, Hood Canal is an important location for both fisheries and shellfish aquaculture industries and the people of Hood Canal continue to exhibit a strong cultural connection to the region as an oyster production area. Salmon and shellfish are highly prized commodities and sustainable take, preservation, and restoration of these resources are priorities for local tribes, groups, and agencies. Several shellfish companies operate in Hood Canal's waters, including the largest commercial shellfish operations in the US. To the best of our knowledge, commercial operations are not in conflict with Olympia oyster restoration and success at this point in history. PSRF cultivates partnerships and relies on collaborations with commercial growers to achieve our restoration goals. However, early aquaculture activities introduced the Pacific oyster (*Magallana gigas*, formerly *Crassostrea gigas*) which has become naturalized in Hood Canal. The larger Pacific oyster is a superior competitor for space when compared to the Olympia oyster and may inhibit Olympia oyster growth and recruitment (Trimble et al. 2009).

Olympia oysters are now found naturally-occuring in low densities on numerous shorelines in Hood Canal, as well as in much higher densities in the the main waterway north of Ayock Rock and some discrete locations further south, such as Potlatch State Park (Brady Blake, *personal communication* 2021). The structured biogenic habitat created by Olympia oyster beds that form in abundant and developed assemblages is not present at any location. Historically, large Olympia oyster beds were present in Quilcene Bay and in Lynch Cove where the Union River, Big Mission Creek, and Little Mission Creek deltas come together at the head of the Hood Canal (Blake & Bradbury 2012).

Olympia oysters in WDFW priority restoration areas in Hood Canal

The WDFW Plan for Rebuilding Olympia Oyster (*Ostrea lurida*) Populations in Puget Sound with a Historical and Contemporary Overview (Blake & Bradbury 2012) describes historical Olympia oyster presence in small aggregations and as individuals occurring throughout all of Hood Canal. Large historic beds occurred "in Quilcene Bay, at the Seal Rock/ north Dosewallips tidelands, and on the Union River/ Big and Little Mission Creek(s) deltas." The plan identifies Quilcene Bay and Union River/Big and Little Mission Creek deltas as priority locations for Olympia oyster restoration efforts. For both of these sites the purpose of restoration has been identified as both biological conservation and ecosystem services. The plan recommends small trial sites of hatchery seed outplants and habitat enhancements for both sites. It also identifies land ownership and management issues, eelgrass presence, human health concerns, and predation as barriers to restoration at both sites.

Previous Research in Area

In this project, we knew that challenges to Olympia oyster restoration and that many people had been working to understand those challenges. We would need to specifically consider the potential limitations posed by Pacific oyster naturalization, high predation pressure, and the prevalence of protected eelgrass (Wasson et al. 2014, Valdez et al. 2016).

A test of the efficacy of iterative oyster enhancement projects using different methods within an eelgrass bed was carried out 2013-2015 in the Big Mission Creek area (47.4238°N, 122.8748°W, WGS 84) by Valdez et al. (2016, authors include Betsy Peabody and Brian Allen of Puget Sound Restoration Fund). Through tests of Olympia oyster seeded cultch (2013, 2015) and single oysters spread at 4% cover (2015), the authors determined that oyster restoration methods do not negatively impact eelgrass. Interestingly, these tests uncovered some key messages about predation threat in the Big Mission Creek area. Mortality reached 99% in all tests - after 2 years for the 2013 trial and after 9 months for the 2015 trial. Mortality was attributed to predation by drills, as evidenced by holes in shells, and possibly the sea star *P. ochraceous*, which were observed consuming oysters during a field survey. Plots of seeded cultch saw an increase in oyster drill density in comparison to reference plots. The authors also suggested that the low density of the outplants may have contributed to the poor performance of the outplanted oysters, implying that higher Olympia oyster densities may fare better.

Valdez & Ruesink (2017) analyzed historic and new oyster recruitment data from sites in Hood Canal and found increasing recruitment of Pacific oysters over time and positive correlation between seasonal Pacific oyster recruitment and July-Aug water temperature. In addition, they found that Olympia oysters recruit earlier at lower temperatures, which potentially implies that introduced Pacific oysters may be favored over Olympia oysters in the context of climate change.

Olympia Oyster Restoration Project Assessment Pathway

Purpose

The goal of the PSRF Olympia Oyster Restoration Program is restoration of Olympia oyster bed habitat at ecologically-significant scales within areas in Puget Sound where this habitat is imperiled or has been lost. We do this through restoration actions that work to rebuild Olympia oyster populations and the structured habitat they provide in their developed and persistent assemblages. We focus our efforts largely within 19 priority waterbodies throughout Puget Sound identified in WDFW’s updated Olympia oyster Stock Rebuilding Plan (Blake & Bradbury 2012). Our work with partners on the ground and research conducted in the field and at our conservation hatchery broadly support WDFW’s Olympia oyster recovery efforts. As with other PSRF habitat restoration efforts, awareness of the ecological processes that develop and maintain the habitat of interest are needed to design actions that catalyze natural development of the local population and biogenic habitat.

A systematic approach to information gathering to support evidence-based project work that can measure outcomes has been in development at PSRF for a few years. The result is the Olympia oyster Restoration Project Assessment Pathway (Assessment Pathway). The Assessment Pathway describes the information needed for both strategic development of recovery actions and to monitor change in priority areas for conservation and/or rebuilding. The approach is intended to guide project work and facilitate measurement of outcomes related to oyster population attributes and ecosystem services. The Assessment Pathway consists of steps to establish baseline information to compare with subsequent monitoring, and to inform subsequent, focused assessments and actions. Information collected will assist with project development and decisions on when, where and how project actions proceed.

The Assessment Pathway is programmatic and intended for use by any practitioner, in any waterbody with an Olympia oyster bed conservation or restoration effort. It applies at the spatial scale of an independent waterbody (e.g., harbors, bays, inlets). This is done to reflect the scale of “priority areas” for Olympia oyster population conservation and recovery (WDFW 2012), which are based on historical aggregations, or “oyster beds”. While the evidence suggests some population connectivity within the major basins of Puget Sound (Stick 2012), population dynamics within distinct waterbodies are considered independent and modulated by the magnitude of local Olympia oyster aggregations.

Existing tools

Oyster distribution, demography, and evidence of recruitment are important characteristics to evaluate and play a large role for PSRF in site selection. This is consistent across the oyster restoration tools we use (Baggett et al. 2014, Wasson et al. 2014). Several methods and metrics in the Assessment Pathway are derived from the Oyster Habitat Restoration and Monitoring Handbook; for example, quadrat methods for quantifying oyster density, and the practice of establishing baseline reference sites (Baggett et al. 2014).

We have also referred to the Native Olympia Oyster Collaborative's (NOOC, https://Olympiaoysternet.ucdavis.edu/) Olympia oyster restoration site evaluation tool. The tool can be used to determine the appropriateness of a site for restoration, seeding (if oysters are absent), or for conservation. Inputs range from oyster population characteristics to environmental factors such as salinity, temperature, and chlorophyll.

The Assessment Pathway is modified to fit the conditions observed for Olympia oyster habitat within the Salish Sea. It also includes two major categories of information that are absent from the existing tools: (1) current human use, management preferences, cultural history, and financial leverage; (2) environmental factors that determine how to approach restoration, such as sediment, drainage pathways, and water residence. Sites without adult oyster presence are scored very low with the NOOC tool, however, this is in contrast to our experience in Puget Sound where recurring reintroduction of oysters to sites with limited or no adult oysters has been successful at producing self-sustaining populations (e.g., Dogfish Bay). Much of our site selection is based on broader environmental characteristics (e.g., sediment size), as well as external/human factors. Our process incorporates information including priority Olympia oyster restoration areas as determined by WDFW based upon historic records; pollution, turbidity, and other environmental characteristics; patterns of water movement and retention; and public support for restoration projects in a given area.

Description of the Assessment Pathway

The Assessment Pathway divides oyster restoration projects into three parts:

Part 1: Comprehensive investigation of potential sites in an identified water body and selection of project areas with high likelihood of success

> The majority of the work on any project takes place in Part 1, which includes several phases of information gathering, data evaluation, and regulatory activity. At the end of Part 1, enough information exists to propose a restoration action (Part 2).

Part 2: Selection, testing, and implementation of restoration actions

> Part 2 involves the selection from among potential actions and specific locations within sites and both the testing of methods and implementation of one or more in-water restoration actions.

Part 3: Post-restoration assessment and ongoing monitoring

> Part 3 consists of short and long-term assessment of effectiveness of restoration actions, that can then inform modifications to Parts 1 and 2.

Each of the three parts is described below, preceded by the key questions the part is poised to help address.

PART 1. RESEARCH AND SELECT SITES FOR RESTORATION

Questions: Which sites have a greater suitability for Olympia oyster stock and oyster bed habitat recovery?

1. What waterbodies in a region are of interest?
    a. Where are historic "oyster beds" located?
    b. other?
2. What sites within the waterbodies of interest are potentially suitable?
    a. How is the oyster resource generally distributed?
    b. What can we learn from historical information?
    c. What are the contemporary limiting factors to oyster bed recovery?
        i. habitat loss?
        ii. local oyster abundance?
        iii. local oyster settlement structure?
        iv. alternative human use of land?
3. How do key environmental, oyster, community and substrate parameters compare within and across sites?
4. How do test amendments/enhancements perform at ranked sites?

Approach: Develop pathway for selection of regional waterbodies and restoration sites [* denotes tasks that may be completed in Phase A or Phase B, depending on availability of existing data]

Phase 0 - Sites of Cultural or Historical Significance, Populations Served, & Support for Restoration Actions

1. Broadly evaluate site history and cultural uses by identifying:
    a. WDFW 19 priority areas
    b. Tribal Usual and Accustomed resource areas
2. Determine feasibility of regulatory approval and of securing funding
    a. Create list of regulatory agencies who will need to approve restoration actions; make early contact with key resource managers
    b. Explore funding option contingencies - e.g., did the site have an historic oyster reserve (e.g. USDA), are there potential commercial benefits (e.g. TNC SOAR), and/or community-specific benefits (e.g. private philanthropists)

Phase A – Regional Habitat Suitability. Use qualitative metrics and broad-scale quantitative metrics to identify key bays and inlets within the waterbody.

1. Compile existing data
    a. Imagery - e.g., Google Earth Pro, Shoreline Photo Viewer
    b. Elevation contour layer for tidal elevations from +1 to -3 (MLLW), if available
    c. Longshore transport - drift cells: e.g., GIS layer available from Dept. of Ecology (https://ecology.wa.gov/Research-Data/Data-resources/Geographic-Information-Systems-GIS/Data)
    d. Circulation patterns - hydrodynamics*: e.g., Salish Sea Model's simulation of circulation, transport and biogeochemistry (https://salish-sea.pnnl.gov/)
    e. Water residence spatial analysis*

2. Use Dohrn Habitat Suitability Index (HSI) to score waterbodies of interest on the scale of whole bay or sub-bay*

Phase B – Oyster Resource and Water Body Characteristics. Determine suitability of specific sites within key bays and inlets identified in Phase A.

1. Water body assessment
    a. Exposure - wind, waves, storms
    b. Circulation patterns - hydrodynamics*
    c. Water residence spatial analysis*
    d. Key water quality factors (from pre-existing or novel data):
        i. Temperature
        ii. Salinity - does salinity drop outside of tolerance for a prolonged period of time during seasonal flushing events (see Wasson et al. 2014)
        iii. Chlorophyll, a proxy for a suite of environmental conditions
    e. Oyster qualified presence/absence
        i. Identify primary aggregations
    f. Historic locations
    g. Terrestrial inputs
2. Limiting Factors
    a. Habitat loss
    b. Local oyster abundance
    c. Local oyster settlement structure
    d. Alternative human use of land
    e. Predation
3. Recruitment monitoring
4. Locate potential reference, Before-After-Control-Impact (BACI) control site(s), though assessment can wait until restoration action(s) and locations(s) are finalized in Part 2

Phase C - Site Suitability Ranking. Use fine-scale quantitative metrics to created ranked list of site suitability, identifying site of highest potential for restoration success.

1. Collect additional field data as needed to identify a short list of potential sites.
    a. Environmental Assessment - Check if permits are required to install instruments.
        i. Temperature monitoring
        ii. Salinity monitoring
    b. Beach characteristics (1 day survey)
        i. Slope
        ii. Composition
        iii. Firmness
        iv. Water features
            1. Seep drainage, pools
        v. Emergent substrate
        vi. Vegetation
            1. Note seasonal accumulation of macroalgae, if present
            2. Delineate the shallow distribution of eelgrass

    c. Oyster characteristics (over a season, when possible)
        i. Population assessments
            1. Geolocated presence observations (can be done during beach characterization - 1st survey)
            2. Oyster demographic survey (Gross community data collected concurrently - 2nd survey)
        ii. Community data
            1. Predators – drills, seastars, flatworms
            2. Competitors - Pacific oysters, sand dollars, burrowing shrimp
2. Use modified NOOC Site Evaluation framework to rank site candidates

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PART 2 = SELECT, TEST, AND PERFORM RESTORATION ACTIONS

Questions: **What is the suite of enhancement actions?**

1. Initial testing & assays
2. BACI monitoring stations/sites established and surveyed
3. Restoration project

Approach: Determine and implement restoration actions.
This is the stage in the Assessment Pathway where strategic project actions begin. These activities are strategic because they are informed by the evidence, site rankings, and feedback of the method up to this point. Assessments to date will also be the foundation for evaluations that are concurrent and subsequent to restoration activities. An addendum to the Assessment Pathway methodology will include descriptions of available practices, with specific guidance for typical scenarios experienced in Puget Sound.

1. Population enhancement
2. Substrate enhancement (e.g. shell amendments)

Phase D - Site In Situ Assessment. Conduct trials at top candidate site(s) identified in Phase C.

1. Environmental Assessment
    a. Temperature monitoring
    b. Salinity monitoring
2. Structure amendment trial
3. Biological Assessment
    a. Oyster bioassay = spat on shell transfer
    b. Recruitment monitoring

Select action.
Oyster restoration actions include shell enhancement, broodstock enhancement (singles), or both (spat on shell or seeded cultch enhancement).

Establish reference that will be relevant.
Include survey of BACI control/reference site(s).
Make action(s).

PART 3 = ASSESS ONGOING SUCCESS OF RESTORATION

Question:

What short- and long-term changes have been observed since restoration efforts began?

Approach: Determine to what extent specific project goals are met.

Potential goals include: (1) local population rebuilding; (2) oyster bed habitat recovery; (3) increasing ecosystem services (in value or magnitude) of Olympia oyster beds on a waterbody basis.

Phase E - Assessing change in response to restoration efforts

1. Measurements taken to characterize biotic and abiotic features of habitat before and after restoration efforts
2. Environmental parameters (summer & winter). See Phase C for parameters
3. Olympia oyster population demographics
    a. Recruitment Index
    b. change observed at reference (BACI) control site(s)
4. Associated intertidal communities (biodiversity)
    a. Community response
    b. Species Richness & Biodiversity
5. Processes, services important at ecosystem level
    a. Food web enhancement
    b. Filtration
    c. Nutrient cycling
6. Measurements taken to characterize biotic and abiotic features of restored habitats compared to healthy, existing oyster reefs, e.g. Dyes Inlet, Case Inlet

Phase F - Ongoing long-term monitoring. Specific aspects of Phase E may be extended beyond initial assessment of effects of restoration efforts to be used as long-term background information for future restoration projects.

1. Oyster demographics
    a. Shell budget
    b. Recruitment index
    c. Change in demographics at reference sites
2. Ecosystem services
3. Associated intertidal communities (biodiversity)
    a. Species Richness & Biodiversity

Table 1. Timeline for Implementation of Assessment Pathway

Year	Step
1	Parts 1-A & 1-B: Gather information
1-3	Parts 1-B & 1-C: Conduct site assessment
3-4	Part 2: Apply for permits to conduct in-situ testing to inform selection of final restoration actions
5	Part 2: Implement initial restoration action(s)
6	Part 2: Implement secondary restoration actions
8-10	Part 3-E: Assess short-term change in response to restoration actions
15	Part 3-F: Assess long-term change in response to restoration actions

The information gleaned from each step of the Assessment Pathway from Phase A through Phase D and how it impacts project design is summarized in Appendix A.

Lessons learned from implementing the Assessment Pathway in Hood Canal

Modifications made to the Assessment Pathway

Through this project, we were able to substantially improve earlier versions of the Assessment Pathway to better reflect the stages of projects from development through implementation and post-project assessment. We made the following three notable updates:

- Developed a list of data metrics to be collected when developing a new Olympia oyster restoration project and suggestions for how to use those data in complex decision-making (see Appendix A). By considering how we collect data and how they are used to quantitatively support the subjective process of developing a complex restoration project, we were able to make revisions to the Assessment Pathway that reflect the key pieces of information needed to select locations and approaches. Working through PSRF's expertise from implementing past projects and the available literature on restoration practices, we outlined metrics to follow to reach what we predict is the best scenario for restoration outcomes. Nevertheless, as Olympia oyster restoration is a relatively young endeavour, we anticipate that this framework will continue to be refined each time the Assessment Pathway is applied.
- Added Phase 0 to evaluate social implications of working in a project area, and identify resource managers, parties of interest, and potential funders - all done before beginning an assessment of the physical characteristics of the waterbody of interest. By incorporating Phase 0, the Assessment Pathway more accurately reflects the process of project development and ensures that we consider equity implications of project choices at their inception.
- Moved Phase D (Site In Situ Assessment) from Part I (Research & Site Selection) to Part II (Select, Test, & Implement Restoration Actions). Permits are required for shell amendment testing and, in some cases, for the installation of environmental loggers (e.g., temperature, salinity). Accordingly, it makes sense to consider late-stage site exploration after the most likely sites have been identified and to tie permitting for testing and restoration actions together. Importantly, based

on observations from prior projects, we emphasized the importance of shell test plots and following their fate over more than one winter season. We moved shell patch testing at putative restoration sites into Part II.

Additionally, we made the following small modifications:

- Revised description of how early map views are used, as well as importance of determining relative “exposure,” including wind direction and prevalence (Phase A).
- Removed Lidar from consideration after searching through publicly available data and finding that this tool is still rarely used in intertidal areas and not at low enough depths to be useful for our purposes.
- Refined ideas on hydrodynamics and chlorophyll sampling (Phases A & B):
    - “Hydrodynamics” may be estimated/characterized by…
        - Review existing studies (geomorphological, water quality) that may reveal predominant circulation anomalies during the dry season (work in Phase A).
        - Assessment of environmental factors that favor Olympia oyster larval retention (Peteiro and Shanks, 2015), or correlate with empirical larval abundance.
    - Chlorophyll measurement is likely too stochastic in time and space to be a robust proxy for water retention and was therefore removed from the list of optional data to be collected.
- Refined list of limiting factors (Phase B).
- Revised methods of sediment assessment (Phase C).
- Added greater consideration of eelgrass mapping (Phase C).

Recommendations for future development

Part III (Assess Ongoing Success of Restoration), including Phases E and F, was not tested in the course of this project. We anticipate that application and revision of these phases will take place in the future when a restoration action is in the post-project monitoring phase and that adjustments to overall Assessment Pathway structure to promote the greatest amount of learning from monitoring may take place at that time.

Additionally, we recommend the following small modifications:

- During the Beach Characteristics survey, record percent cover of each potential settlement type - rock, clam shell, oyster shell - in lieu of batching these types together as “emergent substrate.”

The Assessment Pathway as a contribution

We consider the Assessment Pathway presented in this report to be a substantial step forward for Olympia oyster restoration efforts in our region. The Assessment Pathway not only builds on other approaches (e.g., NOOC), but is the most comprehensive encapsulation of the 20+ years of experience that PSRF staff has had designing, implementing and learning from Olympia oyster restoration projects throughout the region. In particular, we have challenged ourselves to craft a decision-making matrix (Appendix A), that is both intuitive and informative for restoration planning. Further, the Assessment Pathway can be used as a teaching and engagement tool by regional partners within and beyond Hood Canal. In coming years, the Assessment Pathway can and should be refined as Olympia oyster restoration practitioners - PSRF and others - add expertise and refine recommendations ranging from site selection to quantification of restoration effectiveness.

Application of the Assessment Pathway in Hood Canal

Compilation of pre-existing data

PHASE 0

Broadly evaluate site history and cultural uses

The pre-assessment to broadly evaluate site history, cultural and historical importance, populations served, and feasibility of regulatory approval and of funding support was completed in the development of this project proposal in late 2020. The introduction of the HCSI catalyzed the strong cultural connection to Hood Canal as an oyster production region and priority for Olympia oyster restoration given by WDFW to two Hood Canal regions. Much of the information needed for Phase 0 has been provided above in the Background & Context section.

Determine feasibility of regulatory approval and of securing funding

The northeasternmost reaches of Lynch Cove are closed to shellfish harvest by Washington Department of Health (DOH) due to non-point source pollution and proposed restoration projects in the closed region should be avoided at this time, however the tidelands near Big and Little Mission Creeks and Belfair State Park are outside of the closed region. Potential overlap with eelgrass meadows will warrant special consideration during the permitting process. Historic oyster reserves, such as the Clifton Reserve in the head of Hood Canal, may make a Olympia oyster population enhancement project eligible for USDA funding.

PHASE A - Regional Habitat Suitability

A1. Compile existing data

A1a. Satellite or aerial imagery

At the outset of new project development, we review satellite imagery in Google Earth Pro and shoreline aerial images. In Washington, these are available for viewing at the Department of Ecology website for Shoreline Photo Viewer (https://apps.ecology.wa.gov/shorephotoviewer/Map/ShorelinePhotoViewer). The images are sometimes taken during daylight low tides, and can reveal extensive tidelands. The images are timestamped, so water level verification is possible. By reviewing the shoreline images, regions of interest can be identified for further assessment. We are looking specifically for regions with tideland benches near and below MLLW, and how these features relate to what we intuit from residence and exposure gradients in the waterbody. These photos can reveal hints about substrate composition, slope, vegetation, or terrestrial inputs. Landmarks, developments and other features can also be identified in shoreline photos.

For Hood Canal, one can immediately see that the two WDFW priority areas are at the heads of their respective waterbodies (Fig. 4); often the location for primary terrestrial inputs, alluvial islands and the high part of the residence time gradient. Satellite and shoreline views allow for a broad Satellite imagery is often revisited in later phases of the Assessment Pathway to examine and interpret close-up features of the shoreline once specific beaches of interest have been identified (for example, see Fig. 17.) In both Quilcene Bay and Lynch Cove, we were able to identify key features and tideland reaches to initially target during our planned Olympia oyster reconnaissance surveys. In Quilcene Bay these were Fisherman’s Point and Frenchman's Points near the mouth, the managed tidelands on east and west sides of the Big Quilcene River drainage. In Lynch Cove, these included Belfair State Park, Belair Cove, and Twanoh State Park.

A1b. Elevation contour layer

A pre-existing elevation contour layer of the tidal elevations from +1 to -3 (MLLW) does not exist for Quilcene Bay or Lynch Cove. These were created empirically for subsections of each site where Phase B & C surveys were completed.

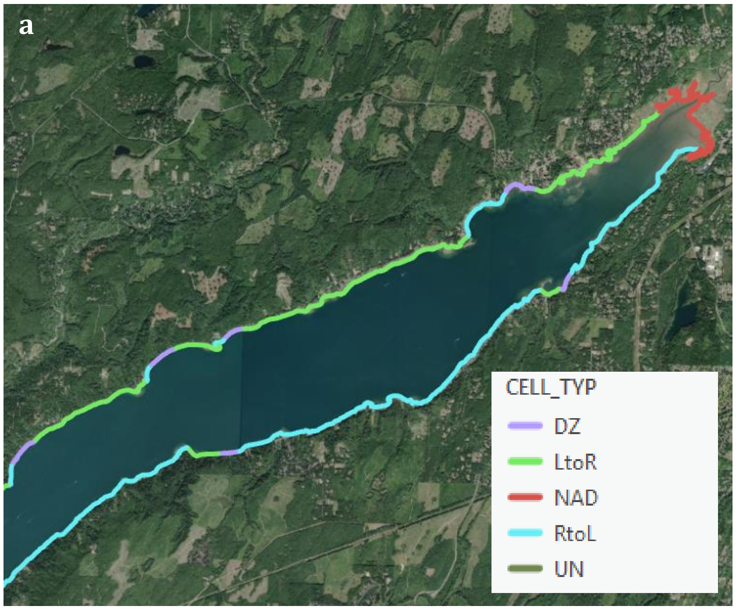
A1c. Longshore transport

Drift cell information is available for all Puget Sound shorelines. No appreciable drift is often the reported drift cell category at the head of the waterbody. The drift cell simply reports the direction on net transport; additional information on longshore sediment transport (magnitude, erosion or accretion) may also be available. Sediment transport can inform an exposure characterization of the shoreline and reveal something about prevailing wind, wave and current. A GIS layer of drift cell patterns can be downloaded from the Washington Department of Ecology (DOE): https://ecology.wa.gov/Research-Data/Data-resources/Geographic-Information-Systems-GIS/Data (Fig. 4). From the drift cell direction categories for both Quilcene Bay and Lynch Cove, net transport is moving from the entrance at the south toward the head; in the same direction along both shores. This indicates that exposure to the prevailing south winds may be a factor for the exposure regimes on these shorelines.

Figure 3. Google Earth satellite imagery of Hood Canal (a) and each of WDFW's priority areas: Lynch Cove (b) and Quilcene Bay (c).

A1d. Circulation patterns

Circulation patterns can be evaluated from the best available nearshore oceanographic model or empirical description for the waterbody. An understanding of the prevailing circulation features, especially in the dry season for Puget Sound, may identify regions with prevailing circulation anomalies that could affect residence time and larval retention for Olympia oysters. Contemporary sediment or water quality studies, or other circulation model outputs may be available. The Salish Sea Model is a resource suited for larger scale evaluation of circulation throughout the estuary (https://salish-sea.pnnl.gov/), but can be informative for larger waterbodies. Salish Sea Model data were incorporated into the Dohrn HSI model generated for each area (below).



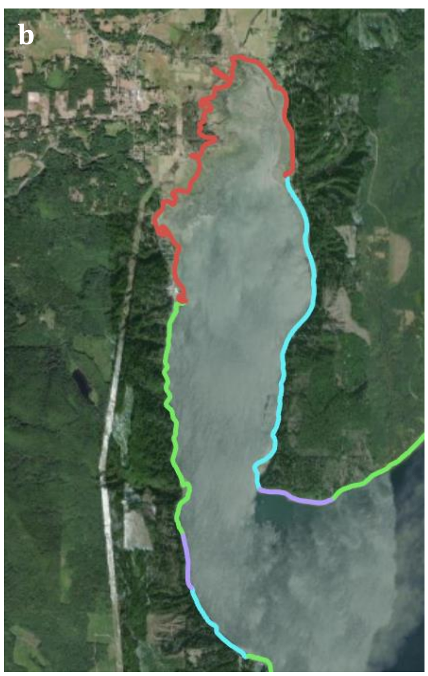


Figure 4. Drift cell information from WA Department of Ecology for Lynch Cove (a) and Quilcene Bay (b). Data can also be viewed on the Coastal Atlas (https://apps.ecology.wa.gov/coastalatlas/tools/Map.aspx).

A1e. Water residence spatial analysis

No additional water residence spatial information was found for Hood Canal. This is not surprising, as these types of data are still rarely collected in the small sub-basins of bays and estuaries.

A2. Dohrn Habitat Suitability Index (HSI)

In Quilcene Bay, an HSI=~0.75 for most of the head of Quilcene Bay (Fig. 5). There is a narrow band of HSI=1 ringing most of the shoreline. Elevation and winter salinity conditions are the limiting factors that reduce the HSI score in this area. The salinity data from DOH would suggest that salinities are not suitable at the very head of the bay, and somewhat below optimal throughout most of the bay. Other conditions are optimal, so the HSI score is still high in this area.

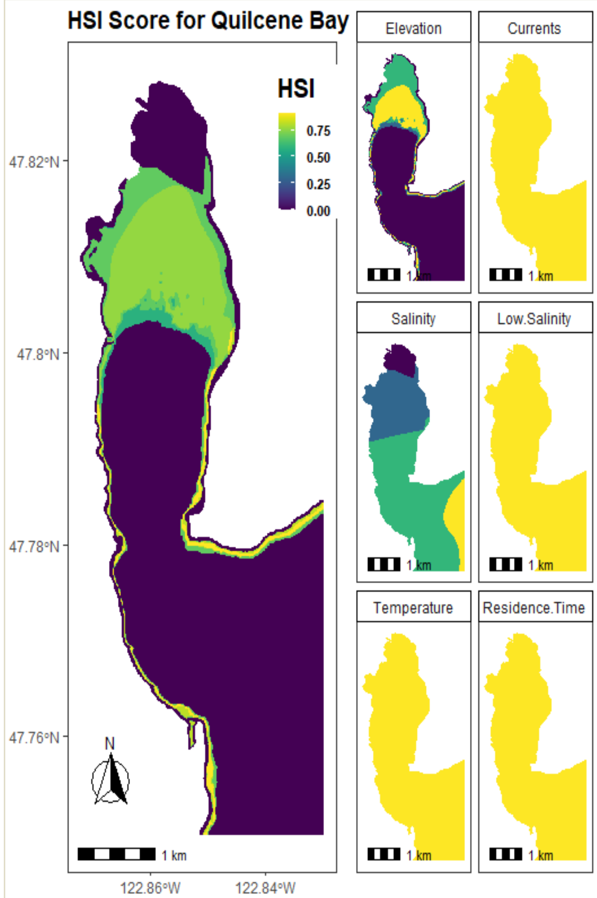


Figure 5. HSI Results from Dohrn model for Quilcene Bay. Left panel shows summary results, right panels show results based on individual parameters. Yellow indicates a score of 1, highest possible habitat suitability, purple indicates a score of 0, lowest possible.

In Lynch Cove, very little habitat was deemed suitable by Dohrn's Habitat Suitability Index (HSI, Dohrn 2020, Fig. 6). Small amount at the very western end near Tayhua. Current velocities estimated high through the central part, salinity estimated unsuitable or moderately suitable throughout. Low salinity events possible at the very head of the cove, residence time scored as unsuitable in most areas. Dohrn noted ~65 DOH stations and ~90 model nodes in this area and surmised that Union River/Big and Little Mission Creeks may be a good example of a location where the HSI

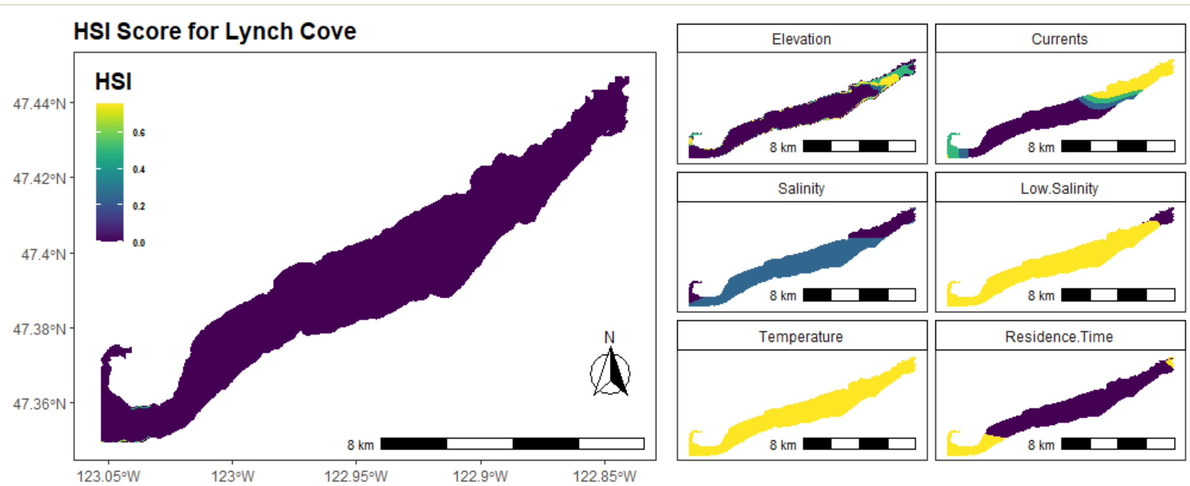


Figure 6. HSI Results from Dohrn model for Lynch Cove/East arm of Hood Canal (Dohrn 2020). Left panel shows summary results, right panels show results based on individual parameters. Yellow indicates a score of 1, highest possible habitat suitability, purple indicates a score of 0, lowest possible.

may not be very accurate, because the low HSI score is not consistent with large historical beds. Dohrn cited classification of water residence time and accurate estimation of intertidal salinity as potential metrics to scrutinize in future revisions.

PHASE B – Oyster Resource and Water Body Characteristics

B1. Water body assessment

B1a.Exposure - wind, waves, storms

Exposure (fetch + wind direction + wind speed) ranking to wind and can be used to estimate wind and wind wave exposure. The model output of Newton et al. 2007 (Fig. 7) shows a high exposure at the south end of the main basin, and relatively quiescent waters in both Quilcene Bay and the head of Lynch Cove.

B1b. Circulation patterns - hydrodynamics

For some places, hydrodynamic models have been made based upon acoustic doppler transect data. Where available, these should be consulted to evaluate the prevailing circulation anomalies during the dry season. If no model outputs are available, empirical assessment via drifter surveys are an approach to estimating circulation vectors. Empirical assessment is beyond the general scope of the Assessment Pathway, but may be recommended in some cases.

B1c. Water residence spatial analysis

Within major basins, spatial representations of water residence, age, and flushing times have been useful to identify regions where residence time is relatively protracted. Experts in Washington suggest that they are only available for some regions (e.g. south Puget Sound, see Ahmed et al. 2017) and generally look at basin-wide dynamics, not unlike the Salish Sea model (Anise Ahmed, *personnel communication* 2021). Studies that describe sediment transport, geomorphology, or water quality dynamics within the water body may be available; this information that can be useful to evaluate residence time. Empirical assessment is beyond the general scope of the Assessment Pathway, but may be recommended in some cases.

B1d. Key water quality factors (from pre-existing or novel data):

Temperature

No pre-existing data. See Summary of Additional Data Collected in 2021.

Salinity

No pre-existing data. See Summary of Additional Data Collected in 2021.

Chlorophyll

Chlorophyll concentration surveys along the spatial gradients of water bodies have been useful in creating habitat suitability index models (Ted Grosholz, *personnel communication* 2016). Concentrations of summer phytoplankton blooms can indicate autochthonous production and can serve as a proxy for evaluating relative water residence within the water body. However, phytoplankton dynamics make interpretation difficult and this metric is only suggested. No empirical assessment of chlorophyll concentrations was produced for this report.

B1e. Oyster qualified presence/absence

On May 16, 2018, several teams walked the shorelines of Quilcene Bay to make Olympia oyster presence observations, as depicted with blue lines in Fig. 10. Oysters were found present along the entirety of the area surveyed and were more often common (10-100 oysters/m^2) than rare (1-10 oysters/m^2). Along the steeper west shoreline of Quilcene Bay, oysters were associated with the basalt cobble of which that shoreline is composed. Oysters were commonly found on exposed surfaces as well as on the underside of small boulders and cobble. On the east shoreline, where the beach has a generally lower grade slope, Olympia oysters were typically associated with the lower portions of Pacific oyster hummocks and relic Pacific oyster shell.

B1f. Historic locations

Our focus on Quilcene Bay and Union River/Big and Little Mission Creeks (Lynch Cove) is primarily derived from descriptions of these locations as WDFW priority recovery sites. See Blake & Bradbury 2012.

B1g. Terrestrial inputs

Estimated from Google Earth imagery (Fig. 3) and mapped in 2021. (See Summary of Additional Data Collected in 2021.)

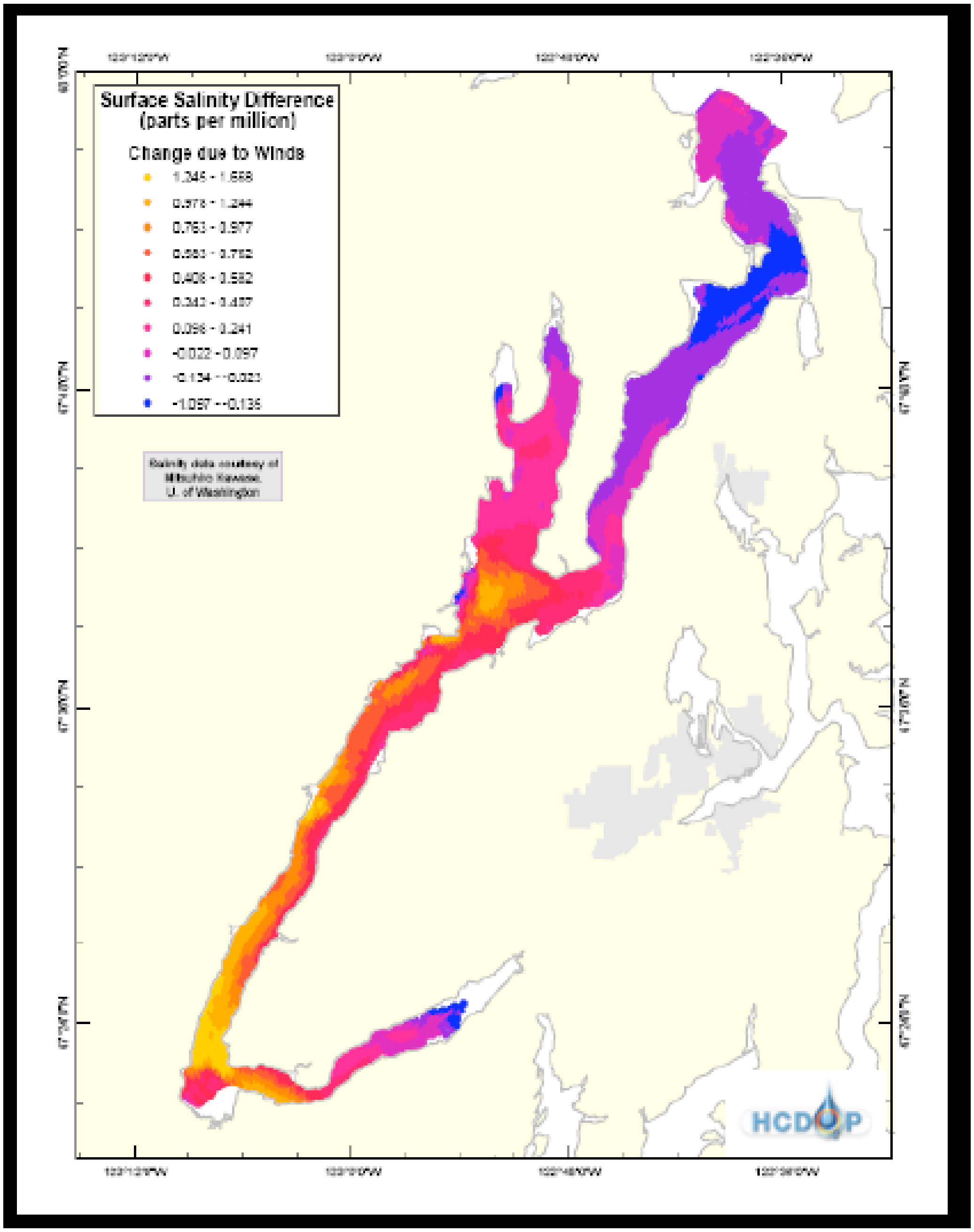


Figure 7. Salinity patterns in Hood Canal from Newton et al. 2007. This image shows relative net impact of wind and can be used to estimate wind and wind wave exposure (warm colors high and cool colors low, with yellow as the highest and deep blue as the lowest).

B2. Limiting factors

B2a. Habitat loss

Alternate uses of shellfish habitat occurred over the past ~150 years in both priority areas. See Blake & Bradbury 2012.

B2b. Local oyster abundance

As a follow-up to the qualitative oyster reconnaissance conducted in 2018 along the eastern and western shorelines of Quilcene Bay (see Quilcene Phase B), oyster demographic surveys were conducted in 2019 and 2020, targeting the primary aggregations discovered in the 2018 reconnaissance. On July 18, 2019, PSRF conducted Olympia oyster demographic surveys near area QB2 (see Fig. 6b) on the eastern shoreline near the mouth of the bay. Mean oyster density was found to be 101.2 oysters/m² +/- 13.1 SE within the survey area. That same day in 2019, PSRF also surveyed area QB3 (see Fig. 6b) and estimate mean oyster density to be 70.3 oysters per m² +/- 25.5 SE. At both QB2 and QB3, oysters were primarily in the 20 to 30 mm shell height size class (Fig. 10).

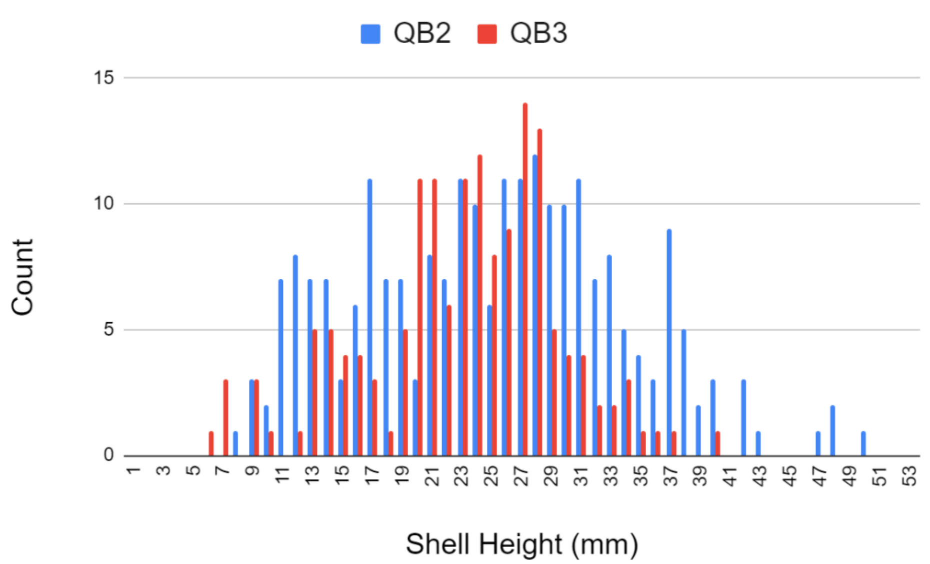


Figure 8. Frequency distribution of shell heights (mm) for oysters surveyed on July 18, 2019 at QB2 (blue) and QB3 (red).

B2c. Local oyster settlement structure

Emergent gravels and shell are substrates utilized by settling oysters. White et al. (2010) provides a list of preferred settlement substrates). Without an oyster population to produce relic shell, this resource can be limiting oyster population development. Empirical data on emergent shell type and cover is reported in Summary of Additional Data Collected in 2021.

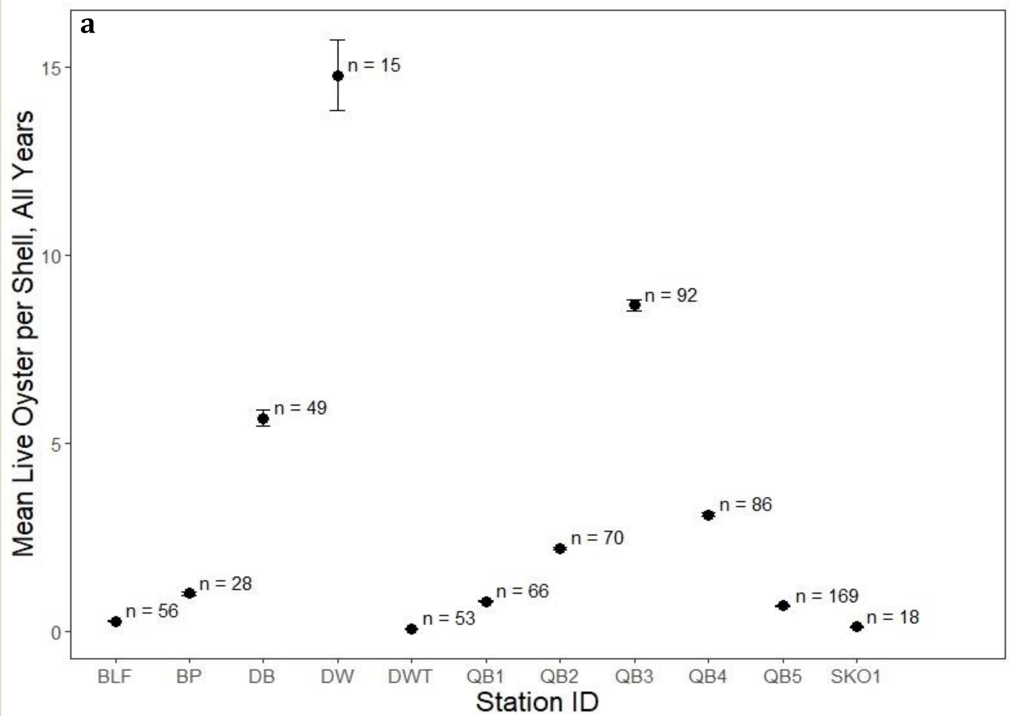
B2d. Alternative human use of land

Following Olympia oyster population declines of the late 19th century, the spaces once occupied by natural Olympia oyster beds were frequently developed for shellfish cultivation. In many cases, what had once been Olympia oyster habitat was replaced by cultivated Pacific oysters or Manila clams. In the Clifton/Belfair Reserve of Lynch Cove, a good portion of the reserve was leased out for Pacific oyster cultivation after the reserve was discontinued in the early 1930s. Commercial and recreational shellfish activity is described Discussion and Recommendations.

B2e. Predation

Both Quilcene Bay and Lynch Cove are WDFW control areas for the oyster drill (*O. inornatus*).

B3. Recruitment monitoring



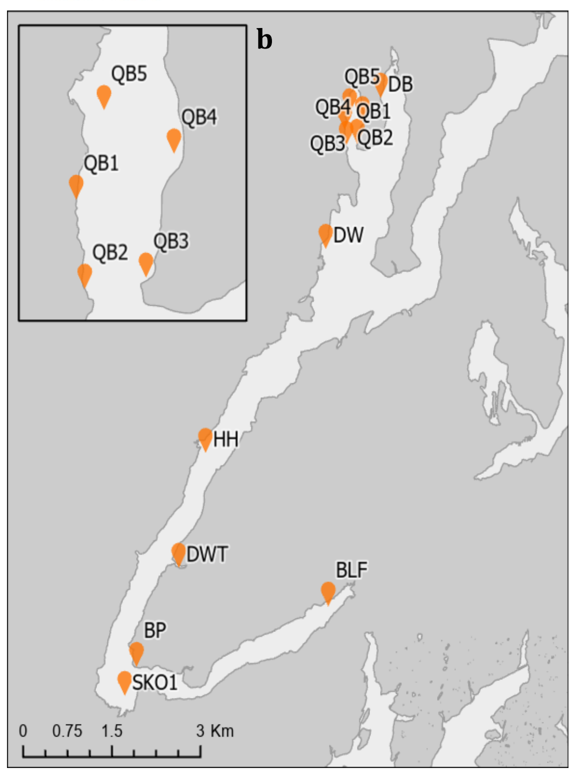


Figure 9. Mean live Olympia oyster per shell (+/- SE) for all Hood Canal Recruitment stations for all years (a) and map of all Hood Canal Recruitment stations (b). Number of shells total sampled (all years) for each station labeled at upper right of point. Station positions are represented by an orange teardrop and labeled with the corresponding station ID code (see table 1). Inset map to upper right depicts Quilcene Bay at a smaller geographic scale for clarity.

A summary of the recruitment index records for Hood Canal stations reveals some locations have had a relatively moderate or high Olympia oyster recruitment over the past six years. The station with the highest mean live Olympia oysters per shellface was Dosewallips (DW) at 14.8 +/- 0.9 SE, although that station was deployed only in 2015 and only 15 shells from the recovered station were processed (Fig.9, Table 2). Other stations that have a moderate recruitment index magnitude for Hood Canal include QB2 (2.2 +/- 0.0 SE), QB3 (8.7 +/- 0.2 SE), and QB4 (3.1 +/- 0.1 SE), which were all deployed from 2018 to 2021 (Fig. 9, Table 1). Results from 2021 monitoring and more details on the recruitment monitoring methods are discussed in section 2.1 of this report. A station was deployed at Hama Hama (HH) in 2015, but this station was eliminated from analyses because only a single shell was recovered.

Table 2. Recruitment station water body, station name, station ID code, and years deployed.

Waterbody	Station Name	Station ID Code	Years Deployed
Union River/Mission Creek	Belfair State Park	BLF	2015, 2019, 2020, 2021
Hood Canal	Bald Point	BP	2015
Dabob Bay	Dabob Bay	DB	2019
Hood Canal	Dosewallips	DW	2015
Dewatto Bay	DNR 48	DWT	2019, 2020
Hood Canal	Hama Hama Oyster Co.	HH	2015
Quilcene Bay	DNR North	QB1	2018, 2019, 2020
Quilcene Bay	DNR South	QB2	2018, 2019, 2020, 2021
Quilcene Bay	Fishermans Point	QB3	2018, 2019, 2020, 2021
Quilcene Bay	WDFW NE	QB4	2018, 2019, 2020, 2021
Quilcene Bay	WDFW Rec	QB5	2016, 2017, 2018, 2019, 2020
Annas Bay	Skokomish Tideflats	SKO1	2021

B4. Locate potential reference site(s)

Potential Before-After-Control-Impact (BACI) control site(s) identified for Quilcene Bay include the previously surveyed areas near QB2 and QB3, and for Lynch Cove include the shorelines of Twanoh State Park or Belair Cove. Assessment of control sites occurs once restoration action(s) and locations(s) are finalized in Part 2.

Summary of Additional Data Collected in 2021

Quilcene Bay

PSRF Staff conducted two days of new survey work in Quilcene Bay in 2021 in addition to analyzing previously collected data. Locations of the research areas are shown in Fig. 10, and specific activities further described below.

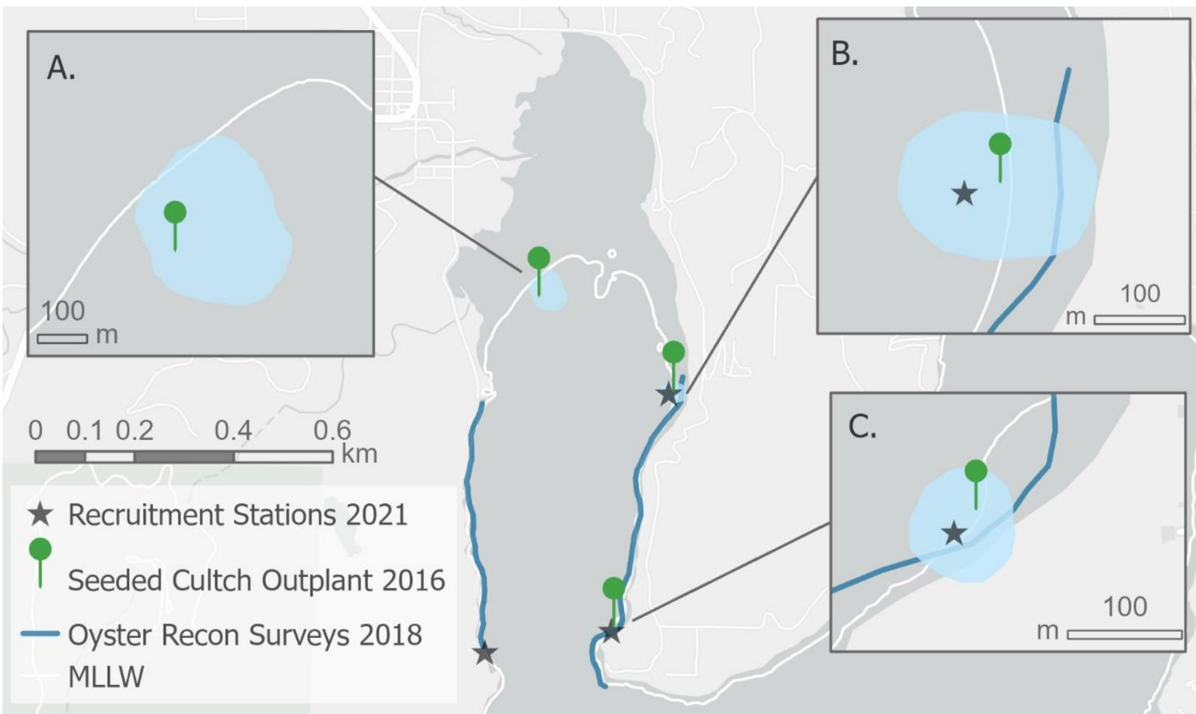


Figure 10. Map of previous and new research areas in Quilcene Bay. Green pins indicate seeded cultch test plot locations. Extent of 2018 Olympia oyster reconnaissance survey is shown with a dark blue line. The MLLW contour is approximated with the white line. Recruitment index station positions are shown by dark grey stars. Study areas in light blue: A. Habitat characterization and elevation survey 2021. B. Olympia oyster reconnaissance and elevation survey 2020, Olympia oyster demographic survey 2021. C. Olympia oyster demographic surveys 2019 & 2021.

PHASE B – Oyster Resource and Water Body Characteristics

B1. Waterbody assessment

Olympia oyster qualified presence/absence

Building upon the 2018 surveys, PSRF staff walked a large section of the beach at the head of the bay (near Area A on Fig. 10), including up the river channel along public lands in the Northwest Corner of the bay, and found no Olympia oysters.

B3. Recruitment monitoring

Three recruitment index stations were deployed in Quilcene Bay this year: QB2, QB3, and QB4 (see Fig. 11b). Recruitment index stations are composed of 3 replicate stacks of 11 Pacific oyster shells (right valves, 10 m to 12 cm) threaded on a wooden dowel, positioned approximately 2 feet apart (Fig. 11a). Recruitment index stations were deployed in Quilcene Bay on May 13, 2021 and retrieved on September 7, 2021, then processed in the lab. We examined each shell using a stereo dissecting scope under 10x magnification and for each shellface (nacre surface). Recorded data include the count of live Olympia and Pacific oysters, count of dead Olympia and Pacific oysters (disarticulated at collection, indicating post-settlement mortality). Shell heights were recorded to the nearest tenth of one millimeter using

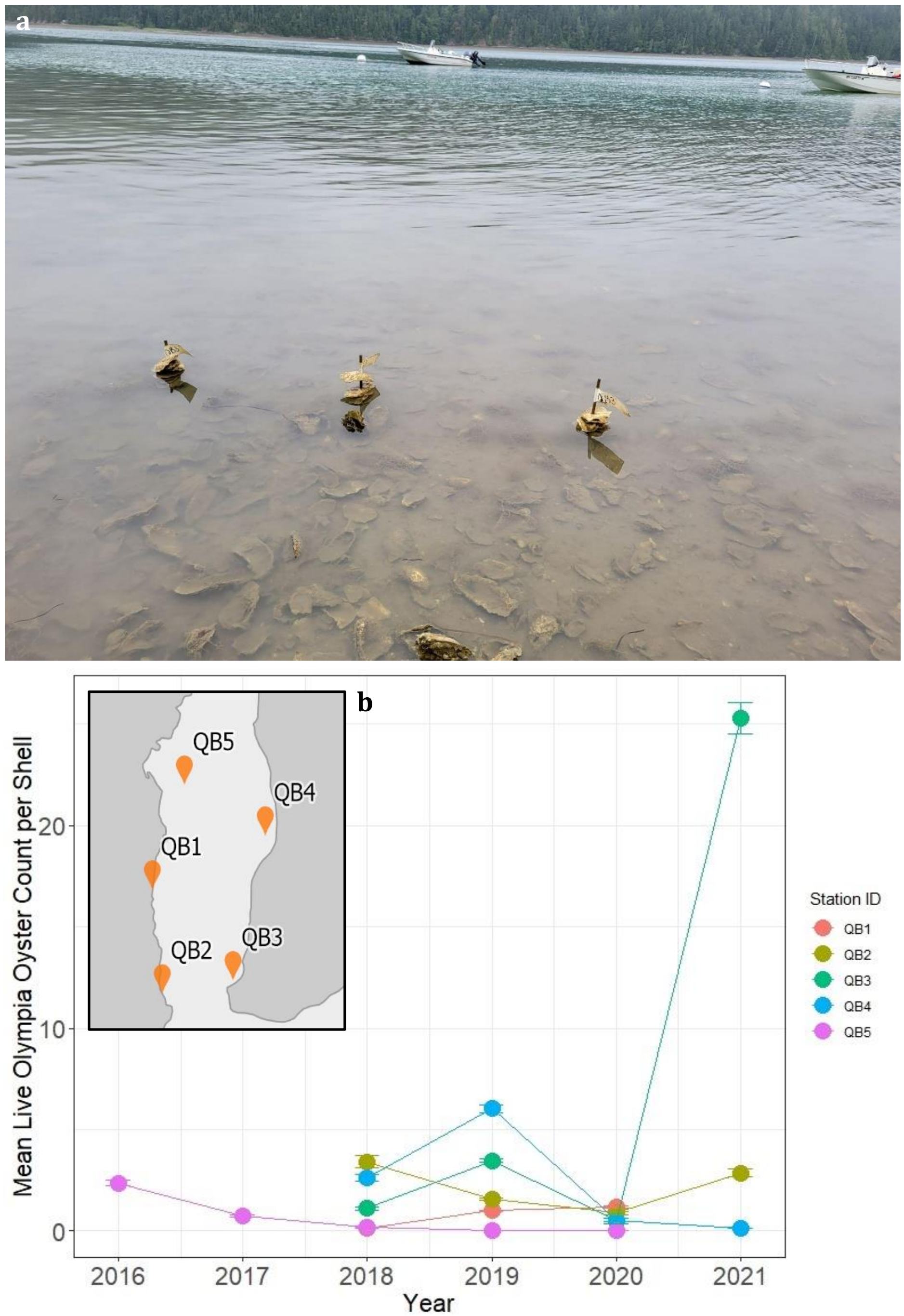


Figure 11. Image of recruitment station QB3 after deployment in 2021 (a), mean live Olympia oyster count per shell (+/- SE) for each recruitment index monitoring station in Quilcene Bay from 2016 to 2021 (b). Color corresponds to Station ID (red = QB1, olive = QB2, green = QB3, blue = QB4, magenta = QB5). Not all stations were deployed for all years. Inset map shows locations of stations within Quilcene Bay.

digital calipers for the first 10 live and first 10 dead Olympia oysters. Due to the high count of Pacific oyster set at Quilcene Bay stations, we subsampled and processed 5 shells per dowel for all stations, where n=15 shells per station processed for 2021.

Recruitment index results indicate the presence of a larval supply in Quilcene Bay. Olympia oyster recruitment occurs more consistently at the mouth of the Bay (QB2 & QB3) than at the head of the bay (QB5, Fig. 11b, Table 3). We observed low-level but persistent Olympia oyster settlement at QB2 from 2018 to 2021, with a slight increase in 2021 (2.9 mean Olympia Oysters/shellface +/- 0.2 SE) compared to 2019 and 2020 (Fig. 11b, Table 3). At QB3, we observed a record high magnitude Olympia oyster recruitment index for 2021 (25.3 mean Olympia oysters/shellface +/- 0.8 SE) compared to previous years and other stations. QB4 has reported lower recruitment index values for 2020 (0.5 +/- 0.1 SE) and 2021 (0.1 +/- 0.0 SE) since it peaked in 2019 at 6.0 +/- 0.2 SE. QB1 reported low recruitment index values in 2018, 2019 and 2020. The QB4 recruitment index value peaked in 2019 and has since reported very low values. The QB5 station, closest to the June 2021 habitat survey area, reports low recruitment index values for most years since 2016. The recruitment index stations at QB1 and QB5 were discontinued after 2020 due to low reported recruitment index values.

Table 3. Summary of recruitment index data for each Quilcene Bay station. Shells sampled (n) varies across stations and years because (1) stations are not always fully recovered intact each year and (2) subsampling is employed for stations and years with abundant Pacific oyster recruits.

Station ID	Year	Shells Sampled (n)	Mean Live Olympia oyster per Shellface	Standard Error
QB1	2018	20	0.2	0.02
	2019	30	1.0	0.03
	2020	16	1.2	0.07
QB2	2018	17	3.4	0.29
	2019	29	1.6	0.05
	2020	9	0.9	0.09
	2021	15	2.9	0.19
QB3	2018	30	1.1	0.06
	2019	30	3.5	0.08
	2020	6	0.5	0.14
	2021	26	25.3	0.77
QB4	2018	30	2.6	0.17
	2019	30	6.0	0.19
	2020	11	0.5	0.08
	2021	15	0.1	0.02
QB5	2016	30	2.4	0.13
	2017	50	0.7	0.03
	2018	29	0.2	0.04
	2019	30	0.0	0.01
	2020	30	0.0	0.00

PHASE C - Site Suitability Ranking

C1a. Environmental assessment

Temperature monitoring

We collect intertidal temperature data with deployments of data loggers positioned near MLLW – within the upper distribution of Olympia oysters – to characterize the conditions within this microhabitat. Intertidal temperature was monitored using an Onset Hobo U20L-01 temperature logger deployed at -0.5 ft. (MLLW). Loggers were deployed on the beach at Quilcene Bay (47.80177N, 122.84711W, WGS84) on June 23, 2021, and data was recovered using an Onset Waterproof Data Shuttle (U-DTW-1) on October 4, 2021. Reported temperatures thus represent a mix of water and air temperatures, depending upon water level throughout the tidal cycle. During the months with daytime lower low tides (April through September), the daily maximums represent air temperature, whereas the daily minimums represent water temperature. This trend may be reversed during the months with nighttime lower low tides (October through March), especially if there are extreme low winter temperatures. The maximum temperature logged during that time was 24.9°C on June 27, 2021 at 14:30 (Table 4). This observation was recorded during the Pacific Northwest heat dome event which co-occurred with extreme low tides (see pressure record, Fig. 12b). The surrounding days in late June also had very hot daily maximums (Fig. 12a). The minimum temperature recorded (13.4°C) occurred at 06:00 on October 04, 2021. With the exception of the unprecedented heat dome, observed temperatures in both Quilcene Bay and Union River/Big and Little Mission Creeks were within the reported tolerances for Olympia oysters (Fig. 12, Fig. 21).

Table 4. Summary of logged temperature (°C) at Quilcene Bay.

Site	Elevation	Deployment Date	Recovery Date	Max Temp. (°C)	Min Temp. (°C)	Mean Temp. (°C)	n	Standard Deviation	Standard Error
Quilcene Bay	0 to -1 ft MLLW	2021-06-23	2021-10-04	24.93	13.46	18.30	4968	2.58	0.04

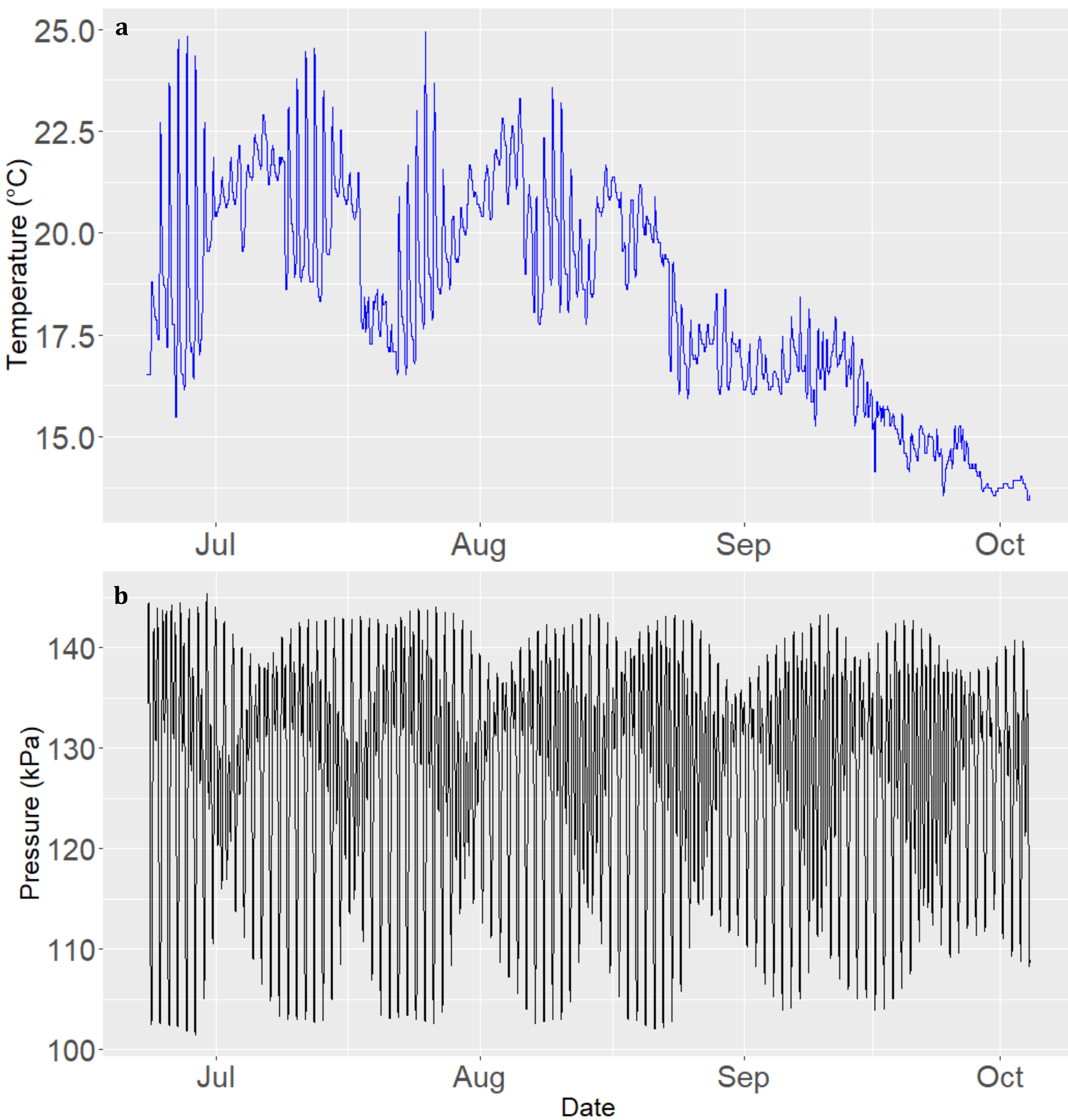


Figure 12. Temperature (a) and pressure (b) time series data from Quilcene Bay, June 23 - October 4, 2021. Temperature (°C) represents either air or water temperature, depending on water level during the tidal cycle. See main text for further interpretation (a). High relative pressure (kPa) indicates high tide; low relative pressure indicates low tide and may include exposure of the sensor; spring tidal cycles can be seen where the difference between daily high and daily low pressure is greatest. The 10-year mean for atmospheric pressure in Quilcene, WA during these months is 101 KPa (weatherwx.com) (b). X-axis tick marks represent the 1st day of each month.

Salinity monitoring

We are interested in whether salinity drops outside of the published tolerance for a prolonged period of time during seasonal flushing events (see Wasson et al. 2014). A conductivity logger (Onset HOBO U24-002-C) was deployed on the beach, adjacent to the temperature logger, at Quilcene Bay (47.80177N, 122.84711W, WGS84) on June 23, 2021, and data was recovered using an Onset Waterproof Data Shuttle (U-DTW-1) on October 4, 2021. Salinity was calculated from specific conductance and temperature using HOBOware Pro v. Conductivity Assistant which employs a non-linear sea water compensation based on PSS-78. These values were corrected using temperature and salinity measurements observed in the field using a liquid-in-glass thermometer and optical refractometer, respectively. Mean salinity for this logger deployment was 28.639 ppt (Table 5). Observed low salinity values are due to instrument exposure during extreme low tides. Quilcene Bay values are within the reported salinity tolerances for Olympia oysters (Fig. 13).

Table 5. Summary of salinity (ppt) results from Quilcene Bay, June 23 - October 4, 2021.

Site	Elevation	Deployment Date	Recovery Date	Max Salinity (ppt)	Mean Salinity (ppt)	n	Standard Deviation	Standard Error
Quilcene Bay	0 to -1 ft MLLW	2021-06-23	2021-10-04	36.16	28.64	4966	4.53	0.06

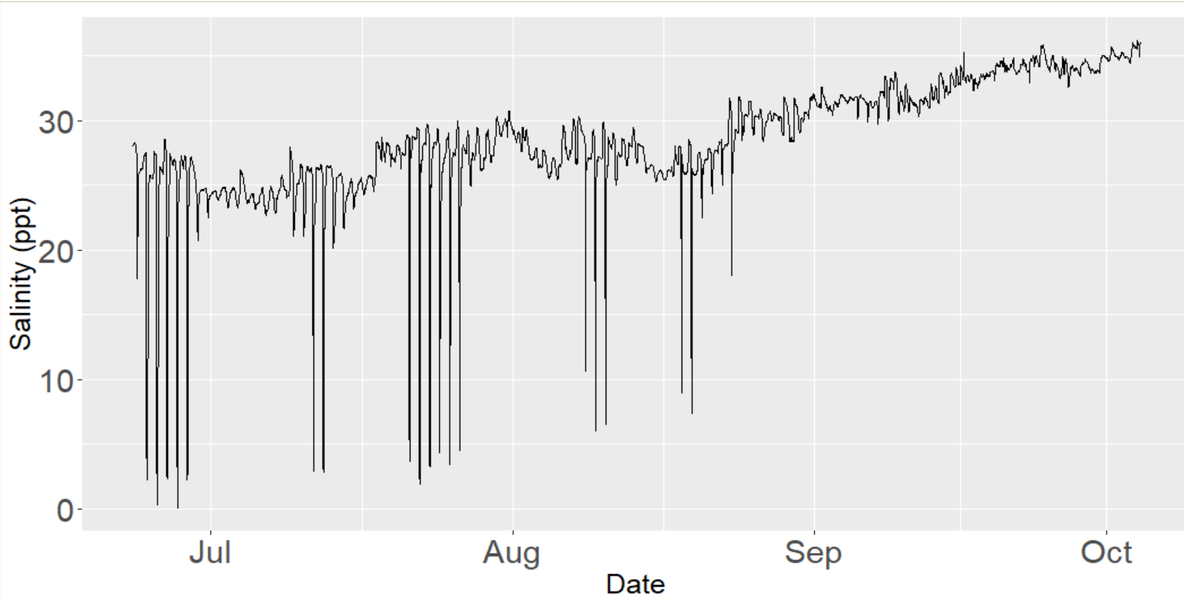


Figure 13. Salinity time series resulting from instrument deployment in Quilcene Bay, June 23 - October 4, 2021.

C1b. Beach characteristics

On June 24, 2021, PSRF staff conducted habitat characterization and elevation surveys at the head of Quilcene Bay (Fig. 10, area A). Shoreline contours, drainage channels, eelgrass distribution, and other geographical features of interest on the beach were mapped using the ESRI FieldMaps Application on an iPad connected to a Trimble R1 handheld GNSS receiver. This allowed PSRF staff to collect point, line, and polygon spatial information in the field and load those observations directly into an ArcGIS feature class.

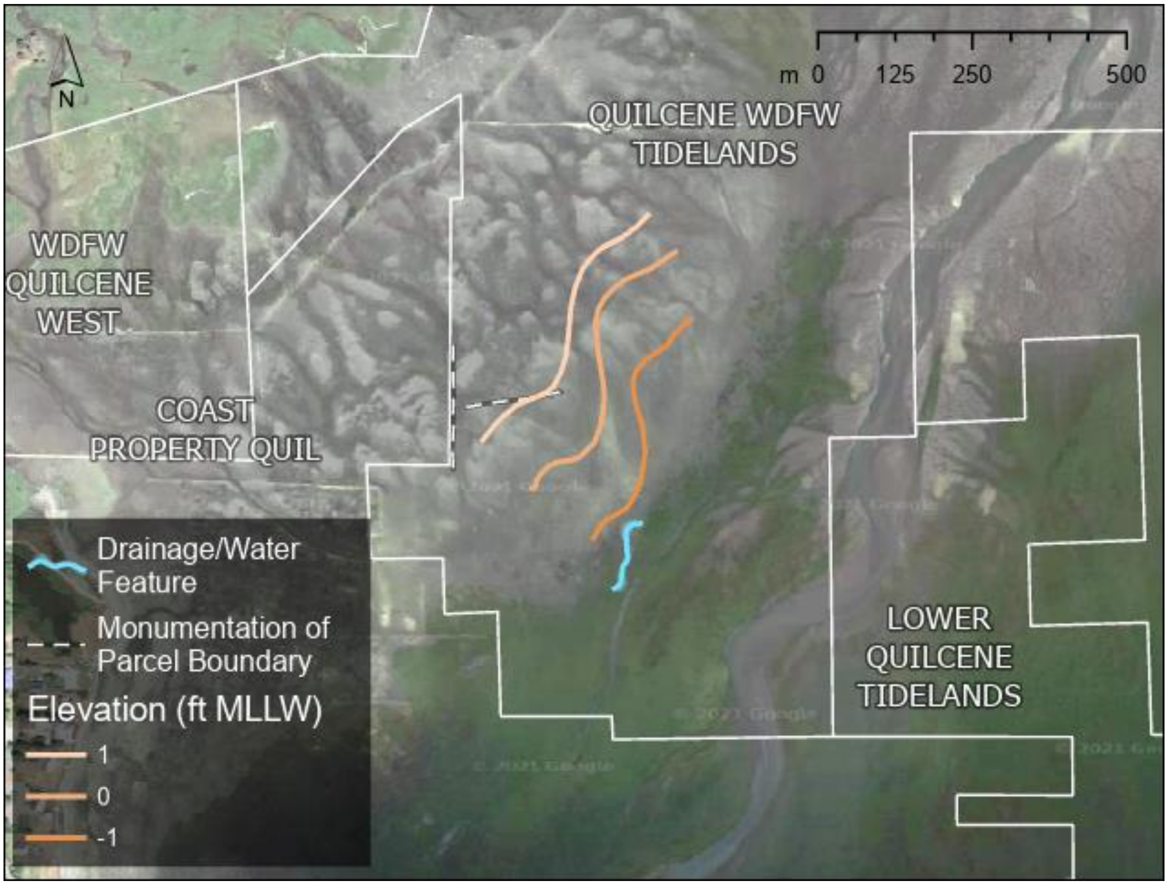


Figure 14. Map depicting results of empirical feature mapping at the head of Quilcene Bay on June 24, 2021, including elevation contours (orange: lighter = higher elevation, darker = lower elevation), drainage channels (blue lines), and on-beach monumentation line indicating parcel boundary (white dotted lines). Solid white lines indicate boundaries associated with a Beach Identification Number (BIDN) layer (WDFW 2021), and beaches are labeled by name.

The habitat characterization survey features multiple components including sediment composition, substrate firmness, presence of vegetation including eelgrass, emergent substrate type and cover, and the presence of predators and competitors.

Slope

Tidal elevations, within our survey area, were measured to the nearest inch using an auto level transit and stadia rod. Elevations were observed approximately every 10 m along 3 transects oriented perpendicular to the contour and approximately 200 m in length. Surveyed points were captured in an ArcGIS feature class. Elevation of seawater level at an exact time was later corrected to NOAA verified water levels. Beach slope was calculated from the distance between the highest and lowest shoreline points. Tidal elevation contour lines were visually interpolated using ArcGIS Pro 2.8.

Elevation and water features were mapped in the field on June 24, 2021 (Fig. 14). The average slope for this beach from three elevation survey transects conducted was 0.42% grade.

Water Features

A large drainage channel cuts across the Quilcene Bay tidelands. We mapped a small portion of the drainage channel (Fig. 14, blue line) but the channel was primarily outside of our target survey area.

Sediment composition

Sediment composition was assessed following modified visual-analytical methods of Dethier and Schoch 2006: three replicate 0.25 m2 photoquadrats were taken at random locations along an elevational contour. Photoquadrats are analyzed in the laboratory by using ImageJ (https://imagej.nih.gov/ij/) to measure grain lengths at 16 standardized, pre-set locations within each replicate and assigning each grain to a class on the Wentworth scale (Wentworth 1922, Table 6). A flat ruler or section of transect tape was included in each photo for image calibration.

Based on photoquadrat analysis, sediment at Quilcene bay was primarily composed of granules up to 3.9 mm in diameter, with coarse sand (up to 0.9 mm grain diameter) and very coarse sand (up to 1.9 mm in grain diameter) making up the second and third largest proportion of sediment (Table 6, Fig. 15).

Table 6. Wentworth Scale used to classify sediment grains for processing photoquadrats.

Grain diameter upper limit (mm)	Type	Grain diameter lower limit (mm)	Category
0.00049	Dust	0.00049	Mud
0.00389	Clay	0.00389	Mud
0.00779	Very fine silt	0.00779	Mud
0.01559	Fine silt	0.01559	Mud
0.0309	Medium silt	0.0309	Mud
0.06249	Coarse silt	0.06249	Mud
0.1249	Very fine sand	0.1249	Sand
0.2499	Fine sand	0.2499	Sand
0.4999	Medium sand	0.4999	Sand
0.9999	Coarse sand	0.9999	Sand
1.9999	Very coarse sand	1.9999	Sand
3.9999	Granules	3.9999	Gravel
64.9999	Pebbles	64.9999	Gravel
249.9999	Cobbles	249.9999	Gravel
1000	Boulder	1000	Boulder

Firmness

Substrate firmness was assessed at the standardized survey points along the aforementioned transects. Firmness was determined by pressing the substrate surface with a hand-held spring penetrometer (Pocket Penetrometer, AMS, Inc., American Falls, ID) and recording the resistant force (tons per sq ft). Geolocation of firmness values were recorded in an ArcGIS feature class. Three replicates were taken at each sample location.

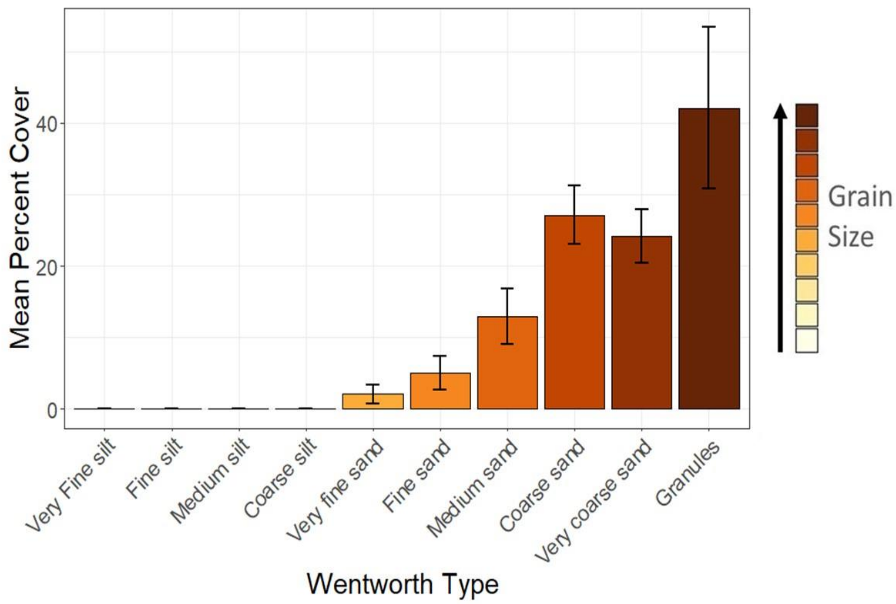


Figure 15. Mean Percent cover of sediment in each Wentworth Grain Type size class (see Table 6) for Quilcene Bay.

Substrate firmness was greater than 4.5 tons per ft² (maximum reading of the spring penetrometer) for all points surveyed at Quilcene Bay except one, where it was 4.3 tons per ft².

Emergent substrate

Emergent substrate was assessed concurrently with substrate firmness. The dominant emergent substrate type was described at each sample position (e.g. rock, Clam shell, Live Pacific oyster). The percent cover of any emergent substrate type was assessed using the point-intercept method.

Vegetation

Presence of vegetation (including eelgrass) was assessed concurrently with substrate firmness, at the same survey points. Vegetation presence at the survey point was categorized as red, green, or brown macroalgae, or eelgrass, and as either drift or attached. Macroalgae abundance was assessed by observing cover (%) using the point intercept method in a 0.25 m^2 quadrat with a 4x4 grid (16 intersections). If eelgrass was present, shoots within the quadrat were counted. If the eelgrass meadow edge entered the survey area, an upper delineation was mapped in the field using a handheld Trimble R1 GNSS receiver that supplied position information to ESRI Field Maps application, which loads the feature geometry, notes, and photos directly into an ArcGIS Feature Class.

Eelgrass was present in very low density at the lower edge of one of our survey transects, but the high density meadow edge was below our survey area and consistently submerged, so was not delineated. Standing at the water line when the low tide was -3 ft on June 24, 2021, the eelgrass meadow remained more than 100 m offshore. The beach is divided into multiple managed parcels and there are posts in the

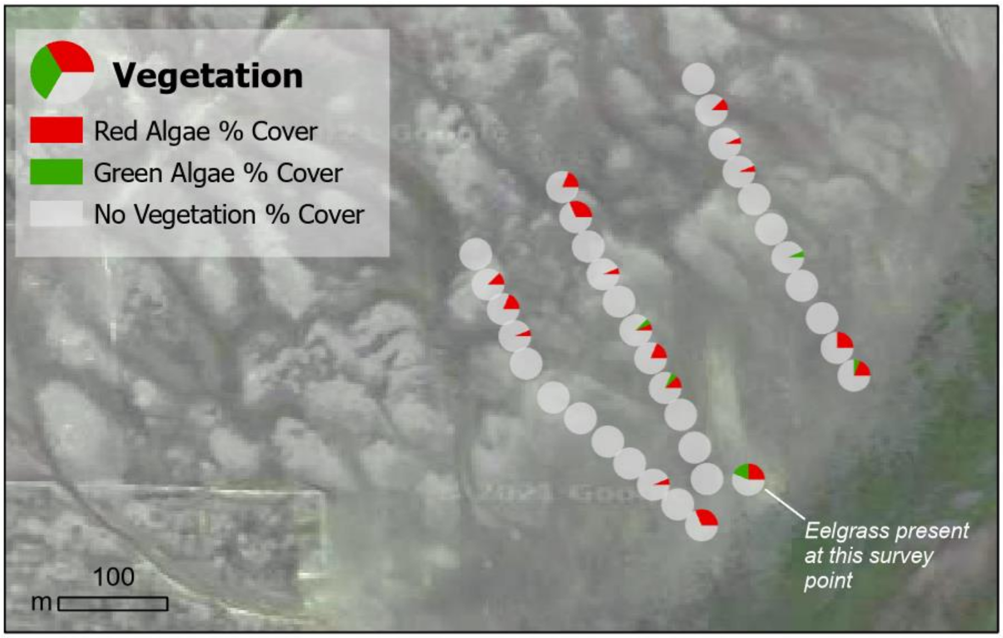


Figure 16. Map of seasonal vegetation presence and percent cover from June 24, 2021 habitat characterization survey at the head of Quilcene Bay. Percent cover of red and green macroalgae shown as pie chart at each point (red = red algae % cover, green = green algae $ cover, gray = no vegetation % cover). Eelgrass was absent except in one sample, indicated with label and leader line at lower left corner of map.

ground indicating the boundaries - we mapped some of these lines in our survey area for reference (Fig. 14, white dotted lines).

Vegetation presence was low overall, with less than 50% cover in all samples, and less than 25% cover at all but two samples. Vegetation was most commonly red macroalgae attached to substrate and occasionally green macroalgae attached to substrate (Fig. 16). Attached brown algae was observed at only one survey point and constituted less than 6.5% cover for that point. Eelgrass was observed at only one survey point (labeled in Fig. 16), where 5 eelgrass shoots (*Zostera marina)* were counted in the sample, a density of 20/m^2. A shallow eelgrass meadow delineation was not mapped for this area since the primary distribution of eelgrass was not close (within 50 m) of the survey area.

C1c. Oyster Characteristics

Population Assessments

On June 23, 2021, PSRF staff conducted targeted demographic surveys at previous seeded cultch outplant test plots (Fig. 10, areas B and C). For QB3 (Fig. 10, area C), haphazard sample positions were selected within the observed footprint. A 0.25 m^2 quadrat was placed at each sample position and all oysters were counted. For the first ten individual Olympia oysters observed in each quadrat, shell height (mm) was measured from the umbo to the furthest point on the shell margin. In the QB4 seeded cultch test plot (Fig. 10, area B), the entire footprint (14.9 m^2) of emergent shell was censused due to the small area. At QB3, we estimated the mean density for Olympia oysters at 33.1/m^2 +/- 7.9 SE from 7 haphazard 0.25 m^2 samples. Multiple year-classes were observed; the shell heights observed ranged from 17 mm to 46 mm, mean shell height was 29.8mm (n = 57, Fig. 17a). This suggests multiple successful recruitment events since the 2016 outplant.

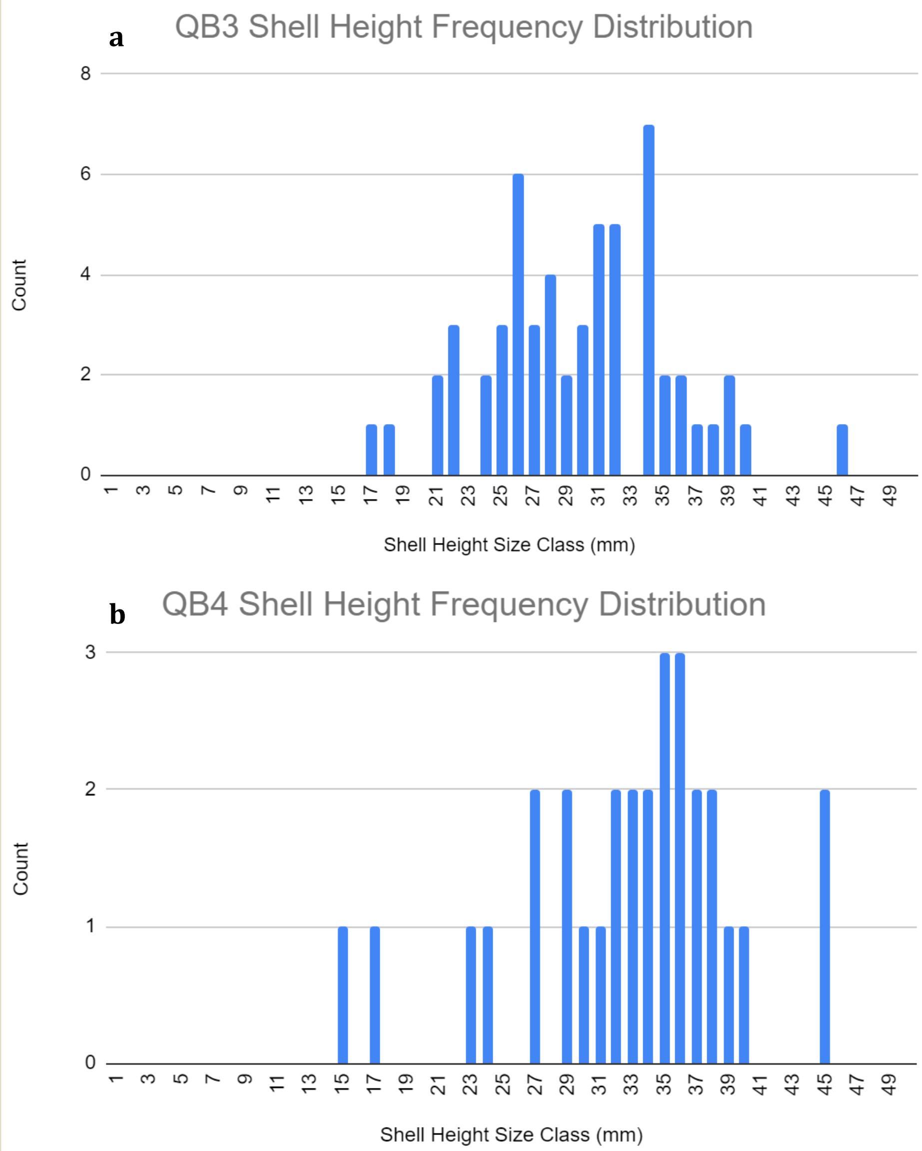


Figure 17. Shell height (mm) frequency distribution resulting from demographic surveys in QB3 (a) and QB4 (b) on June 23, 2021. Note the different y-axis scales.

At QB4, we surveyed the entire 2016 seeded cultch site (14.9 m^2) and found a total of 30 live Olympia oysters in our census; a density of 2 oysters/m^2. Multiple size classes were also observed at QB4; shell height ranged from 15mm to 45mm; mean shell height was 32.7mm (n = 30, Fig. 17b).

Community Data

Olympia oyster predator and competitor presence was assessed concurrently with substrate firmness, at the same sample points. Oyster drills (*Ocinebrellus inornatus*) were recorded as present (1 or more) or absent for each sample point if they were observed within a few meters of sample point, and any presence observations outside the targeted survey area were described in field notes. Oyster drill egg case observations were recorded as qualitative notes if they were observed at any sample point. Olympia oyster competitors, including Pacific oysters were noted if present near the sample point. If generally observed during fieldwork in the tideland, presence was qualitatively described in field notes.

Predators: Oyster drills were observed in 3 out of 35 samples during the habitat characterization survey. Notably, Quilcene Bay is a WDFW control area for the oyster drill (*O. inornatus*) and we expect the low numbers found in our samples may reflect the low level of three dimensional structure providing desirable drill habitat in the survey area. Predatory polyclad flatworms (*Pseudostylochus ostreophagus*) were cited as the cause of oyster mortality with the Jefferson County MRC 2016 seeded cultch test plots at the head of Quilcene Bay (Gordon King, *personal communication* 2019), although predation by Japanese oyster drills was also high in this test (Chris Eardley, *personal communication* 2021). PSRF staff did not observe this flatworm in our survey area, nor did they appear to cause mortality at the 2016 PSRF seeded cultch test plots at QB4 (Fig. 10, area B), or QB5 (Fig. 10, area C). We did observe evidence of predation and egg cases left by moon snails (*Neverita lewisii*), although we did not observe moon snails during our surveys. No observations of sea stars were made during our surveys.

Competitors: Pacific oysters are present along both the eastern and western shorelines of Quilcene Bay. They are more common along the more expansive eastern shoreline, and form hummocks above +1 ft MLLW elevation, approximately, whereas along the western shore they are primarily attached to the cobble substrate. Sand dollars (*Dendraster excentricus*) were not observed in the survey area.

Hardshell clam beds: Abundant Manila clam beds are present at the head of Quilcene Bay, and recreational and commercial harvesters were out on the tideland during our fieldwork. Clam beds were present in the upper portion of our survey area (above MLLW), but generally absent below MLLW. The area where we conducted our habitat survey (Fig. 14) falls within a WDFW managed tideland which supports a recreational and commercial clam fishery.

C2. Use modified NOOC Site Evaluation framework to rank site candidates

We used empirical data collected in 2021 to estimate both a Restoration Score and a Seeding Score via the NOOC Site Evaluation Table. Our sites in both Quilcene Bay and Union River/Big and Little Mission Creek sites ranked in the 20-30% range both for Restoration Score and Seeding Score. Quilcene Bay was ranked slightly higher in both scores, likely due to the higher recruitment index. However, the subtle difference in scores between the two sites and the low overall scores don’t provide a clear path forward. We started project development in Hood Canal knowing that there would be unique challenges and anticipated that those unique challenges might require a higher level of scrutiny and testing to overcome. If anything, calculating NOOC scores supports this notion.

Union River/Big and Little Mission Creeks

PSRF staff conducted two days of fieldwork surveys on June 22 and June 25, 2021. Locations of the research areas are shown in Figure 18, and specific activities further described below.

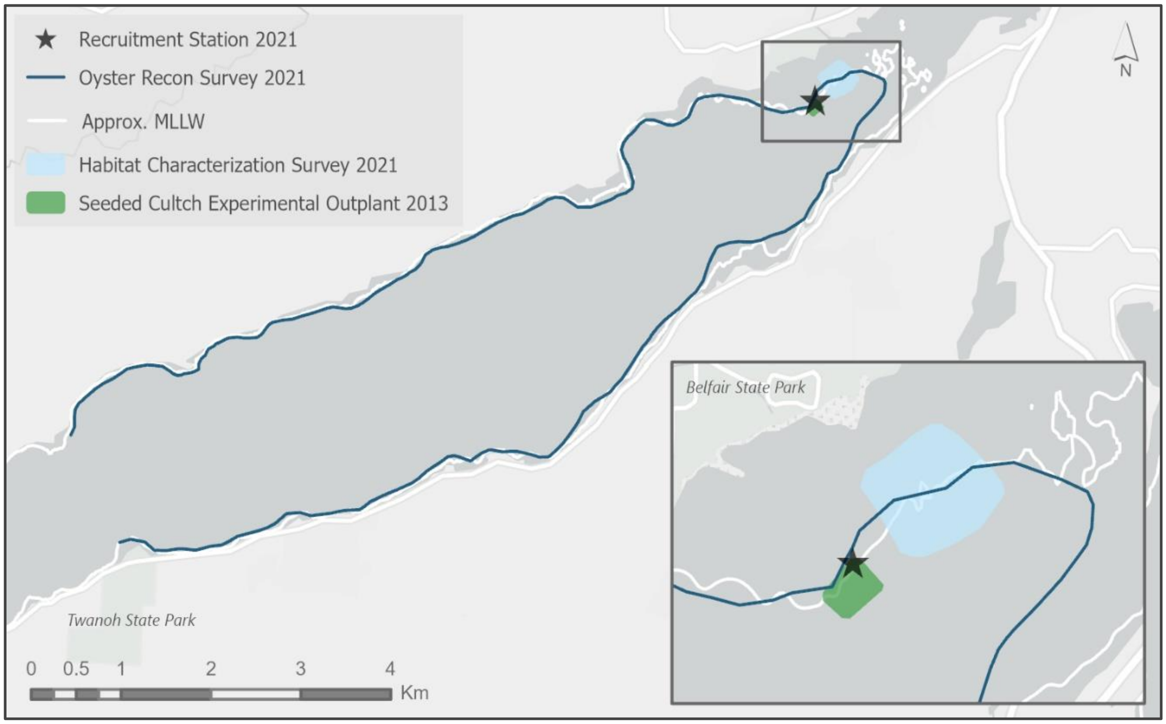


Figure 18. Map depicting previous and new study areas in Lynch Cove in the eastern arm of Hood Canal. The dark blue line shows the 2021 Olympia oyster reconnaissance survey extent, where PSRF made qualified presence observations of Olympia oysters. The habitat characterization survey area is shown in light blue. The green area indicates the extent of a 2013 experimental seeded cultch outplant (see Valdez et al. 2017). Approximate MLLW is shown as a white line on the tideland. The dark grey star indicates the position of the 2021 Olympia oyster recruitment index monitoring station.

PHASE B – Oyster Resource and Water Body Characteristics

B1. Waterbody assessment

Olympia oyster qualified presence/absence

Olympia oysters were detected in low densities (mostly rare, occasionally common) on both shores of Hood Canal as we moved southwest from UR/MC, but were absent within 3.75km of Big Mission Creek tideland where our habitat characterization survey was conducted (Fig. 19).

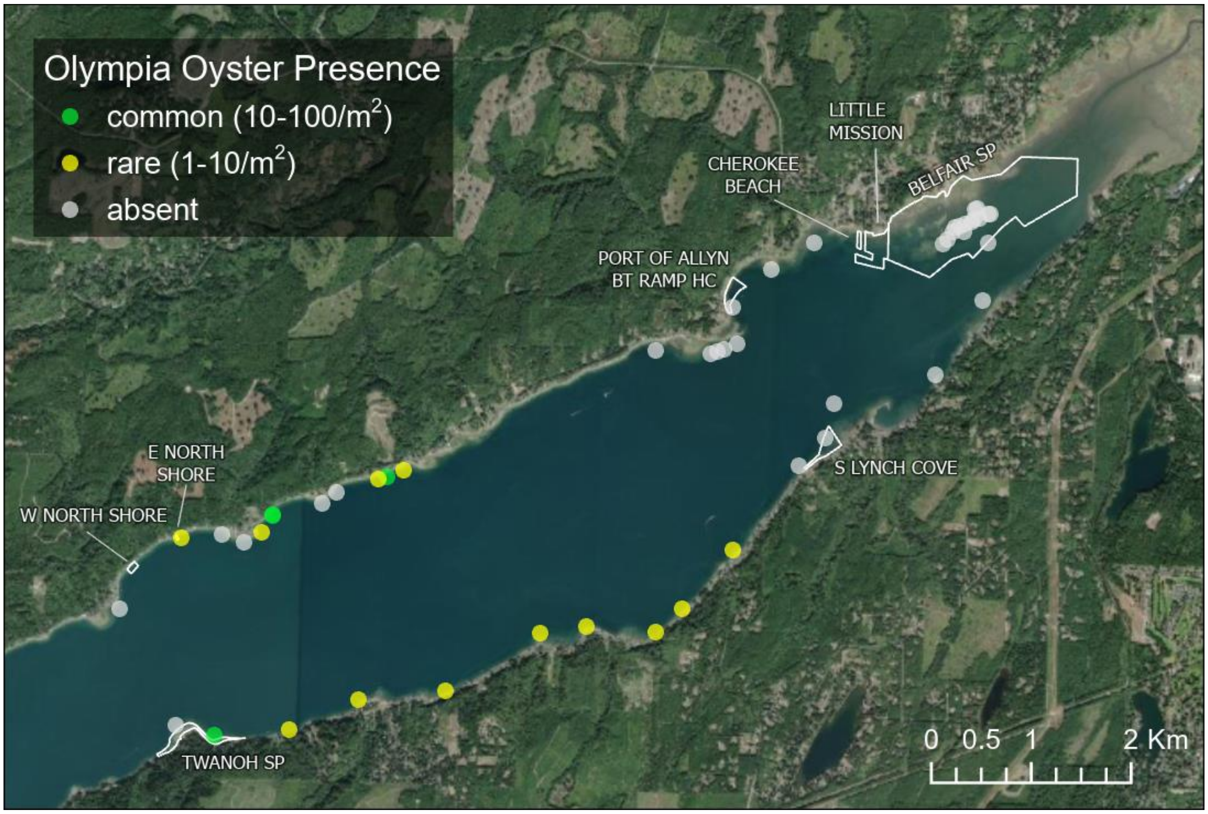


Figure 19. Olympia oyster qualified presence in Lynch Cove in the east arm of Hood Canal, as assessed on June 22, 2021. Each dot corresponds to an observation and dot color indicates qualified oyster abundance, where green = common (10-100 Olympia oysters/m^2), yellow = rare (1-10 Olympia oysters/m^2), and grey = absent. White solid lines indicate boundaries of beaches from the BIDN layer (WDFW 2021); beaches are labeled by name.

B3. Recruitment monitoring

Belfair State Park

Our Belfair State Park (BLF) station was deployed on May 5, 2021, and retrieved on August 21, 2021 for processing in the lab. This station was processed using the same methods described for the Quilcene stations. We also used subsampling due to the high volume of pacific set on many of the shells for 2021. There was a recruitment deployment in 2015, but only one shell was recovered and 8 Olympia oyster recruits were identified. Due to the small sample size, it is excluded from Fig. 8 below. Recent years with higher sample size have shown consistently low to no recruitment of Olympia oysters at this site, with mean live counts per shell at 0 +/- 0 SE in 2019, 0.2 +/- 0.0 SE in 2020, and 0.3 +/- 0.1 in 2021 (Fig. 20).

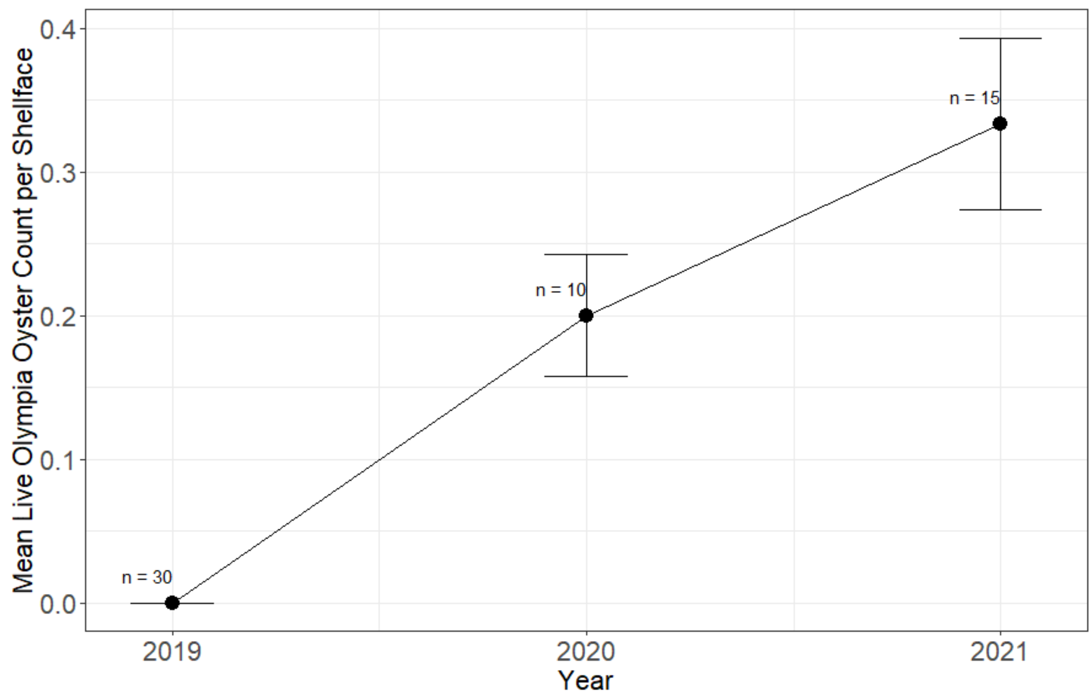


Figure 20. Mean live Olympia oyster (*Ostrea lurida*) count per shell (+/- SE) for the Belfair State Park recruitment index station for 2019, 2020, and 2021. Sample size (number of shells) for each year listed next to each point. 2015 results excluded from this graph due to low sample size (n = 1).

Skokomish Tideflats

A single station was deployed on the Skokomish tideflats at Annas Bay (47.3462N, 123.14012W, WGS84) by Blair Paul, Shellfish Biologist for the Skokomish Tribe, on May 21, 2021, and partially retrieved on September 7, 2021; the remainder of shells were recovered on September 16. Only two of three shell posts (stacks of 10 shells) were ultimately recovered, one of which was damaged and missing two shells. The recovered 18 shells were processed and two Olympia oyster recruits were discovered amongst abundant Pacific recruits. Mean live Olympia oysters per shell was 0.1 +/- 0.0 SE, indicating very low recruitment overall.

PHASE C - Site Suitability Ranking

C1a. Environmental assessment

Temperature monitoring

Intertidal temperature was monitored using Onset Hobo U20L-01 temperature logger, positioned near the -0.5 ft. (MLLW) elevation. Loggers were deployed on the beach at Belfair State Park (47.42468N, 122.87466W, WGS84) on June 23, 2021, and data was recovered using an Onset Waterproof Data Shuttle (U-DTW-1) on August 9, 2021 and again on October 15, 2021. The maximum temperature logged during that time was 34.691 °C on June 27, 2021, at 15:00 during the Pacific Northwest heat dome event in late June which co-occurred with extreme low tides (Table 7). The surrounding days in late June also had very hot daily maximums (Fig. 21a). The observed temperature extremes reported here generally co-occur with spring tidal cycles (see Fig. 21b). The minimum temperature recorded (5.76°C) occurred during an evening in October.

Table 7. Summary of logged temperature (°C) at Belfair State Park.

Site	Elevation	Deployment Date	Recovery Date	Max Temp. (°C)	Min Temp. (°C)	Mean Temp. (°C)	n	Standard Deviation	Standard Error
Belfair	0.5 to 0 ft MLLW	2021-06-23	2021-10-15	34.69	5.76	19.52	10979	3.78	0.04

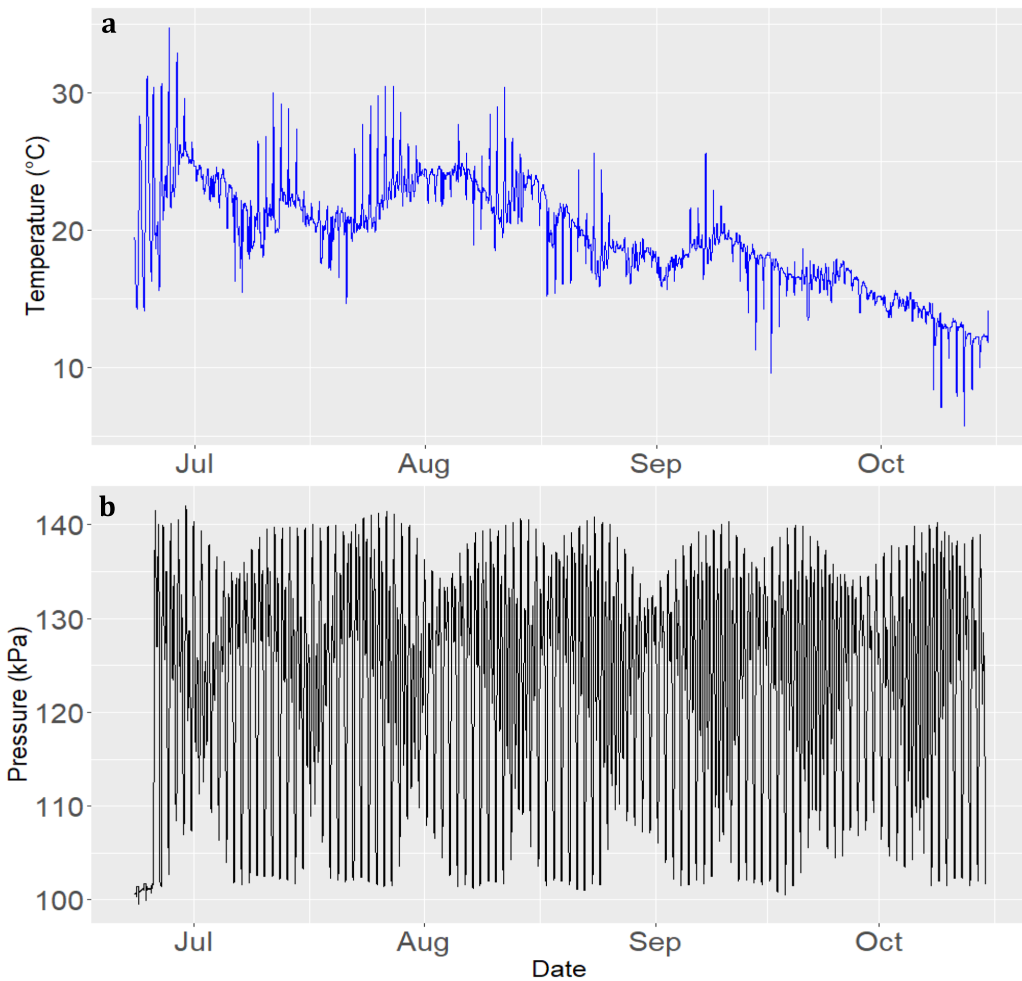


Figure 21. Temperature (°C) results from deployed instrumentation in Belfair State Park, June 23-October 15, 2021 (a). Pressure (kPa) time series data from the logger deployed at Belfair State Park, June 23 - October 15, 2021 (b). High relative pressure indicates high tide; low relative pressure indicates low tide and may include exposure of the sensor; spring tidal cycles can be seen where the difference between daily high and daily low pressure is greatest. The 10-year mean for atmospheric pressure in Belfair, WA during these months is 101 KPa (weatherwx.com).

High relative pressure indicates high tide; low relative pressure indicates low tide and may include exposure of the sensor; spring tidal cycles can be seen where the difference between daily high and daily low pressure is greatest. The 10-year mean for atmospheric pressure in Belfair, WA during these months is 101 KPa (weatherwx.com).

Salinity monitoring

Salinity data was not recovered from our conductivity logger at Belfair State Park in time for inclusion in this report. Our conductivity logger remains deployed on the beach and continues to log data, precluding an unforeseen technical issue. PSRF staff plans to recover data from that logger during daylight low tides in 2022.

Salinity data is available for this area from the 2020 Dohrn HSI model. Data interpolated based on points from the Washington Department of Health Shellfish Growing Area Monitoring Program finds mean winter salinity (November - April) in the Big Mission Creek tidal drainage area to be 13.8 +/- 0.2 ppt. Given that Big Mission Creek is not snow-melt fed, these winter months likely experience maximum creek flow and maximum freshwater input and are therefore the likeliest times for low salinity events.

C1b. Beach characteristics

On June 25, 2021, PSRF staff conducted habitat characterization and elevation surveys at Belfair State Park within the alluvial tidelands of Big Mission Creek following the same methodology described above for Quilcene Bay. At Big Mission Creek, we conducted 3 transects with a total of 40 sample points (Fig. 22).

Slope

The mean slope calculated from the 3 elevation transects surveyed at Big Mission Creek was 0.42%.

Water features

We observed multiple meandering and intersecting drainage channels of Big Mission Creek and other intertidal seeps that span the tidelands of Belfair State Park (UR/MC, Fig. 23). These drainages vary in width and depth.

Sediment Composition

Based on analysis of photoquadrats, sediment within the habitat characterization survey area at the Big Mission Creek tideland was primarily composed of fine sand (0.125-0.25 mm diameter), very fine sand (0.0625-0.125 mm diameter), and coarse silt (0.031-0.0625 mm diameter, Fig. 23, Table 6).

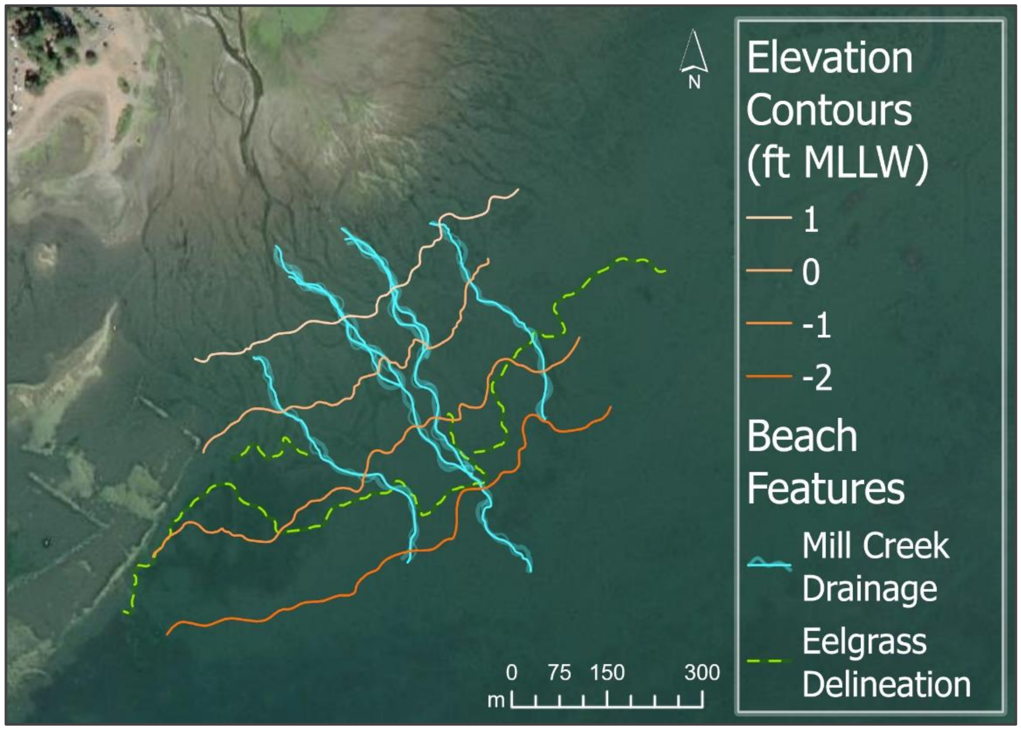


Figure 22. Map depicting the results of empirical feature mapping on the Big Mission Creek alluvial tideland area near Belfair State Park on June 25, 2021, including elevation contours (orange: lighter = higher elevation, darker = lower elevation), drainage channels (blue lines), and the shallow eelgrass delineation (green dotted lines).

Firmness

The median substrate firmness at Belfair State Park was ≥ 4.5 tons/ft², the maximum reading of the instrument. Substrate firmness ranged from 2.0 to ≥ 4.5 tons/ft².

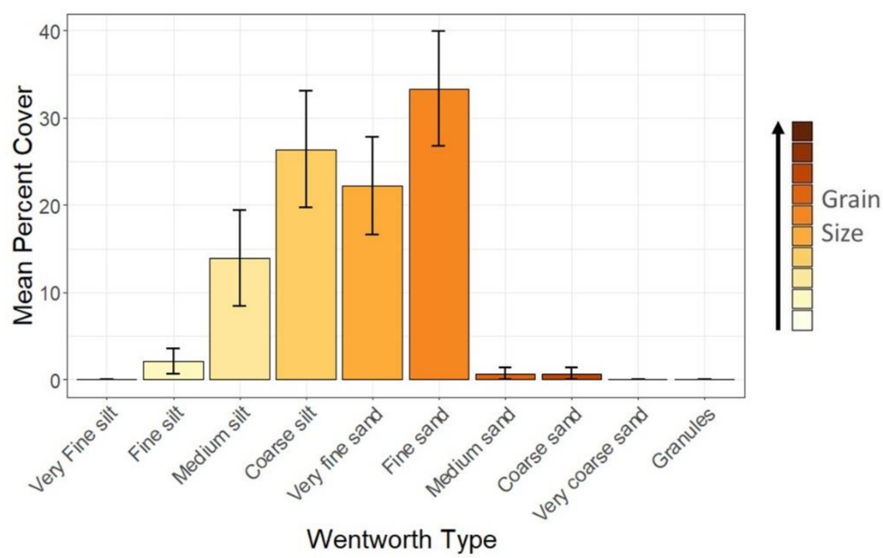


Figure 23. Mean percent cover of sediment in each Wentworth Type size class (see Table 6) for the survey area near Big Mission Creek.

Vegetation

Macroalgae was not common at the surveyed area on Big Mission Creek tideland. Some attached green macroalgae was observed in the lower southeast portion of the habitat characterization survey area, but the mean percent cover for this site was low (4.0% +/- 2.4 SE, Fig. 24). Attached red macroalgae was observed at one sample point, where it constituted less than 6.25% cover in that sample. No brown macroalgae were observed in samples.

Both *Z. marina and Z. japonica* are present around Big Mission Creek. The shallow delineation for *Z. marina* tracks closely with the -1 ft elevation contour (Fig. 22). *Z. japonica* was observed in a patchy distribution in a few locations above the deeper *Z. marina* delineation. Both grasses were observed in the habitat characterization surveys.

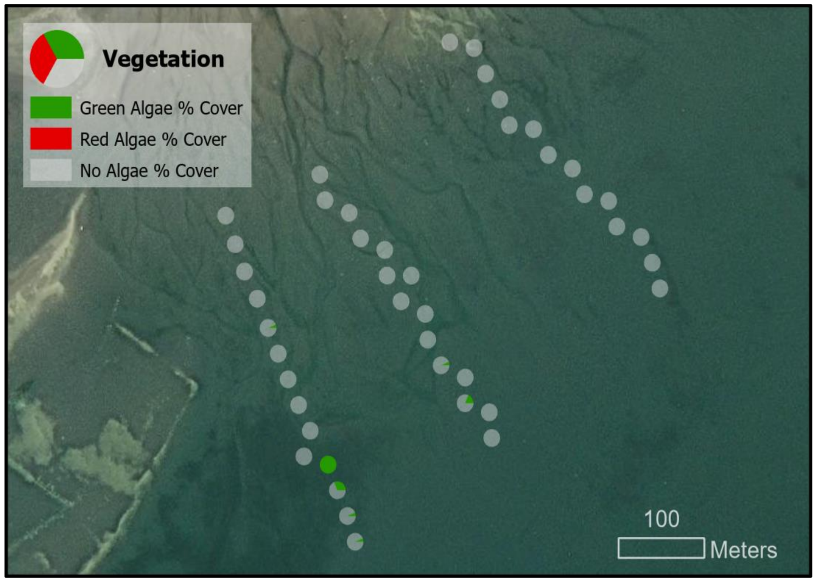


Figure 24. Map of observed vegetation presence and percent cover from the June 25, 2021 habitat characterization survey at the Big Mission Creek tidelands. Percent cover of red and green macroalgae shown as pie chart at each point (red = red algae % cover, green = green algae % cover, gray = no vegetation).

C1c. Oyster Characteristics

On June 22, we completed an Olympia oyster resource reconnaissance of much of the shoreline in Union River/Big and Little Mission Creeks, east of Twanoh State Park (Fig. 19, blue line). From a vessel, we maneuvered along the shoreline, periodically walking segments and searching for Olympia oysters, specifically targeting favorable habitat. Observations were recorded in an ArcGIS feature class via the ESRI FieldMaps application using a Trimble R1 GNSS receiver to source position information. The nature of Olympia oyster presence was described as single oysters, clusters, or structure-forming. Presence or abundance was further qualitatively assessed as either being absent (0 oysters), rare (1-10 oysters/m^2), common (10-100 oysters/m^2), abundant (>100 oysters/m^2) or aggregated structure (>100 oysters/m^2 with oysters primarily set on other Olympia oysters or relic Olympia oyster shell).

Population Assessments

No demographic surveys of Olympia oyster populations were conducted at the Big Mission Creek area because no aggregations were identified in the area during the June 2021 resource reconnaissance survey. The closest aggregations that warrant these assessments were found at Twanoh State Park on the south shore, and the Belair Cove community or Cady's Pebble Beach on the north shore.

Community Data

<u>Predators:</u> Oyster drills (*Ocinebrellus inornatus*) were not observed in the habitat characterization samples in the Big Mission Creek tideland area. Oyster drills were observed associated with Pacific oyster hummocks around the oyster dikes to the southwest. Oyster drills were also observed during the reconnaissance survey in one location, further out into the east arm of the Canal (47.404477, -

122.893526), on a cobble beach along the southeast shoreline associated with a rare Olympia oyster presence observation. The seastar, *Pisaster ochraceus*, has a known presence on these tidelands, but was not commonly observed in surveys. Ruesink & Valdez (2017) suggest the mortality of Olympia oysters in their experiment in this area may have been due in part to *P. ochraceus* predation based on their field observations. No observations or evidence of predatory flatworms were noted during the June surveys around the Big Mission Creek area.

<u>Competitors:</u> Pacific oysters are abundant at Belfair State Park and form hummocks above the +1 ft. (MLLW) contour. Sand dollars (*Dendraster excentricus*) are abundant in some areas of the east arm of Hood Canal, but generally at elevations below the survey area.

<u>Hardshell clam beds:</u> Hardshell littleneck clams (*Ruditapes philippinarum*) are present and common in and around the old oyster dikes, southwest of the area where the habitat characterization survey was performed. Hardshell clams were present in low abundance above MLLW in the surveyed area. The habitat characterization survey was conducted within the Belfair State Park tideland which is seasonally open for recreational clam harvest.

C2. Use modified NOOC Site Evaluation framework to rank site candidates

See section C2 for Quilcene Bay (p.41).

Observations in other areas - Hahobas Preserve

Hahobas Preserve is adjacent to robust populations of Olympia oysters (DNR48), however, none were observed at this site exposed to air or in shallow waters on October 3, 2021 when the tide was at +1ft above MLLW. It’s possible that Olympia oysters are present on the lower edge of their typical elevational range and would be observed on an extreme low tide. The shoreline was rocky with high relic shell content (clams and Pacific oysters).

Lessons learned from previous projects

Skokomish tideflats

Overview of Project Activities

A 2020 seeded cultch transfer and outplant was a planned component by the Skokomish Tribe for the development and management of their shellfish tidelands. Project materials for the Olympia oyster stock enhancement were funded, in-part, by the USDA. In May of 2020, 400 bags of seeded cultch from the Ken Chew Center for Shellfish Research and Restoration (Chew Center) were transferred to the Tribe's Annas Bay tideland and outplanted by the Skokomish Tribe. Some shells were tagged [mark and recapture]to monitor the post-transfer mortality of Olympia oysters.

Assessment of Project Results

Estimates of Olympia oyster spat/shell were assessed at the Chew Center hatchery prior to their transfer in 2020. The assessment was repeated one year post-outplant, in April of 2021, and again in August of 2021. Mean Olympia oyster count/shell declined one year after outplant by April of 2021, and declined again within the subsequent 5 months (Fig. 25, Table 8). The initial decrease is within the range of expected post-settlement mortality in field setting. Some Olympia oyster mortality that occurred between sampling dates in 2021 may have been related to the June 2021 heat wave; severely negative impacts were recorded for Pacific oysters in lower Hood Canal (Raymond et al. *submitted manuscript*).

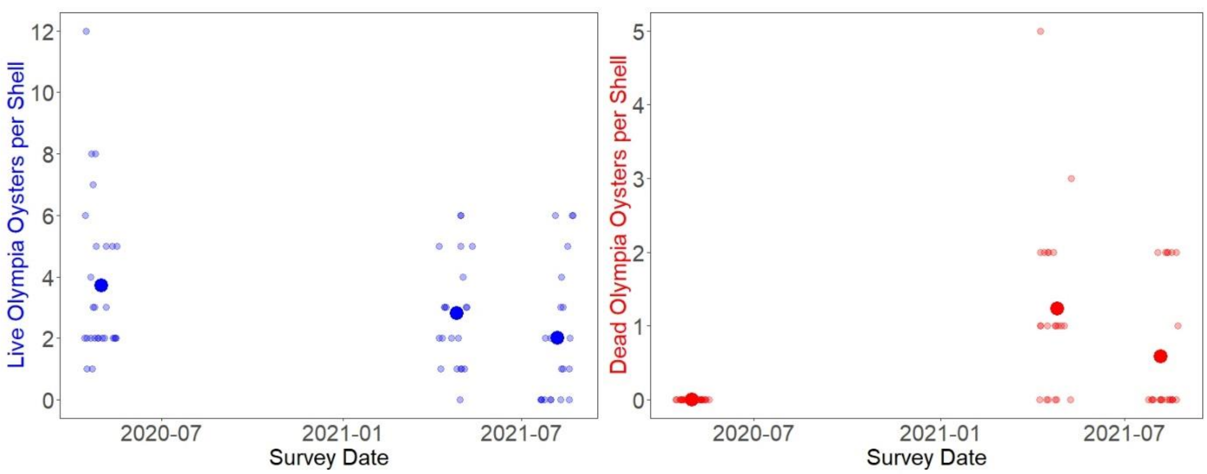


Figure 25. Live Olympia oysters (blue, right) and dead Olympia oysters per shell at Skokomish tideflats at three different survey dates; April 2020 pre-transfer, April 26, 2021, and August 6, 2021. Smaller circles represent raw counts per shell, larger circles represent mean counts for each survey. The X Axis is jittered for better visualization of raw counts.

Table 8. Summary statistics of Live and dead Olympia oysters per shell from one survey prior to outplanting and two additional surveys the following season.

Survey Date	Shells Counted (n)	Mean Live Olys per Shell	Standard Deviation	Standard Error	Mean Dead Olys per Shell	Standard Deviation	Standard Error
Pre-Transfer April 2020	27	3.7	2.62	0.50	0	0	0
4/26/2021	21	2.8	1.77	0.38	1.2	1.22	0.27
8/6/2021	22	2.0	2.16	0.46	0.6	0.91	0.19

Shell material from this project is being transported to slightly higher elevations on the beach by wind and water movement, evidenced by personnel communication with the Tribe's Fisheries staff. This site is exposed to afternoon north winds (Fig. 7).

Conclusions from Skokomish tidelands project

1. Olympia oysters grow in Skokomish tidelands.
2. Oyster cultch material is being transported up the beach, indicating there is a need to evaluate exposure and shell fidelity in some areas of Hood Canal.
3. Olympia oyster recruitment appears to be low, but this information is incomplete and limited.
4. If the Skokomish Tribe plans to continue investments in Olympia oyster population enhancement, we encourage continued monitoring of oyster recruitment in this area and potentially shell assay tests for spatial fidelity in different subregions to identify where this might be most successful. The Tribe may be more successful managing this location as an aquaculture site, as key characteristics of an Olympia oyster bed restoration site are not present. This suggests that conditions for Olympias are adequate in this part of Hood Canal and is likely so in nearby regions.
5. We should be cognizant of other Hood Canal areas with a similar wind exposure.

Port Gamble Bay

Overview of Project Activities

PSRF partnered with the Port Gamble S'Kallam Tribe in 2010 and was involved in some natural resource projects in Port Gamble Bay and Hood Canal. With funding support from the Russell Family Foundation, Port Gamble S'Klallam Tribe and Washington Department of Ecology, private property owners in southern Port Gamble Bay were approached in 2012 and 2013 about including their tidelands in a planned shell amendment project. The presence of Olympia oysters at the time was primarily in the south end and associated with relic shell and seep water below Pacific oyster hummocks found, generally, above MLLW around the Bay. A shell amendment was planned between MLLW and -3 ft. The purpose of shell amendment was to increase the available oyster settlement structure in the lower tideland. The shell amendment was completed in association with population enhancement actions along the Kitsap tidelands on the western shore, and other private tidelands on the south shore. PSRF completed a 10 acre shell amendment in August of 2014. Thereafter, iterative Olympia oyster seeding efforts were conducted using multiple methods (Table 8). Location selection for spreading single oyster seed targeted beach areas with some characteristics known to support Olympia oysters.

Table 9. Summary of the number of seed produced, seed type (seeded cultch or single oysters), and the outplant date in Port Gamble Bay.

# Seed Produced	Year	Bags/Singles	Date Outplanted	# Seed Outplanted
450,000	2014	250 bags	April 20-23, 2015	47,687
21,000	2014	Singles	May 8, 2015	16,683
50,000	2015	Singles	May 26, 2016	23,054
165,000	2016	50 bags	Apr & Aug 2016	96,982
515,264	2016	Singles	May 25, 2017	221,723
1,201,264 Total				**406,129 Total**

Assessment of Project Results

The mean density (m^{-2}) for Olympia and Pacific oysters reported from demographic surveys of the project area is shown in Fig. 26.

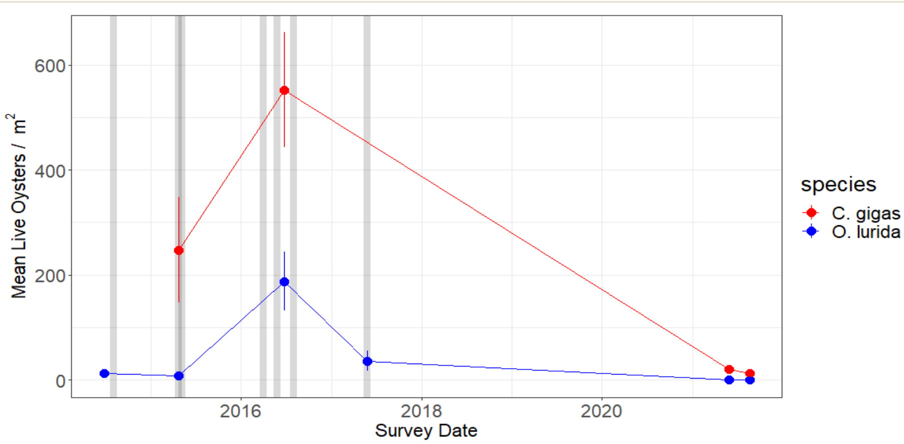


Figure 26. Mean live Olympia oyster (blue) and Pacific oyster (red) densities at Port Gamble Bay resulting from oyster demographic surveys conducted between 2014-06-25 and 2021-08-20. Grey vertical bars indicate restoration actions (see Table 8).

The recruitment index record indicates a moderate but inconsistent Olympia oyster settlement at PGK, the station deployed within the project area on the Kitsap County tidelands (Fig. 27).

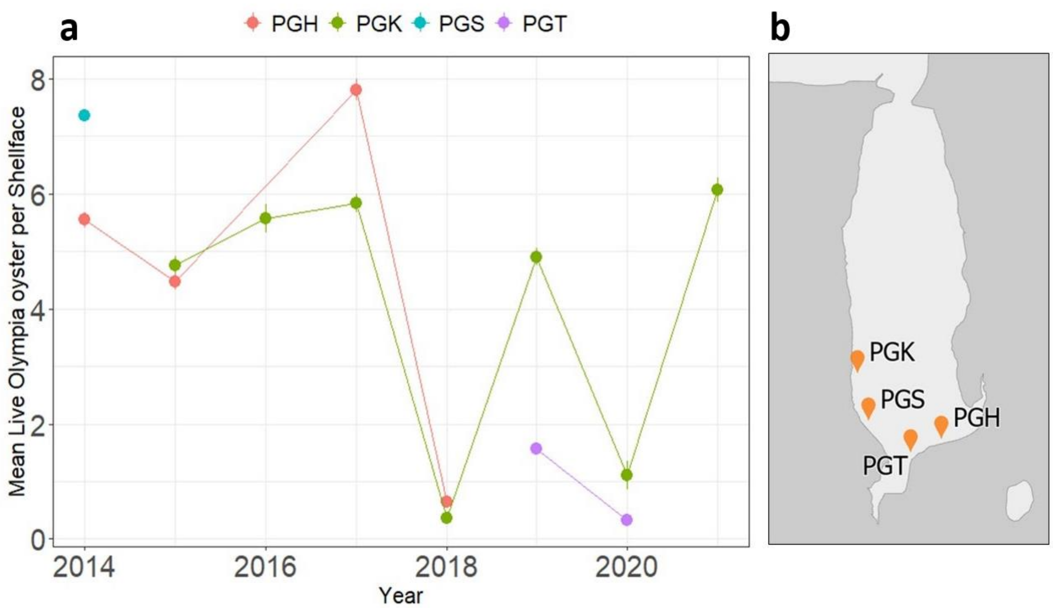


Figure 27. Recruitment index results for all Port Gamble Bay stations - Mean Live Olympia oysters/shell +/- SE across the years for which we have data (a). Map of station locations within Port Gamble Bay (b).

Conclusions from the Port Gamble Bay project

1. Pacific oyster recruitment is high relative to observations for the Olympia oyster, however a moderate Olympia oyster recruitment index was observed in the southern region (past data) and western shoreline (current data).
2. Settlement substrate is limiting in the lower elevations below MLLW and Olympia oysters are generally limited to the lower margins of the Pacific oyster hummocks. We have no evidence from within the project area to suggest that Pacific oysters preclude Olympia oyster presence, however Olympia oysters are rarely observed within Pacific oyster hummocks. Olympia oysters settled onto Pacific oyster shells could be removed from the shore by commercial harvesting of Pacific oysters. However, the hand-take methods employed in the southern regions of Port Gamble Bay are unlikely to have the same magnitude of impact as areas where dredging is employed.
3. Shell does not display spatial fidelity on western shoreline, presumably due to wind exposure from the southeast. Shell moved higher, above MLLW, potentially exacerbating the difference in magnitude between Pacific and Olympia oyster set.
4. Need to look for places that are less exposed to the prevailing winds; practitioners should include exposure ranking in the assessment of project areas. Longshore transport and hydrodynamics should be assessed, if possible. The southern end of the Bay is not impacted by winds to the same extent.
5. Seeded cultch assays are critical prior to larger enhancement actions, and should be monitored for longer than one year (to capture a range of conditions).

6. Practitioners can use these lessons to better structure their approaches (as we did here in the Assessment Pathway).

Henderson Inlet

Overview of Project Activities

Single Olympia oysters were outplanted between 2018 and 2020 on the Nisqually Tribe's tidelands in Henderson Inlet. Single oysters were used instead of seeded cultch at the request of the Tribe. At the time, they were concerned that the additional shell would complicate the issues they were experiencing with control of the oyster drill (*Ocinebrellus inornatus*). The oyster drill will utilize emergent structure in their seasonal reproductive assemblages.

1. 150,000 singles transferred in 2018
2. 140,000 singles transferred in 2019
3. 40,000 singles transferred in 2020

Assessment of Project Results

Prior to the Olympia oyster outplant in 2019, two small surveys of Japanese oyster drill density found fewer than 1.0 individual m^{-2} (Table 10). Olympia oyster demographic surveys in 2019, prior to the outplant at Henderson Inlet, and in 2020, the year following the outplant, revealed a slight increase in density from 0 to 0.24 individuals m^{-2} (Table 11).

A subset of single oysters were tagged (mark and recapture) prior to being transferred to the beach. Twenty-two of these marked oyster shells were recaptured on August 4, 2020 during monitoring surveys. Of the 22 animals recaptured, only seven were live (68% mortality). The mean shell height for live oysters was 20.7 mm (+/- 1.6 SE) and the mean shell height for dead oysters was 22.7 mm (+/- 1.1 SE).

Table 10. Drill (*Ocinebrellus inornatus*) density results from biological characterization surveys from 2019-06-20 (first half of transect) and 2019-07-29 (second half of transects).

Survey Date	Samples (n)	Total Area Surveyed (m^2)	Mean Drills per m^2	Standard Error
2019-06-20	6	1.5	0.9	0.25
2019-07-29	4	1	0.3	0

Table 11. Results from Olympia oyster demographic surveys pre- (2019-07-29) and post- (2020-08-04) outplant at Henderson Inlet.

Survey Date	Samples (n)	Total Area Surveyed (m^2)	Mean Live Olympia Oyster/m^2	Standard Error	Mean Dead Olympia Oyster/m^2	Standard Error
2019-07-29	4	8	0	0	0	0
2020-08-04	10	3.25	0.2	0.08	8.8	2.79

Conclusions from the Henderson Inlet project

1. Emergent shell substrate as oyster settlement structure does not appear to be limiting in that part of Henderson Bay.
2. Juvenile single oysters are a preferred prey for Japanese oyster drills (*Ocinebrellus inornatus*). The increase in mean size at outplant for single oysters compared to seeded cultch is not an effective deterrent for snail predators. We do not recommend using single oysters for population enhancement in areas with a high predator density.
3. The threat of drill predation cannot be eliminated. Many practitioners choose to avoid restoration projects in regions of excessively high drill density, but project-specific priorities can take precedent over predation risk. Practitioners need to continue exploring methods for areas where predator densities are high but restoration is highly desirable.
4. Drill or drill egg removal or similar management strategies can be employed to reduce predation threat.
5. Oyster drills can be present in persistent Olympia oyster beds, if alternative prey are present and oyster density and recruitment are sufficient (Buhle 2007). The balance between oyster drill and Olympia oyster densities that will sustain oyster populations will vary from location to location. Oyster drills can be very cryptic in this habitat when they are not emergent in their spring assemblages, therefore, quantifying densities when doing detailed place-based surveys such as in the Site Suitability Ranking (Phase C) step of the Assessment Pathway will be important to the continued development of guidelines on drill densities and restoration recommendations.
6. Monitoring of oyster seed transfers should be extensive on these projects so that fates can be determined.

Discussion and recommendation of next steps

Quilcene Bay

Olympia oysters are present along much of the shoreline of Quilcene Bay. The biogenic bed habitat that Olympia oysters form, however, is absent based on recent assessments. Generally, Olympia oysters are concentrated near the entrance to the Bay at the southern end, along both the east and west shores. In our recent population surveys at Fisherman's Point and Frenchman's Point, we found dense assemblages of Olympia oysters that represent multiple year-classes.

The west shore of the Bay consists of steep and rocky tidelands with only a small intertidal bench to support Olympia oyster bed development. Olympia oysters are found aggregated in moderate density on the surface of cobbles, live Pacific oysters, and Pacific oyster shell (Brady Blake, *personal communication* 2021; Fig. 10, area C). The east shore of the Bay is composed of sands and gravels and has a few beaches at lower elevations. Pacific oyster hummocks and relic shell are abundant above MLLW. Olympia oysters are found between the northeast corner (QB4) and Frenchman's Point, associated with the relic oyster shell found below the Pacific oyster hummocks. The elevations below MLLW along most of this east shore quickly become steep as they approach extreme low water.

The head of Quilcene Bay includes a large salt marsh, bisected by the Big Quilcene River, which drains towards East Quilcene, and large tidelands accessed from Linger Longer Road. The tidelands on the east side of the river drainage are soft mudflats with eelgrass meadows distributed up to MLLW; elevations above MLLW include patchily distributed Pacific oyster hummocks.

Tidelands at the head of the Bay are absent of Olympia oysters. Our information suggests they would have been concentrated in this location, based on protracted residence time and shellfish resources. Today these tidelands used for commercial aquaculture and recreational shellfish harvest, primarily for Manila clam, with some harvest of Pacific oyster.

Assessments of test plots of seeded cultch from 2016 that were located in the northeast corner of the Bay (Fig. 10, Area B) and showed good growth and survival of oysters when they could remain emergent above the soft ground. However, the soft conditions ultimately consumed the cultch, which was found near completely buried when surveyed in 2021. From our experience in other sites with soft substrate (e.g. Liberty Bay, Kitsap County and Fidalgo Bay, Skagit County), the biological and geomorphological paradigms that create these soft conditions do not necessarily preclude the possibility of oyster bed development. However, establishment of persistent oyster bed habitat will require a considerable population of oysters and regular recruitment. There is evidence of some larval production in this area of Quilcene Bay, observed through consistently low-magnitude spatfall seasons (Fig. 11b) at the recruitment index station (QB4). The low level is likely insufficient to maintain the Olympia oyster aggregation and settlement structure at the site. We recommend that further assays or habitat enhancement actions east of the river drainage should only be conducted after determining how extensive larval retention is predicted to be at the head of Quilcene Bay and developing a robust Olympia oyster population elsewhere in the Bay.

West of the river drainage, the substrate conditions in our survey area were primarily sand and gravel (Fig. 15), in contrast to those to the east of the drainage. The west side site (QB5, Fig. 10, area A) is a firmer beach than what we observe east of the river drainage. Beach firmness may indicate that water processes such as movement from the tidal prism, river drainage, and exposure or circulation are sufficient to transport finer sediments such that they do not accumulate. Intertidal bioturbator species, like the burrowing shrimp (*Neotrypaea californium*) or other infauna that affect benthic firmness do not appear to have developed assemblages in this area.

We also observed some remnants of the Jefferson County MRC seeded cultch test plots established in 2016 (Fig. 10, area A). This shell fidelity suggests that the transport regime on this tideland is sufficiently moderate so the shell does not move far; this condition would benefit from further assessment. Additional evidence is needed to avoid a situation where shell enhancement material is transported into higher elevations where it would conflict with the hardshell clam fisheries. This type of evaluation is important, as we learned from the shell amendment project in Port Gamble Bay, and to a lesser extent by the population enhancement project on the Skokomish tidelands. Emergent shell fidelity assessments are among the benefits of conducting and monitoring seeded cultch assays in potential project sites. The confluence of habitat conditions west of the river drainage, and below existing aquaculture and clam areas, suggests that this is a region that merits further assessment and consideration.

Olympia oyster larvae are in the system in Quilcene Bay; this is evident in the recruitment index record, with all stations recording the presence of Olympia oyster settlement (Fig. 11b). There is a gradient of adult abundance from north to south, with the primary aggregations concentrated near the south entrance (see Olympia oyster resource reconnaissance and demographic survey, Fig. 10). Similarly, we could characterize the recruitment index as being low-magnitude in most years, with the exception of QB3, near Frenchman's Point in 2021. Considered all together, evidence of primary aggregations and recruitment activity, the Olympia oyster resource and activity appears concentrated in the southern half of Quilcene Bay. Alternatively, the tideland space we associate with Olympia oyster bed (lower littoral bench, etc.) is concentrated near the head of the Bay and is well-represented by the green shaded areas in the Dohrn HSI model (Fig.5, HSI scores 0.5-0.75).

The evidence collected to date suggests that there are factors at play that are restricting the development of Olympia oyster populations at the head of the Bay in spite of the favorable habitat conditions (substrate composition, shell fidelity, firmness, grade). These include indicators described in this report; primarily the absence of conspecifics, a settlement substrate limitation, and a low-magnitude recruitment index. Olympia oyster recruitment may also be limited by an undescribed hydrodynamic in Quilcene Bay that separates the primary resource and assumed larval source concentrated in the southern half of the Bay from tidelands at the head of the Bay.

The reported mortality observed with the Jefferson County MRC oyster seed assay in 2016 (see B1e. Predation). suggest that there may be a predation-related factor for oyster juveniles as well; however, this was not confirmed or observed at PSRF oyster seed assays sites at QB3 and QB4. One difference between these seeded cultch plots from 2016 was that the Jefferson County MRC cultch bags were temporarily stored on the tideland for a practice called "hardening", while the seeded cultch for the PSRF plots were outplanted directly without this step. Hardening oyster spat-on-shell is a common practice in shellfish aquaculture to provide the juvenile oysters a level of protection during the juvenile stage. Seeded clutch bags are stacked in piles and left in the intertidal for 6 to 12 months prior to being spread onto the beach. These formations of stacked cultch bags are also an attractive refuge for the predatory flatworm (Jason Regan, *personal communication* 2021), which may have facilitated the observed mortality with the Jefferson County MRC plot.

We are aware of ongoing work in this watershed and along the Big Quilcene River for salmon habitat restoration, led by the Hood Canal Salmon Enhancement Group. A project of this nature may alter river discharge, floodplain and tidelands. In consideration of this effort, it may adjust the timeline for Olympia oyster population and habitat enhancement action recommendations. An evaluation of the historic and contemporary conditions in Quilcene Bay and discussion with resource managers have concentrated the interest for further Olympia oyster bed habitat restoration project assessment and initial actions at the head of the Bay, west of the river drainage.

Recommendation for future action in Quilcene Bay

Further actions in Quilcene Bay would benefit from an evaluation of hydrodynamic vectors, gyres, and eddies that may limit mixing and affect water quality, larval distribution and residence. A spatial representation of this information would help identify areas that facilitate autochthonous production and oyster larval retention. An appreciation of this dynamic is fundamental to correlate the physical and biological conditions on the ground. Should a hydrodynamic be described that deters mixing from north and south parcels in the Bay, stock rebuilding should be considered as a possible action to achieve larval enhancement and retention at the head of the Bay.

In spite of the low-magnitude recruitment index observed at the stations in the head of the Bay (QB4 and QB5), a substrate amendment could be used to increase population abundance since there is more space within the appropriate elevation range. Further habitat characterization, a hydrodynamic assessment and further oyster and shell [seeded cultch] assays focused on the area west of the Big Quilcene River drainage is the recommendation for initial future actions. The eelgrass meadow is extensive at the head of Quilcene Bay, and its shallow distribution may have encroached on areas historically occupied by Olympia oysters. Future Olympia oyster restoration work could explore enhancement activities adjacent to, or in association with eelgrass, a protected habitat. Working in eelgrass can be successful for Olympia oysters (Valdez & Ruesink 2017), however, careful design and specific regulatory considerations will be needed.

A key takeaway from the work to date in Quilcene Bay is that further assessments are needed to identify candidate sites prior to investments in population enhancement activity. The seeded cultch assay is the recommended approach. Once the ranking of assay performance suggests a feasible location, iterative enhancements should proceed in earnest and at scale to build the resulting adult population to near 1 million oysters. Small enhancements may not provide a sufficient population abundance to overcome predation pressure (Valdez & Ruesink 2017, Jefferson County MRC seeded cultch test near QB5). Below is a distilled and prioritized list of future actions to consider in Quilcene Bay for Olympia oyster bed habitat restoration.

1. Continue to follow progress of HCSEG and the project on the Big Quilcene River and coordinate actions
2. Continue to coordinate actions with resource managers (Tribes, WDFW), Jefferson County Marine Resource Committee, commercial shellfish growers, and regional stakeholders.
3. Expanded hydrodynamic assessment
    a. Evaluate existing information
        i. Oceanographic modelling
        ii. Water Quality surveys and assessments
        iii. Drogue / drifter survey
        iv. Geomorphological, or sediment dispersal studies
        v. Acoustic Doppler Current Profiler survey
    b. Empirical survey (during the dry summer season)
        i. Water quality continuous or cast data to evaluate stressors and stratification
        ii. Chlorophyll survey as a proxy for parcel residence time
        iii. Drifter survey to identify circulation anomalies (eddies)
4. Larval distribution assessment
    a. Apply existing models
    b. Empirical survey
5. Continued oyster and shell assays
    a. Focused on areas west of the Quilcene River and below commercial and recreational shellfish utilized areas
6. Continued recruitment index monitoring, with additional stations maintained at the head of Quilcene Bay
7. Iterative [200 bags/year for 5 years] Olympia oyster population enhancement at scale for larval enhancement and conspecific recruitment facilitation once a feasible enhancement site is determined.
8. Shell amendments, once regular recruitment is observed, are recommended to further develop the population and increase the habitat space to ecologically relevant scales.

Union River/Big and Little Mission Creeks (Lynch Cove)

This location in the east arm of Hood Canal is one of WDFW's priority sites in Puget Sound for Olympia oyster recovery (Blake & Bradbury 2012). Lynch Cove is on this list largely due to its importance for historic harvest and landings recorded from this area and historic seed production and cultivation; the remnant intertidal dikes at Belfair State Park are a relic of prior exploitation. The historic oyster bed habitat is estimated to cover thousands of acres at the head of Lynch Cove. This would have been an important marine resource for native people and a large functional component of the habitat complex at the head of Hood Canal. Today this area hosts an expansive salt marsh, intertidal flats, a naturalized Pacific oyster (*C. gigas*) population and expansive meadows of eelgrass (*Z. marina*).

PSRF staff covered a portion of the shorelines in Lynch Cove during an Olympia oyster resource reconnaissance survey looking specifically for the current distribution of Olympia oysters, and to identify the closest aggregations of oysters to the priority recovery site at the head of Lynch Cove, at Big Mission Creek. That effort revealed a near complete absence of Olympia oysters in the neighborhood of the priority recovery site, and low abundance within 6-8 kilometers of the area (Fig. 19). An oyster presence of this nature suggests a limiting source population, limited and infrequent recruitment and/or limited post-set survival. Due to the nature of the spatial distribution, it is probable that the larval source for the observed presence is outside Lynch Cove.

PSRF focused our limited scope for site assessment on the identified WDFW priority recovery site east of Belfair State Park, an alluvial tideland below Big Mission Creek. Here we found the sediment composition and firmness, water features, and beach slope are congruent with Olympia oyster bed development (see C1b. Beach characteristics). It is a mix of soft and firm ground composed of gravels, sands and silt (Fig. 23). Eelgrass is present below -1 ft. (MLLW) and appears to retain tidewater and attenuation of water movement, based on the water features and softer substrate observations in samples near the -1 ft. (MLLW) contour. Oyster settlement structure is limited and tidelands below MLLW are largely unstructured. The Olympia oyster recruitment index record for Belfair State Park (2018-2021) is consistently near zero (Fig. 20).

Based on this limited evaluation of oyster resource and habitat conditions at the priority site, our initial conclusions are that the existing Olympia oyster resource is limiting the further development of the population in Lynch Cove. As a consequence, local larval production and settlement substrate are limited; larval production, available settlement substrate and regular recruitment are all dependent on a well-developed local source population. These attributes are the factors that, in turn, facilitate the oyster bed to persist. This circumstance would need to change in Lynch Cove in order to proceed with investments in Olympia oyster bed habitat restoration.

To work toward this change, proponents would need to empirically identify locations with habitat conditions that contribute to emergent shell fidelity, oyster survival and larval retention on a spatial scale relevant for oyster bed development. This recommendation is based on lessons learned from previous project work in Port Gamble Bay and Quilcene Bay. Historically, these were locations of protracted water residence (terminal heads of waterbodies). We suspect the priority recovery site, or this region of Lynch Cove may support these conditions. The distribution of eelgrass (*Z. marina*) may present a regulatory consideration to this work, depending on the chosen site. These species (Olympia oyster and eelgrass) are intertidal neighbors relative to their zonation, so it is fair to assume this work would involve a close association with eelgrass.

Oyster predators were not observed in abundance during the habitat characterization survey at Big Mission Creek, though they are known to be present. The entire ear arm of Hood Canal is a WDFW control area for the oyster drill (*O. inornatus*). Predation was an observed problem in an earlier study of enhancements using seeded cultch (Valdez & Ruesink 2017) and with single oysters in our comparison study (Henderson Inlet).

Recommendation for future action in Union River/Big and Little Mission Creeks (Lynch Cove)

Seeded cultch assays are useful to evaluate a variety of locations with a minimal investment of resources. Assays of this nature, combined with the monitoring of their fate over several seasons can elucidate a ranking scheme to identify locations with a higher aptitude for the fidelity of emergent substrate and oyster survival. Further combined with an understanding of the local hydrodynamic process would prioritize feasible sites for their potential with larval retention.

We have the means to conduct stock rebuilding, but location is critical for the survival and growth of oysters, the spatial fidelity of emergent oyster substrate, for larval retention and the potential for regular recruitment. Below is a distilled and prioritized list of future actions to consider in Lynch Cove for Olympia oyster bed habitat restoration. It suggests a larger campaign of information gathering, assessment, monitoring and testing prior to any strategic population rebuilding effort which would have attendant assessment and monitoring components to measure outcomes.

1. Continue to follow progress of HCSEG and regional projects, and coordinate actions
2. Continue to coordinate actions with resource managers (Skokomish Tribe, WDFW), Greater Peninsula Conservancy, commercial shellfish growers, landowners and neighborhood associations, and other regional stakeholders.
3. Further assessment of the entire east arm, east from Sister's Point
    a. Assess hydrodynamic behavior and vectors east of the Skokomish River to Union River
        i. Potential methods are listed above
        ii. Specifically, to examine connectivity from the main basin to the east arm, east of Sister's Point.
            1. Monitoring to assess resource connectivity west and east of Sister's Point, the narrows that likely affects hydrodynamic connectivity.
        iii. Identify and locate systematic eddies, gyres
        iv. Use proxy surveys to identify regions of increased water residence time
    b. Further assess the Olympia oyster resource and demographics
        i. Identify and assess source populations
        ii. Assess larval distribution, suggested methods:
            1. Empirically

            a. Tows or pumped samples
            b. Larval traps
         2. Intuit from source abundance and spatial distribution
         3. Apply existing distribution models
      iii. Monitor recruitment index at several stations along the east arm.
4. Conduct seeded cultch assays to rank potential sites for population and larval enhancement
   a. This provides evidence of oyster growth and survival
   b. This examines spatial fidelity for emergent shell
5. Conduct further habitat assessments as needed
6. Monitor environmental parameters
7. Upon identifying suitable (hydrodynamic alignment, low exposure, high shell fidelity, oyster survival, larval retention, low spatial competition with Pacific oysters) location(s), begin stock enhancement project activity with the goal of larval enhancement within Union River/Big and Little Mission Creeks
   a. Iterative enhancements (e.g. 5 separate conservation hatchery lines) to maximize population genetic diversity and mitigate hatchery selection
8. Build the local [site] adult population to near 1 million oysters in one or more locations
   a. Monitor the developing population (demographics, survival, reproduction)
   b. Monitor larval production and distribution in the east arm of Hood Canal
   c. Monitor Olympia oyster recruitment
      i. Recruitment index stations associated with ambient [ground cultch] substrate sampling
   d. Monitor reference [existing remnant aggregations] locations (e.g. Twanoh State Park, Belaire Cove, Tahuya) for population changes to utilize control and treatment comparisons.
9. Monitor oyster population development at project sites
   a. Demographic survey to identify age and size structure and recruitment

Additional recommendations for future actions in Hood Canal

1. Continue to build collabs and enhance communication between restoration practitioners, resource managers, and local community.
2. Design a study to detect magnitude of positive impact of conservation aquaculture on stock rebuilding in lower Hood Canal between Annas Bay and Lynch Cove. This needed data acquisition is supported by WDFW east of Annas Bay in lower Hood Canal. The Skokomish Tribe is interested in coordinating outplant on their tidelands and with private tideland owners.

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Links

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Washington Coastal Atlas, WA Department of Ecology https://apps.ecology.wa.gov/coastalatlas/tools/Map.aspx

ImageJ, Wayne Rasband. https://imagej.nih.gov/ij/

Salish Sea Model, Pacific Northwest National Laboratory. https://www.pnnl.gov/projects/salish-sea-model

Native Olympia Oyster Collaborative https://Olympiaoysternet.ucdavis.edu/

List of Appendices

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A. Assessment Pathway Data Interpretation Guidelines

Phase A – Regional Habitat Suitability

Characteristic	Factor	Metric	Learned from this step	Proceed if
A1a. Imagery	Visual identification of broad habitat & human use features		Frequently can identify highly dynamic "exposed" regions that should be avoided.	Any.
A1b. Elevation contour	high frequency, verified contour geo-located reference	Elevation in feet, relative to datum for Mean Lower Low Water (MLLW)	This information is not very accessible for intertidal elevations. Water level observations are useful for estimates. Empirical determination through corrected survey is the most reliable and accurate approach.	Accurate intertidal contours are important spatial reference and should be mapped for any project site.
A1c. Longshore transport – drift cells	Longshore transport - drift cells	direction and behavior (erosion or deposition)	In the absence of marine geomorphological study for a project site, these offer some insight into factors affecting sediment composition and prevailing directionality for transport. This factor is often weak, variable or divergent at terminal head tidelands.	These are described for most Puget Sound shorelines. They are models of directionality and behavior of longshore sediment transport and can be useful information to illustrate physical factors for a given location.
A1d. Circulation patterns	Larval retention	Direction and magnitude vector	This information is important to identify shorelines within waterbodies that are spatially associated with hydrodynamics that separate or restrict water parcels (gyres, eddies). These prevailing behaviors influence dispersal and retention of plankton.	Any.
A1e. Water residence spatial analysis	Larval retention	Days to replacement, a.k.a. "turnover"	Spatial analysis of this information aligns readily with historic oyster bed habitat distribution in Puget Sound, and has been useful to identify contemporary aggregations. Residence times at 20-25 days, or more, are of particular interest.	This information is helpful to identify specific water bodies (inlets, bays, coves), and locations within those water bodies, with a protracted water residence time. This information is sometimes available from empirical study or models.
A2. Dohrn HSI	Habitat Suitability Index Score	0-1.0 on a relative scale	Relative proportion of waterbody that has environmental characteristics suitable for supporting Olympia oysters.	Any, but give extra attention to in situ assessment for regions with HSI scores < 0.5 and always select subregions with higher scores when possible.

Phase B – Oyster Resource and Waterbody Characteristics

Characteristic	Factor	Metric	Learned from this step	Proceed if
B1a. Exposure	Receives prevailing winds, waves, storms	Exposure	Used with HSI to evaluate the waterbody.	Shoreline is medium or low exposure.
B1b. Circulation	Qualitative water movement in a regional water body	Vectors from a publicly available model	Sub-locations where water pools & eddies; separation of water parcels by gyres.	Any .
B1c. Water residence	Time for flushing	days	Rank site success = higher residence likely to be more successful if other factors met	Any or no information available. Any over 25 days is ideal.
B1d. Water quality	Air temperature	extreme highs or lows over successive days	Above 30°C or near 0°C (Pritchard et al. 2015) for prolonged periods of time indicates potential stressful conditions. Amelioration may be possible by careful selection of microhabitat features such as availability of pools, seeps, or eelgrass for thermal refuge.	Any.
	Water temperature			Above 0°C year-round. At least 12.5°C in spring for reproduction (Baker 1995).
	Salinity	ppt		Not below 15 ppt for 7 consecutive days. 20 ppt average or higher in all months is best (Baker 1995).
	Chlorophyll (optional)		Proxy for residence time & measure of food availability.	[This is an optional characteristic.]
B1e. Oyster presence	Presence of existing adult population		Evidence of natural settlement Whether an adult population is contributing.	Any.
B1f. Historic locations			Historic locations of oyster beds indicate conditions suitable to support robust populations, at least at that point in time Historic oyster reserves may be eligible for certain types of project funding.	Any.
B1g. Terrestrial inputs		[Use historic native bed x historic discharge to determine level.]	Can contribute to the right shoreline morphology (alluvial flat), but can be a stressor if river is large.	Seeps and channels exist across tidelands, but no obvious high-discharge river.

Phase B – Oyster Resource and Waterbody Characteristics (continued)

Characteristic	Factor	Metric	Learned from this step	Proceed if
B2. Limiting factors	Habitat loss		History of habitat loss can help to explain current stressors limiting natural Olympia oyster recolonization.	Any.
	Local oyster abundance	order of magnitude of Olympia oyster density within area	Estimate total number of individuals from qualitative density estimate and area covered. Consider whether stock enhancement may be recommended.	Any.
	Local oyster settlement structure	singles, clusters, beds	Evaluate current state of Olympia oyster structured habitat on beach. Consider extent of restoration needed.	Any.
	Alternative human use of land		Commercial aquaculture leases, commercial & recreational harvest.	Any.
	Predation	Presence. Density may be appropriate in some cases of site assessment.	Checking with resource managers, growers, or including observations from resource reconnaissance. Determine if a WDFW managed drill area and if bamboo worms, flatworms, seastars known pests for regional aquaculture.	Any.
B3. Recruitment monitoring	Live Olympia oysters	Mean recruits/shell [Assume station is in the right place]	Consider whether stock enhancement may be recommended: High recruitment = high likelihood for success; Medium recruitment = Pay careful attention to shell enhancement test plots, pending evaluation of adult population in water body; Low or no recruitment = Will need broodstock enhancement, pending evaluation of adult population in water body.	Any: High = Mean recruits/shell >5 in any years is considered high; Medium = 0 < mean recruits/shell < 5 in 3 of 5 years (3 of 10 in Blake & Bradbury 2012); Low = 0 recruits/shell in 3 out of 5 years.

Phase C - Site Suitability Ranking

Characteristic	Factor	Metric	Learned from this step	Proceed if
C1a. Environmental assessment	Temperature	°C	Hone in on location closer to site where work would be done.	Expected range.
	Salinity	ppt	Hone in on location closer to site where work would be done.	Expected range.
C1b. Beach characteristics	Slope	% Grade	Lots of space for an oyster bed to occupy at correct elevation (then millions to rebuild pop).	Shallow grade within appropriate elevation - not high energy shoreline.
	Composition	% composition of Wentworth grain size categories, emergent substrate type	How much substrate amendment is needed to provide settlement structure. If there is lots of large gravel/cobble a shell amendment may not be needed. We recommend that some of emergent substrate be shell.	Not majority consolidated hard substrate - anything in gravel/sand/mud/shell is appropriate .
	Firmness	Qualitative (boot test) & tons per sqft	Oyster bed is associated with conditions that facilitate softer, unconsolidated sediment conditions which contribute to emergent shell spatial fidelity.	Heel to Ankle (not sure what the penetrometer eq. is here); Sweet spot = Below ankle.
	Water features	presence/absence & type (pool, seep, minor drainage)	Retained tide water and intertidal seeps facilitate thermal refugia and mitigate sedimentation.	Present.
	Emergent substrate	% cover	Extent to which desirable settlement substrate - rock or shell - is present emerging from any layer of soft sediment.	

Phase C - Site Suitability Ranking (continued)

Characteristic	Factor	Metric	Learned from this step	Proceed if
C1b. Beach characteristics (continued)	Vegetation	type (red, green, brown macroalgae; attached or drift) and cover	Macroalgae presence can facilitate a thermal refuge for oysters. Seasonal and perennial macroalgae (specifically red, and brown) correlate with a low exposure disturbance which is favorable to oyster bed development.	Accumulated seasonal drift abundance is low enough such that hypoxic conditions aren't likely to develop.
		eelgrass - delineation of shallow distribution	Eelgrass meadows are features that can attenuate exposure and facilitate tidewater retention. Eelgrass and Olympia oysters overlap in range, but special considerations and permits may be required for projects that extend into eelgrass.	There is an expanse of Olympia oyster habitat at a higher tidal elevation than eelgrass -or- if working with regulatory agencies on permissions for working in eelgrass.
C1c. Oyster characteristics	Geolocation of existing oyster resource	qualitative presence (absent, rare, common, structured)	Reconnaissance of the entire waterbody is a critical early step to assess the level and spatial distribution of the existing oyster resource. This step is the mechanism to identify the primary assemblages.	Any.
	Targeted demographic survey	density (oysters / m^2)	Assess need for stock enhancement. Identify and begin data collection for a "reference population" to assess impact of restoration action on previously existing Olympia oyster population.	Any.
		size distribution within population	Consistent absence of certain sizes suggests recruitment limitation (Wasson et al. 2015).	Any. Success greater likelihood if broad distribution of sizes.

Phase C - Site Suitability Ranking (continued)

Characteristic	Factor	Metric	Learned from this step	Proceed if
C1c. Oyster characteristics (continued)	Presence of predators	qualitative presence, density (individuals / m^2)	Consider locations within sites. Consider exploratory tests. Consider management methods that might accompany restoration when predator density is high.	Predator threat has been incorporated into recommended project actions, either in the form of attempted risk reduction or in further experimental tests.
	Presence of competitors	qualitative presence, density (individuals / m^2)	Consider how competitors may respond to a restoration action given environmental conditions. Ex: On a wind-exposed beach, if shell gets moved to higher elevation via wind/wave energy, Pacifics.	Any. Presence of competitors may help inform decision about appropriate restoration action for a site.
C2. NOOC eval	Site restoration score	0%-100%, from estimated data	One way to rank sites based on relative environmental suitability. Consider whether stock enhancement is recommended. Evaluate intended outcome and success metrics if very low score.	Any.
	Site seeding score	0%-100%, from estimated data	One way to rank sites based on relative environmental suitability. Consider whether stock enhancement is recommended. Evaluate intended outcome and success metrics if very low score.	Any.

Phase D - Site In Situ Assessment

Characteristic	Factor	Metric	Learned from this step	Proceed if
D1. Environmental assessment	Intertidal temperature monitoring	Temperature (°C)	PSRF uses temperature monitoring to monitor oyster temporal reproductive behavior, correlate to empirical information, describe intertidal exposure regimes, and can be used to describe other microhabitat attributes directly or in proxy.	Temperature monitoring is efficient and useful in a variety of applications in project development, implementation and for monitoring outcomes.
	Intertidal salinity monitoring	Logged Conductivity (µsec/cm) data, with start and end observations of atmospheric pressure, temperature, and salinity (ppt) can readily converted datasets to Salinity (ppt)	This metric is useful generally to describe habitat conditions, exposure to terrestrial inputs, mixing.	Salinity within tolerated stressor range.
D2. Structure amendment trial	Persistence of shell emergent above the substrate for multiple years	Percent Cover, and or displacement volume. Maps and standardized photos are also useful for comparisons at T0, T1, T2, etc.	Spat on shell assays are useful to evaluate a variety of locations with a minimal investment of resources. Assays of this nature, combined with monitoring their fate over several seasons can elucidate a ranking scheme to identify locations with a higher aptitude for the fidelity of emergent substrate and oyster survival.	Shell generally maintains location with respect to: (1) persistence as emergent above the benthic surface (not buried in sediment); and (2) fidelity to original position (not transported longshore, or scattered by drainages, or to higher elevation via exposure).
D3. Biological assessment	Oyster bioassay	Growth and survival	See above.	Evidence suggests oysters are capable of growing and recruiting to the adult population at this location. These assays may also provide other evidence of physical or biological factors to oyster survival.
	Recruitment Index monitoring	Young-of-the-Year (YOY) index (mean counts and sizes for live and dead Olympia oysters)	Recruitment Index monitoring, combined with resource assessments can be useful to intuit reproductive behavior within and among waterbodies.	Recruitment index monitoring is a useful monitoring tool made more useful from comparative spatial or temporal index data.

B. Data inventory (files transferred to HCCC)

Task	File Name	Site(s)	File Type	Survey Type	Data Collection Date	Description
1.1	quilcene_oysterrecon_scannednotes_2018	Quilcene Bay	.pdf	presence/absence recon	2018	scanned notes of qualitative observations of Olympia oyster presence along Quilcene Bay shorelines from 2018 survey
1.1	quilcenebay_oysterdemographic_count_2019-07-18	Quilcene Bay	.xlsx	oyster demographic - count	2019-07-18	Olympia oyster demographic (shell height, count per m2) around QB2 & QB3
1.1	quilcenebay_oysterdemographic_shellheightfr_2019-07-18	Quilcene Bay	.xlsx	oyster demographic - shell height frequency	2019-07-18	Olympia oyster demographic (shell height, count per m2) around QB2 & QB3
1.1	oyster_assessmentpathway_quilcenebay_2020_oysterdemo_rawdata_2020-07-31	Quilcene Bay	.xlsx	live-on-shell and oyster demographic	2020-07-31	Olympia oyster count and shell height from a few surveyed quadrats, and 2 quadrats of live-on-shell counts near QB4
1.1	HSI_areas_results_0720	Quilcene Bay, Belfair State Park	.docx	HSI	2020-07	Dohrn HSI results for Quilcene Bay and Lynch Cove (Belfair/East Arm)
1.1	hoodcanal_recruitmentdata_all_2021-11-19	Quilcene Bay, Dabob Bay, Dosewallips, Belfair State Park, Dewatto Bay, Bald Point, Port Gamble Bay, Hama Hama	.csv	recruitment data	2014-2021	all hood canal recruitment data from 2014 - 2021, includes inventory of which stations were deployed which years, all count data and, all shell height data
2.1	oyster_assessment_belfairstatepark_elevationtransect_2021-06-25	Belfair State Park	.xlsx	elevation	2021-06-25	elevation data, raw and corrected, for Belfair State Park
2.1	hoodcanal_belfair_beachrecon_20210625_TableToExcel	Belfair State Park	.xlsx	habitat characterization/beach recon	2021-06-25	exported from GIS layer, general habitat characterizations done in association with elevation survey
2.1	2021_MissionCrk_SubstrateComposition_Raw	Belfair State Park	.xlsx	sediment composition	2021-06-25	results from processed sediment composition photos
2.1	HCSI_belfair_temp_pressure_RAW_2021-06-22	Belfair State Park	.csv	logger - temperature/pressure	2021-08-09	temperature and pressure logger data from 2021-06-22 to 2021-08-09

2.1	HCSI_belfair_temp_pressure_RAW_2021-08-09	Belfair State Park	.csv	logger - temperature	2021-10-15	temperature and pressure logger data from 2021-08-09 to 2021-10-15
2.1	HCSI_EastArm_Belfair_FilesForTransfer.gdb	Hood Canal East Arm/Belfair State Park	ZIPPED .gdb	all spatial data associated with surveys	2021-06-22, 2021-06-25	all spatial data collected for fieldwork in Hood Canal East Arm and Belfair State Park; includes oyster presence survey points throughout east arm and detailed habitat characterization survey points and lines - files were compiled in ESRI ArcGIS Pro 2.8
2.1	HCSI_EastArm_Belfair_KML_FilesForTransfer.kmz	Hood Canal East Arm/Belfair State Park	.kmz (compressed KML)	all spatial data associated with surveys	2021-06-22, 2021-06-25	spatial files in KML format - can be opened in Google Earth
2.1	quilcenebay_QB3_oysterdemographic_count_2021-06-23	Quilcene Bay	.xlsx	oyster demographic - count	2021-06-23	oyster demographic survey near QB3 (2016 seeded cultch) - counts - 7 haphazard samples
2.1	quilcenebay_QB4_oysterdemographic_count_2021-06-23	Quilcene Bay	.xlsx	oyster demographic - count	2021-06-23	oyster demographic survey near QB4 (2016 seeded cultch) - counts - only 1 sample
2.1	quilcenebay_QB3_oysterdemographic_shellheightfr_2021-06-23	Quilcene Bay	.xlsx	oyster demographic - shell height	2021-06-23	oyster demographic survey near QB3 (2016 seeded cultch) - shellheights - associated with 7 samples
2.1	quilcenebay_QB4_oysterdemographic_shellheightfr_2021-06-23	Quilcene Bay	.xlsx	oyster demographic - shell height	2021-06-23	oyster demographic survey near QB4 - shell heights for that 1 sample
2.1	HCSI_Quilcene_FilesforTransfer.gdb	Quilcene Bay	zipped GDB	all project spatial data	2021-06-24	all spatial data from Quilcene Bay collected for this project including habitat characterization points, interpreted elevation contours, and mapped lines in the field. File geodatabase was packaged in ESRI ArcGIS Pro 2.8
2.1	HCSI_Quilcene_KML_FilesforTransfer.kmz	Quilcene Bay	.kmz (compressed KML)	all project spatial data	2021-06-24	kmz (compressed KML) version of spatial files, compatible with Google Earth
2.1	oyster_assessment_quilcenebay_2021-06-24	Quilcene Bay	.xlsx	elevation	2021-06-24	elevation survey (corrected) in association with the habitat characterization survey points

2.1	quilcenebay_beachrecon_20210624_TableToExcel	Quilcene Bay	.xlsx	habitat characterization/beach recon	2021-06-24	beach recon/habitat characterization for the head of Quilcene Bay, close to the MRC outplant
2.1	2021_QuilceneBay_SubstrateComposition_Raw	Quilcene Bay	.xlsx	sediment composition	2021-06-24	results from photos processed in ImageJ for sediment composition in Quilcene Bay
2.1	HCSI_Quilcene_Salinity_2021-05-13	Quilcene Bay	.csv	logger - salinity	2021-10-15	contains salinity data calculated from conductivity and temperature via HOBOware Pro for deployment of logger 2021-05-13 to 2021-10-04; values corrected using field-collected measurements
2.1	HCSI_QB_temp_pressure_raw_2021-05-13	Quilcene Bay	.csv	logger - temperature pressure	2021-10-15	temperature and pressure data from logger deployment in Quilcene Bay, 2021-05-13 to 2021-10-04
2.2	hendersoninlet_oysterdemographic_count_2019-07-29	Henderson Inlet	.xlsx	oyster demographic - count	2019-07-29	Olympia oyster demographic survey pre-project; no olys found in 4 x 2m transects
2.2	oyster_postprojectmonitoring_hendersoninlet_2020_processeddata_2020-08-04	Henderson Inlet	.xlsx	oyster demographic, tagged animal survey	2020-08-04	demographic data from 2020 survey of 2019 singles transfer and mark and recapture
2.2	hendersoninlet_biolcharacterization_2019-06-20AND2019-07-29	Henderson Inlet	.xlsx	biological community	2021-06-20, 2019-07-29	biological community survey, epibenthic cover survey, firmness survey using 5 strike penetrometer.
2.2	2014 PGB kitsap tideland_June 25 population survey	Port Gamble Bay	.xlsx	oyster demographic	2014-06-25	oyster demographic survey in Port Gamble Bay kitsap tidelands
2.2	PGB kitsap tideland_April 23,2015 population survey	Port Gamble Bay	.xlsx	oyster demographic (oly & pacific), emergent substrate volume	2015-04-23	oyster demographic survey and emergent substrate volume sampling in Kitsap tidelands
2.2	2017_density samples	Port Gamble Bay	.xlsx	oyster demographic	2017-05-25	oyster demographic survey in Port Gamble Bay
2.2	portgamblebay_postproject_liveonshellcount_raw_2021-05-27	Port Gamble Bay	.xlsx	live on shell	2021-05-27	oyster demographic survey in Kitsap tidelands

2.2	portgamblebay_postproject_oysterdemographic_count_raw_2021-05-27	Port Gamble Bay	.xlsx	oyster demographic - count	2021-05-27	oyster demographic survey in Kitsap tidelands in project area and reference area
2.2	portgamblebay_postproject_oysterdemographic_shellheights_raw_2021-05-27	Port Gamble Bay	.xlsx	oyster demographic - shell height	2021-05-27	oyster demographic survey in Kitsap tidelands in project area and reference area
2.2	oysterdemographic_portgamblebay_2014outplant_2016-06-22	Port Gamble Bay	.xlsx	oyster demographic - counts only, oly & pacific	2021-11-23	oyster demographic survey in 2014 PGB seeded cultch outplant area
2.2	2021_04_26_Oly_survival_Skok.xlsx	Skokomish Tidelands	.xlsx	post project - live and dead oysters on marked shells	2021-04-26	From Blair Paul 2021 - spat on shell counts for marked shells (no other data as of 10/11/2021)
2.2	Oly_numbered_shell_counts_2021	Skokomish Tidelands	.xlsx	post project - live and dead oysters on marked shells	2021-08-06	From Blair Paul 2021 - spat on shell counts for marked shells (no other data as of 10/11/2021)
2.2	HC20_SOS tagging	Skokomish Tidelands	.xlsx	pre project spat-on-shell count	Pre May 2020	Spat on shell counts for marked shells - pre deployment

C. Photo inventory (files transferred to HCCC)

Category	Date(s)	Number of Photos
GPC Walk & Talk at Hahobas	Oct 3, 2021	43
GPC Land Labs at Belfair State Park	Sept 20 & 21, 2021	371
PSRF Fieldwork Photos - Hood Canal East Arm/Mission Creek	June 22 & 25, 2021	10
PSRF Fieldwork Photos - Quilcene	June 23 & 24, 2021	25

D. List of collaborators and meetings held

Washington Department of Fish and Wildlife (WDFW)

Brady Blake, Shellfish Biologist, Brady.Blake@dfw.wa.gov
Chris Eardley, Puget Sound Shellfish Policy Coordinator, Christopher.Eardley@dfw.wa.gov

Skokomish Indian Tribe

Blair Paul, Shellfish Biologist, bpaul@skokomish.org

12/16/2021 - WDFW, 1 h (online)
12/18/2021- Skokomish Shellfish Dept, 1 h (online)
04/12/2021 - Skokomish Shellfish Dept, 1 h (online)
06/24/2021 - Skokomish Shellfish Dept, 0.5 h (in field at Quilcene Bay)
07/08/2021 - WDFW, 2 h intermittent (in field at Kilisut Harbor)
07/09/2021 - WDFW, 2 h intermittent (in field at Kilisut Harbor)
11/03/2021 - Skokomish Shellfish Dept, 1 h (online)
11/04/2021 - WDFW, 2 h (online)
11/23/2021 - WDFW, 1 h (online)

E. Regulatory Compliance

Any in-water activity in Puget Sound that involves the placement of material, like many of the recommended actions for Olympia oyster bed habitat restoration assessments and enhancement projects, requires several layers of authorization. Permissions from property owners (private or public), concurrence from affected treaty tribes, regulatory review, authorization and permits from federal, state and local agencies are all part of that process. In PSRF's experience it is best to plan ahead, be inclusive as you develop proposals, and allow for the time resource managers and regulators need to review and provide determinations. There are minimal application fees for this process under most circumstances, but it does take a dedication of time to gather required information, research your area, prepare proposals, applications and to manage the review process. It can take 6 months to a year to move through the process, depending on your level of preparation and experience.

Agencies, Resource Managers, and Regulators

Below is a list of agencies, resource managers and regulators and the authorizations they manage. This report focused on recommendations for two specific regions of Hood Canal, which have some differences in property ownership, stakeholders, resource managers and regulatory agencies.

Agencies and jurisdictions

US Federal: US Army Corp of Engineers, Seattle District Regulatory Branch reviews proposals for projects involving the placement of bulk, loose or bagged shell or other substrate enhancement, or other proposed discharges or fill in federal water. Depending on the proposal, there are a variety of authorization and permitting paths they may recommend. Endangered Species Act consultation is completed with US Fish and Wildlife Service and National Oceanic and Atmospheric Administration (NOAA) Fisheries; this is specifically germane for work in eelgrass or for work interactions with other trust species or protected habitats. Clean Water Act, and Coastal Zone Management authorizations are through the federal permit coordinator at Washington Dept. of Ecology.

Tribal: Treaty tribes in the Hood Canal include the Skokomish Indian Tribe, and Point No Point Treaty Council representing Port Gamble S'Klallam, Jamestown S'Klallam, and Lower Elwha Klallam tribes; natural resources staffs from these tribes should be consulted for assessments, during project development, and included in proposals to other regulating agencies for concurrence.

State: Early consultation with WDFW on Olympia oyster restoration projects is advised. For enhancement projects (shell or other substrate enhancement), The WDFW Habitat Program regulates this activity with a Hydraulic Project Approval (HPA). The WDFW Habitat Program may be able to sponsor some projects, which facilitate an expedited HPA review through the Fish Habitat Enhancement Process (FHEP) HPA (See RCW 77.55.181(1a)(i)(B)(iv)). If shell or other substrate enhancement will be performed, a WDFW transfer permit is required to transfer material into State waters; this includes hatchery supplements of oysters which have additional health and disease screening requirements. If projects occur on State-owned Aquatic Lands

(SOAL), regulatory permission is required from the Washington Department of Natural Resources, and will require a Licence for Use, and a Study Plan. Unless exempt through acquisition of a FHEP HPA, the lead State agency or Shoreline authority will require a determination under the State Environmental Policy Act (SEPA).

Shoreline Authority: In Quilcene Bay, Jefferson County Office of Community Development regulates any project with Shoreline Management Act jurisdiction. In Lynch Cove, the Mason County Department of Community Development regulates any project with Shoreline Management Act jurisdiction. Most conservation or restoration projects can apply for a Substantial Shoreline Development Exemption (SSDE) permit. The acquisition of a FHEP HPA for the project offers an administrative path with the Shoreline Authority to qualify for a SSDE permit, along with other statutory benefits.

Local jurisdiction: Washington State Parks Department, Belfair State Park. Activity on Park property requires permission from the agency and may have additional fee or permit requirements.

Other concerned parties: In Quilcene Bay, this includes tideland owners, Hood Canal Salmon Enhancement Group, Jefferson County Marine Resources Committee (MRC), and Hood Canal Coordinating Council. In Lynch Cove, this includes tideland owners, Great Peninsula Conservancy, Hood Canal Salmon Enhancement Group, and Hood Canal Coordinating Council.

Joint Aquatic Resources Permit Application

The Joint Aquatic Resource Permit Application (JARPA) is the primary form to use and prepare your proposal for review. Once completed, it can be used to communicate your proposal and apply for regulatory authorizations. The One-Stop JARPA Resource Center is the place to go online to find the JARPA form, attendant attachments and forms, and guidance on how to prepare and where to send your application. The JARPA is intended for project proponents to complete themselves and there is guidance and references embedded in the form for assistance. We recommend reviewing the JARPA Instructions (A and B), which is a comprehensive resource. When it comes to shoreline authorities, there may be additional application forms to complete and submit with your JARPA.

The JARPA form distils the who, where, what, when, how and why of your project proposal. It is important to be accurate and complete before you submit to regulatory agencies - incomplete or revised proposals can delay the review considerably. It is better to be more inclusive in your proposal in time and space, with the possibility of reduced activity or area(s) within the scope of your authorizations and permits, than to propose less and need to return to modify the proposal down the road.

Before you apply

Specific information about your proposed locations are important to know and document before completing your JARPA. It is best to take the opportunity of daylight extreme low tides to survey and document your area. Take the time to review the JARPA and learn the various municipal designations, protections, and documented biological activity in the area. It is always advised to schedule pre-application meetings with tribes, resource managers, federal and state agencies, and local shorelines authorities to discuss your proposal and learn about the process from their perspective. This is important as you gather your information so you know what to pay special attention to as you document your proposed project area. Global Positioning System (GPS) coordinates, photos, descriptions of habitat (beach composition, slope, shellfish resources, flora and fauna), geo-located elevation contours, and delineations of vegetated areas are a minimum of the information you will gather.

JARPA guidance for Olympia oyster bed habitat restoration projects

Parts 1 through 4 of the JARPA are for you to name the project, assign the proponent, and identify the ownership(s). The owner of the proposed property will need to sign JARPA form or JARPA Attachment A, which authorizes the proponent to seek regulatory authorization for the project and for regulators to visit the location to review the proposal. If the project includes work on State Owned Aquatic Lands (SOAL), the proponent will need to contact the Department of Natural Resources and request a signature on JARPA Attachment E.

Part 5 of the JARPA deals with the project location(s). Information on property ownership, location and adjoining property owners can be found on the Washington Coastal Atlas or County parcel maps for Jefferson County and Mason County. If the information is not available through the online portals, the respective county assessor or auditor offices are a good resource. Many tideland parcels are owned by the State of Washington and managed by either the Department of Fish and Wildlife, Department of Natural Resources, or State Parks. The Public Land Survey Office at the Washington Department of Natural Resource is another potential resource to obtain surveys and ownership information for shoreline areas.

Part 5 of the JARPA, and Attachment B for multiple locations, is also where various descriptions of the property are made; current and past uses, and improvements or structures are described here. Habitat and vegetation conditions are described in paragraph 5(l); which are available in this report from some locations in Quilcene Bay and Mission Creek (Lynch Cove).

Part 6 of the JARPA form is where the proponent would describe the project and its purpose. You begin with a brief overview of the project in 6a. You will provide further detail in another section. Example language for 6a:

> The proposed Olympia oyster (*Ostrea lurida*) habitat restoration project is intended to develop the local Olympia oyster population abundance and to increase the available settlement structure for larval oysters. Initial testing (shell and oyster assays) throughout the proposed project area, and monitored outcomes, will inform subsequent and iterative enhancement actions. By this process we intend to facilitate the natural development of Olympia oyster bed habitat, an imperiled constituent habitat of this estuary.
>
> The proposed activities in this JARPA encompass a multi-year scope of project actions for __*the proponent*__ and its partners. The project described may require additional fundraising and coordination to realize the entirety of the project

activities listed under this proposal. The goal is to complete project actions as funding allows, and adaptively manage the project based on empirical monitoring information. The authorizations and permits sought through this proposal are intended to authorize the entire scope of project actions, which could include some or all of the techniques described below.

This Olympia oyster habitat restoration project is proposed to include transfers of juvenile (seed) Olympia oysters on shell (seeded cultch) to conduct assays and rebuild populations, and bulk shell amendments to increase the available settlement structure. The locations and parcels listed include all of the potential area where the proposed activity may occur; this is based on our best information from ___*resource managers, tribes, previous surveys or assessments*. Following initial testing to rank and further delineate project enhancements sites within the proposed properties, we expect to conduct iterative (phased) enhancement actions involving both seeded cultch transfers and bulk shell amendments on up to _______acre(s) on some portion of the identified tidelands.

Part 6b is for you to explain why the proposed activity is necessary or desired. This is an opportunity for you to discuss the needs and/or challenges of the project described in this application. Describe any project alternatives that were considered, and any project modifications that may have resulted from discussions with resource agency staff. You can attach additional sheets to the application if necessary. It is also advised to provide full citations if your narrative includes references. Example language for 6b:

The purpose of this work is to accomplish habitat restoration of an imperiled nearshore biogenic habitat form in Puget Sound, although the project described in this proposal contributes modestly to that overall goal. Olympia oyster bed is estimated to occupy less than 5% of its historic area in Puget Sound (Blake & Bradbury 2013). While the oyster itself is present throughout much of its historic distribution in Puget Sound, developed populations that form and maintain the biogenic habitat are largely absent from the identified priority recovery sites by the Washington Department of Fish and Wildlife (WDFW). The Olympia oyster is the only native oyster species to Washington State and the west coast of North America.

Previous restoration projects in Puget Sound have reached success by increasing local abundance which facilitates larval production and natural recruitment. Shell amendments in areas with regular recruitment have further developed populations that are recognized for the successful restoration of Olympia oyster bed habitat. Examples include restoration projects in Liberty Bay (Kitsap) and Fidalgo Bay (Skagit). Further, studies show a significant increase in salmonid prey-species richness and abundance within the complex structure of Olympia oyster beds and within restoration projects, as compared to adjacent habitat (Cordell et al. 2007, PSRF 2012). The objective of this proposal is to initially identify through testing and evidence the site(s) to further develop the local oyster population with iterative stock enhancements. Subsequent monitoring and evidence of sufficient larval production and natural recruitment will advance the project to include bulk shell amendments to increasing the available oyster settlement habitat. This suite of actions can recover oyster bed habitat at ecologically-relevant scales over time. There are other ecosystem services understood to be provided by functional oyster bed habitat. For example, services like estuary filtration, nutrient cycling, biological richness and production are exported to the larger water body through marine food webs and tidal flows.

WDFW recovery goals for the Olympia oyster and the identified 19 priority areas for oyster recover in Puget Sound can be found in "Washington Department of Fish and Wildlife Plan for Rebuilding Olympia Oyster (*Ostrea lurida*) Populations in Puget Sound with a Historical and Contemporary Overview" (Blake & Bradbury 2013). The proposed project is intended to work toward stated goals for this water body.

Reference:

Blake, B., & A. Bradbury. 2013. Plan for Rebuilding Olympia Oyster *(Ostrea lurida)* Populations in Puget Sound with a Historical and Contemporary Overview. Washington Department of Fish and Wildlife, Brinnon, WA. 26 p.

Cordell, J., B. Bachman, and L.Tear. 2007 Epibenthic Invertebrates at Two Beaches After Addition of Olympia Oysters, with Particular Reference to Prey of Juvenile Pacific Salmon. Puget Sound Restoration Fund, Bainbridge Island, WA 18p.

PSRF 2012. Puget Sound Restoration Fund Final Programmatic Report Narrative. Grant 2010-0045-000 Olympia Oyster Recovery in Puget Sound, WA. National Fish and Wildlife Foundation. 132 p.

Parts 6c and 6d are to characterize the project; you will select Environmental enhancement in 6c and write in "Habitat restoration" in 6d in the "Other" major element section. You might also check Scientific Measurement Device if water quality instrument loggers, or recruitment index monitoring stations are included in your project. Part 6e is for the proponent to describe each of the major elements that you checked in 6c [Other: Habitat restoration]. You will provide detail about the actions you are proposing, including detail (if any) about how the methods and techniques will reduce impacts to the natural environment. List any staging areas and equipment that will be used. Be as specific as possible. Make sure to identify where each element will occur in relation to the nearest water body. Example language for 6e:

All work occurs within the marine waters of _*water body*_, Puget Sound.

For oyster and shell assays:

The tideland parcels identified in this proposal encompass an area within which further assessments are necessary to spatially determine the extent of subsequent restoration project actions. To accomplish this, _*proponent*_ will implement a series of test plots composed of seeded "cultch", which are Olympia oyster juvenile oysters set onto Pacific oyster (*Crassostrea gigas*) shell. The seeded cultch material will be sourced from the conservation shellfish hatchery at the Ken Chew Center for Shellfish Research and Restoration (Chew Center), operated by Puget Sound Restoration Fund (PSRF) in partnership with the NOAA NW Science Center at the Manchester Research Station. *Proponent*_ will acquire a transfer permit from WDFW prior to moving the seeded cultch to the project site.

The bags of seeded cultch are available from the Chew Center in the spring. Once transferred to the project area, the cultch can be distributed into the test plots immediately. Test plots are 10 ft. x 10 ft. (100 ft^2) spaces on the tideland where 10 to 15 bags of seeded cultch are spread out over the ground. Each test plot is arranged in a standard, regular geometry [square or rectangle] with wooden stakes placed at the corners. The cultch is released from the mesh bags and spread to accomplish a 100% cover of the ground within the plot. The mesh bags are accounted for and removed from the project area.

The test plots are distributed across the tideland in a manner to evaluate the various reaches and elevations, utilizing up to ______ test plots within the project area. The test plots are intended to evaluate the spatial fidelity of the shell within the plot and shell emergence above the benthic surface. For the oyster seed, the evaluation will include count per shell, density, and size.

Olympia oyster population enhancement:

When population enhancement at a selected site or sites becomes a project action, _proponent_ will use seeded cultch (juvenile Olympia oysters set on Pacific oyster shell) sourced from Hood Canal. Information collected during the monitoring of the shell and oyster assays will determine the location(s) to conduct the subsequent population enhancement. To build the local population of Olympia oysters, phased enhancements will be conducted annually for up to 5 years. The seeded cultch can be sourced from the conservation hatchery at the Chew Center, as described above. For each iterative enhancement, the Chew Center will use unique broodstocks from Hood Canal to propagate a new generation line of Olympia oysters. The objective for population enhancement is to develop the local adult population to 1 million Olympia oysters. Iterative installments of 100 to 200 bags of seeded cultch will be transferred to the population enhancement site each year to achieve the abundance objective. Movements of oyster seed will be conducted with a transfer authorization from WDFW.

For the population enhancement, a total of 10,000 to 15,000 ft^2 (¼ to ⅓ acre) of space will be used to spread the 500 to 1,000 bags of seeded cultch over the enhancement period. Local population enhancement is intended to provide an adult oyster aggregation within the project area to achieve larval enhancement and catalyze natural settlement within the project site. Population monitoring will be conducted throughout the population enhancement period to evaluate the abundance of adult oysters and the regularity and magnitude of natural recruitment.

For shell amendments:

Should the monitoring activity within the population enhancement suggest that a larval enhancement of the project area is achieved, with evidence of natural recruitment observed, a bulk shell amendment of the tideland can distribute preferred oyster settlement material to tidelands where it is limited. When a shell amendment becomes a project action, _proponent_ proposes to distribute bulk Pacific oyster shell as an amendment to the existing intertidal benthic surface within the proposed project area. The shell material used for this purpose is seasoned Pacific oyster shell, which is sourced from WDFW inspected and authorized suppliers in Washington State. The transport and placement of shell will be conducted with a transfer authorization from WDFW. Shell amendment may occur once or over multiple efforts, depending on the availability of bulk shell and funding support. Shell amendments are proposed on up to _______ acres of tideland within the project area.

A contracted scow/barge or other vessel will transport the oyster shell from a loading site in Puget Sound to the project area. It is ___*proponents*__ intention to create a single and variable layer of complex emergent oyster settlement substrate. This process typically produces a finished amendment whereby a patchwork of about 80% emergent shell and 20% bare substrate remains in the project area. Shell placement is completed during flood conditions above 6 feet (MLLW) in the project area. The target application rate is 100 cubic yards (cy) of substrate material per acre; _*proponent*_ propose to amend the tideland substrate with up to ________ cubic yards of bulk oyster shell.

Skip part 7 and go to part 8 for projects in marine areas; here you describe the impact and mitigation to waterbodies other than wetlands. In part 8a you will describe how your project is designed to avoid or reduce impacts to the aquatic environment. Include whether placement of the project was selected to reduce impacts, and how construction was modified to reduce or avoid impacts. PSRF is not currently making a recommendation for how this restoration activity can occur where eelgrass (*Zostera marina*) is present. Consultation with federal services and state resource managers beyond the scope of the information presented here would be requisite to authorize these activities in eelgrass. Example language for 8a:

The methods and techniques to reduce impacts to the natural environment will include adherence to the relevant conservation measures found within the Conservation Measures and applicable terms and conditions from the Programmatic Biological Opinions for Shellfish Activities in Washington State Inland Marine Waters.

A shoreward delineation of eelgrass (*Zostera marina*), if present in the project area, will determine the placement of assays, seeded cultch enhancements and bulk shell amendments so that these project actions do not occur in eelgrass. A minimum buffer of 16 ft horizontal distance of native eelgrass or kelp (rooted/attached brown algae in the order *Laminariales*) will be maintained.

Shell amendment activity will occur only within designated work windows intended to avoid conflicts with forage fish spawning or movements of outmigrating fish. *Proponent* proposes an in-water work period between July 16 and October 15, for each year there is shell amendment activity. If project activity is to occur after September 15, a forage fish spawning survey would occur prior to the project action.

References:

USACE. 2015. *Shellfish Activities in Washington State Inland Marine Waters, Programmatic Biological Assessment*. U.S. Army Corps of Engineers Regulatory Program, Seattle District, Seattle, WA. 208 p.

U.S. Fish and Wildlife Service (USFWS) Reference Number 01EWFW00- 2016-F-0121

National Marine Fisheries Service (NMFS) Reference Number WCR-2014-1502).

Answer “Yes” to 8b. Answer “No” to 8c and include the explanation “Adverse impacts to non-wetland waterbodies are expected to be negligible; no mitigation plan has been prepared”. Answer “Not applicable” to 8d. In 8e, you will summarize the impacts to the water body for each discrete action in your proposal. Complete the Table in 8e having each action listed in 6e (oyster and shell assay, population enhancement, and shell amendment) in the Activity column. List the water body name (e.g. Quilcene Bay) and Impact location (marine tidelands, aquatic lands) for each activity. Then for each activity row, enter your estimates for the activity duration, or amount of time you expect is required to complete the activity. Placements of seeded cultch for assays or population enhancements can occur in 1 to 3 days for each effort; shell amendments may require up to 4 or 5 days to complete for each amendment, depending on the scale. Enter the amount of material, in cubic yards, that you propose to place in the water body; 34 cultch bags are approximately equal to one cubic yard. In the last column, you will describe the amount of area, in sq. ft., that will be directly affected. This is in reference to the total area [footprint] you propose for each activity.

In 8f, you will describe the materials you listed under the activities in 8e, including the type, source, and the amount of material. Indicate where and how it will be placed in the water body. Your description should include information on specific elevation ranges where your project will occur; the elevations between +1 ft. and -2 ft. (MLLW) are generally recommended for Olympia oyster restoration project enhancements. References to details in your JARPA drawings are recommended. Example language for 8f:

> For assays and population enhancement activity, the seeded cultch material will be sourced from the conservation shellfish hatchery at the Chew Center, operated by PSRF in partnership with the NOAA NW Science Center at the Manchester Research Station. PSRF operates this shellfish hatchery to produce Olympia oyster seed for the purpose of population enhancement under agreement with WDFW (MOU #11-1227). The bags of Pacific oyster (*Crassostrea gigas*) shell used for the cultch, each containing approximately 300 shells per bag, are acquired from WDFW inspected and approved sources in Washington State.
>
> To produce the oyster seed, unique annual broodstocks are collected by the Chew Center staff, under WDFW permit, from certified broodstock sites in Hood Canal where disease and population assessments are maintained. The seeded cultch produced at the Chew Center undergoes further disease screening prior to transfer. The transfer and placement of seeded cultch bags is done by hand, but the distribution of the bags to the test plots may be facilitated by a small vessel. Distributing seeded cultch bags using a small vessel to convey the bags while the tidelands are flooded avoids unnecessary effort and reduces impacts to the natural environment. Test plots for assays and the population enhancement site will be positioned between _________ and __________ (MLLW). Each test plot is arranged in a standard, regular geometry [square or rectangle] with wooden stakes placed at the corners. The cultch is released from the mesh bags and

spread, by hand, to accomplish a 100% cover of the ground within the plot. The mesh bags are accounted for and removed from the project area. The test plots are distributed across the tideland in a manner to evaluate the various reaches and elevations, utilizing up to ______ test plots within the project area.

For population enhancement activities, iterative installments of 100 to 200 bags of seeded cultch will be transferred to the population enhancement site each year to achieve the abundance objective. Movements of seeded cultch will be conducted with a transfer authorization from WDFW.

Seeded cultch transfers for the purpose of population enhancement may benefit from temporary storage onsite within the mesh sack that conveys the seeded cultch. This step is called “hardening” and can provide the juvenile seed a level of protection from predation and desiccation while they grow in their first season. To conduct the hardening step, seeded cultch bags are stacked into rows or short piles and remain contained in the mesh bags and stored on the tideland in the project area until late summer or spring. Movements of seeded cultch bags will be done by hand with the assistance of a small vessel to position the bags at the population enhancement site. After the hardening step, seeded cultch are released from the mesh bags and spread, by hand, at the enhancement site. The cultch is spread to accomplish a 100% cover of the ground within the enhancement area; the mesh bags are accounted for and removed from the project area. For the population enhancement, a total of 10,000 to 15,000 ft^2 (¼ to ⅓ acre) of space will be used to spread the 500 to 1,000 bags of seeded cultch over the enhancement period.

For the shell amendment activities, the material used is seasoned Pacific oyster shell, which is sourced from inspected and authorized (WDFW) suppliers in Washington State. Up to 100 cubic yards of material will be placed per acre, as described in part 6e. For each shell amendment effort, the activity work area is identified with temporary marker stakes, visible at high tide, that are placed to guide shell placement. The oyster shell is spread using pumped seawater to sluice the shell off of the slowly moving barge or scow. The amendment introduces a variable and patchy distribution of emergent oyster shell ranging between 0 and 3 inches above the benthic surface. Placement of the shell will be between the +1 ft MLLW and the -2 ft MLLW in the project area identified for *water body* . It is *proponents* intention to create a single and variable layer of complex emergent oyster settlement substrate. This process typically produces a finished amendment whereby a patchwork of about 80% emergent shell and 20% bare substrate remains in the project area. Shell placement is completed during flood conditions above 6 feet (MLLW) in the project area. The target application rate is 100 cubic yards (cy) of substrate material per acre; *proponent* propose to amend the tideland substrate with up to ________ cubic yards of bulk oyster shell.

Part 9 of the JARPA form is for the proponent to enter additional information that helps the reviewer(s) understand your project. Complete as much of this section as you can. It is ok if you cannot answer a question. In 9a, you will want to list all of the federal, state and tribal government agencies you have discussed the project with while preparing for your application. Parts 9b through 9m are for you to identify the various designations, historic activity, or protected species associated with your project area. Use the help links associated with each subsection to find the requested information. The activities described here comply with the State of Washington water quality standard for turbidity, so answer “Yes” for 9e. The project is not designed to meet the Washington Department of Ecology’s most current stormwater manual, so answer “No” for 9h. In 9j, you will describe what you know or information you were able to gather during your preparation on historic uses; this might include characterizations of relic improvements, recreation, fisheries, or other stakeholder or commercial activity. In 9k, indicate if a cultural resource survey has been performed in the project area; if it has, include the report in your application. Tribes you consult for your project may have information on existing cultural surveys; the help link for this section has additional informational resources for cultural surveys.

Part 10 is the last section of the form where you will identify the permits and authorizations you are applying for. If you are applying for a Fish Habitat Enhancement Process (FHEP) HPA from WDFW, check the Fish Habitat Enhancement Exemption (for SEPA) in part 10a. You will also indicate that this project is exempt from SEPA requirements by checking the appropriate box, and then checking the box next to “Other:” and write in “Statutory Exemption RCW 43.21C.0382”.

In 10b, for local government [shoreline authority], you will indicate by checking the appropriate box, that you are applying for a Shoreline Exemption Type permit, then write in “WAC 173-27-040(2)(o)(i)(C)”.

Under the State Government section, indicate by checking the appropriate box, which Hydraulic Project Approval path you are planning to take for your authorization from WDFW. If you are applying for a Fish Habitat Enhancement Process HPA, include a completed copy of the exemption form with your application to WDFW; you will need a letter of support from the WDFW Habitat Program in order to successfully apply for the FHEP HPA. Contact your WDFW Habitat Program area biologist for more information. If your project is proposed to occur on State owned aquatic lands (SOAL) managed by the Washington Department of Natural Resources (WDNR), you will need a Aquatic Use Authorization from WDNR. If you require an Aquatic Use Authorization, complete JARPA Attachment E and submit with your completed application. Under the section for the Washington Department of Ecology, check the box to indicate your project requires a Section 401 Water Quality Certification.

In the Federal Government Section, you will check both Section 404 and Section 10 boxes, indicating your project requires permitting from the US Department of the Army, Corps of Engineers.

Signatures are required by representatives of the project proponent, authorized agents, and property owners. If there are multiple property owners, their signatures will appear on JARPA Attachment A.

Attendant attachments, drawings, reports and enclosures

The main JARPA form does a nice job of indicating when JARPA form attachments are needed and where to find them using links in the main form. Attachment forms are available at the One-Stop JARPA page. You can list a single property owner on the main form (Part 4), but if there are additional property owners in your project area, have each owner complete and sign Attachment A. A single location can be described in the main form (Part 5), but if there are multiple locations on non-adjacent parcels you will use Attachment B to describe each additional location. You are able to list a few adjacent property owners in Part 5, but if the list is long you can choose to list those ownerships using Attachment C.

Attachment D is used for you to describe the timeline and different phase actions of your project. This is certainly appropriate here, where there are multiple phases of enhancement and monitoring activity. The attachment form is a simple table where you can indicate the timeline (start and end) for assays, population enhancement and shell amendment.

Review and use JARPA Instructions A and Instructions B available on the One-Stop JARPA page for guidance on how to discuss your project with regulators and how to prepare project drawings. You will need to prepare scaled drawings that meet the requirements for vicinity, plan and sectional views of your project area. Helpful guidance and example drawings are available from the Army Corps of Engineers, Seattle District website for permit application drawings.

A completed application includes your main JARPA form, JARPA attachments and JARPA drawings. Enclosures submitted with the JARPA can include letters of concurrence or support, reports, photos or other documentation.

Recommended order of events for submittals

In preparing your project proposal, you should have discussed the project with tribal resource agencies and resource managers at the WDFW Shellfish Program. Once you are ready to submit your completed application, we recommend you begin by contacting your area biologist with the WDFW Habitat Program. By discussing the project with them, you can request a sponsorship letter for your project. WDFW Habitat Program sponsorship is the method to qualify for a FHEP HPA. This determination has considerable impact on your permit application review from the local shoreline authority. It is best to obtain your HPA before you proceed with the local shoreline authority.

After working with WDFW on the HPA, you should submit your application package to the local government [shoreline authority], Washington State agencies (WDNR, Ecology), Tribal Natural Resource agencies, and the Seattle District Army Corps of Engineers Regulatory Branch (COE). Each submission should be accompanied by a cover letter. While all regulators will receive mailed applications, many agencies have online portals to make electronic submissions; see the Seattle District COE site for electronic submissions.

F. Supporting materials for outreach projects

Links to online activity announcements and other materials

Public Engagement:

Walk and Talk with Hilary Hayford (October 3rd, 2021)

- Photos: https://photos.app.goo.gl/rPwEfa5FtJeh9ot39
- Event Details: https://greatpeninsula.org/event/hahobas-shoreline-walk-and-talk-Olympia-oyster-restoration-with-hilary-hayford/

Curriculum and Youth Field Experience:

Olympia Oyster Restoration Field Experience for Middle School Students

- Dates of student interactions:
  - September 15th (In-Classroom Introduction)
  - September 20th and 21st (Field Experience at Belfair State Park and Klingel-Bryan-Beard Wildlife Refuge)
  - September 29th (In-Classroom Reflection)
- Field Experience Photos: https://photos.app.goo.gl/AxKLu9LQR5PHAdqc8
- 56 students reached; 6 hours of science engagement per student (4 hours of which were outdoors)
- ***Full curriculum document: PSSMODULE_OlyOysters.pdf***

Communications:

- **Radio Story from Coastal Cafe (October 27th, 2021)**
  - "Hood Canal Oyster Initiative:" **https://kptz.org/podcasts/coastal-cafe/**
- **GPC Blog (October 6th, 2021)**
  - "How much do you know about Olympia Oysters:" https://greatpeninsula.org/how-much-do-you-know-about-Olympia-oysters/
- **E-News Publications:**
  - October 2021**:** https://greatpeninsulaconservancy.salsalabs.org/oct21
- **Facebook Posts:**
  - October 29th -- Radio Story
  - October 10th -- Blog
  - October 6th -- Walk and Talk Summary
  - September 22nd -- Catalyst Public School Post
  - September 21st -- Walk and Talk Recruit

    - September 15th -- Student Eval
    - July 14th -- PSRF Collaboration
- **GPC Fall Newsletter:** Will be published in late November 2021. We'll send you all a copy!

Belfair Site Monitoring:

GPC Volunteer John Foltz data collection: *Use GPS coordinates to find exact location, remove 2 loggers from mounting station, downloading each logger to data shuttle, wrap loggers in protective tape, and re-mounting to station.*

- Visit Date: October 15th, 2021
- Time: 6:45 am