OLYMPIA OYSTER HABITAT RESTORATION: PILOT HABITAT ENHANCEMENT PROPOSAL FOR WOODARD BAY, HENDERSON INLET
Aquatic Lands Conservation Lease No. 20-077641

Submitted to DNR Aquatics and Natural Areas Programs
by The Nature Conservancy
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GOAL: ***To enhance Olympia oyster recruitment/colonization in areas with larval availability but limited suitable structure available for settlement.***

SUMMARY:

This plan is for a pilot habitat enhancement project in Woodard Bay. The pilot project will test habitat restoration methodology and design in anticipation of implementing a larger-scale habitat restoration project in 2007. Proposed habitat enhancement includes the placement bulk oyster cultch material (whole Pacific oyster shell) across four sites along an elevation gradient spanning intertidal to subtidal habitat. Cultch will be placed in varying depths. This will allow us to test recruitment and survival at various elevations and monitor the effects of exposure, predation, siltation, fouling and other factors.

Results from this pilot project will provide information on the optimal design for promoting Olympia oyster recruitment and survival, including:
- Tidal elevation for cultch placement
- Depth of cultch to avoid problems with cultch sinkage in areas with soft-sediments

We also propose to collect oyster seed within Woodard Bay and to grow it out during the year for use in 2007. It is thought that larval settlement is enhanced by chemical cues emitted into the water from live oysters. Collection of oyster seed from within Woodard Bay, will ensure the genetic integrity of Olympia oysters in the area is maintained.

Three of the four sites are located within the Woodard Bay Natural Resources Conservation Area. The fourth site is an area currently being leased by the Conservancy for the purpose of restorating habitat for Olympia oysters (see attached map). All four sites were included in our 2005 study of Olympia oyster recruitment and survival in Henderson Inlet, completed by Brian Allen.

This plan was prepared by the Conservancy and based upon findings from our Olympia oyster recruitment and survival studies and recommendations from the Puget Sound Restoration Fund. Additional input was provided from Bill Taylor and Joth Davis (Taylor Shellfish), Brady Blake (WDFW), Allen Trimble (UW), Brian Allen (TNC contract biologist) and other attendees of a restoration planning meeting convened by the Conservancy on Dec. 20, 2005.

HYPOTHESES:

1) Tidal elevation affects oyster recruitment
2) Tidal elevation affects oyster survival
3) Cultch depth affects oyster recruitment
4) Cultch depth affects oyster survival

RATIONALE FOR RESTORING OLYMPIA OYSTER HABITAT:
The primary purpose of the project is to increase the availability of substrate for naturally-occurring Olympia oyster populations. Large assemblages of Olympia oysters occurred throughout the Puget Sound prior to their large-scale destruction in the last century from over-harvest, habitat loss and sulfur waste from pulp mills. Olympia oyster restoration involves the re-establishment of a physically complex living shell matrix of three-dimensional habitat that will enhance the suitability of nearshore habitat for oysters and additionally benefit other living marine resources. Proposed enhancement activities (cultch placement) will take place within an area that supported native oysters in the past. Enhancing marginal habitat with shell in areas with known larval availability will allow remnant oyster populations to re-colonize historically occupied areas while also preserving genetic integrity of the stock. It will also have the additional potential benefit of providing habitat for other marine organisms.

Anticipated Results
The low intertidal and shallow subtidal areas in Woodard Bay are relatively uniform fine silt and mud, with some firmer areas of gravel/sand/cobble and do not present a great diversity or number of animals. Two anticipated outcomes are likely to occur in the area when vertical structure (cultch piles) is introduced in Woodard Bay. First, species diversity and biomass will likely increase locally as immigrating and recruiting animals exploit the solid substrate and shelter provided by the cultch. Whether an edge effect is present with these two habitats (cultch pile and mud substrate) is debatable. There will more likely be an "island effect" where diversity and biomass increases in association with the cultch microhabitat and not with the interface or edge. Second, predators will also likely exploit the cultch area for shelter and to prey on barnacles, oysters and other sessile recruits. Oyster predators known in abundance near project area include crabs, moonsnails, welk, sea stars, and barnacles.

Benefits to Other Marine Organisms
The physical structure provided by reestablished native oyster reefs in the low intertidal zone may benefit marine fish diversity and density (Hosack 2003). In particular, "oyster structure is thought to offer valuable refugia from predators and trophic resources for larval and juvenile fish" (Hosack, pers comm.). Oyster reefs provide critical habitat for a wide variety of fishes and invertebrates in the Atlantic and Gulf coasts as a consequence of greatly increased structural relief associated with reefs as compared to other types of intertidal habitats. The design and monitoring of new oyster reefs are increasingly taking these broadly based and micro-scale ecological benefits into consideration (see Harding and Mann, 1999).

Similar ecological benefits of oyster reefs appear to be important on the US West Coast. Several studies have investigated faunal associations with Pacific oyster beds in the Northwest. Perhaps most significantly, Trianni (1996) found that the total biomass of benthic invertebrates – many of which are important components of salmon diets – was higher in oyster shell plots than in surrounding habitats. In Willapa Bay, Hosack (2003) found that oyster shell had a "stabilizing effect" on the diversity of nekton (fish, crab, and shrimp), suggesting that the immobile structure of oysters may provide better habitat for prey species than other habitats.

Hosack postulates that live oyster beds might promote a stable nutrient regime through pseudofecal deposition, which enhances benthic primary production (Newell et al. 2002) and could increase the densities of meiofauna. Whether native oyster reefs provide similar ecosystem benefits is unknown; however, it is likely that some important ecological interactions between native oysters and resident fishes, including salmonids occurred at some spatial scales over evolutionary time frames. It is known that nearshore regions of Puget Sound are critical habitat for threatened chinook salmon. Such areas area also defined in the Magnuson-Stevens Fishery Management Conservation Act of 1996 as Essential Fish Habitat (EFH) for a number of other species including surf smelt, sand lance, Pacific herring, coho, sockeye, chum, and pink salmon, and cutthroat trout. Thus, it is reasonable to surmise that restoring native oyster habitat may confer benefits to other threatened marine species as well.

EXPERIMENTAL DESIGN:

Rationale for Design

Introducing species into an area is an inexact science, where success depends on numerous variables that may be difficult to anticipate with certainty. We propose to approach this project as a pilot undertaking in anticipation of a larger-scale restoration project in 2007. This pilot enhancement project is designed to address DNR's concerns about cultch sinking and to identify the optimal elevation, configuration and depth for cultch placement.

Questions have been raised about the viability of subtidal native oyster restoration in Puget Sound. For instance, Brady Blake (WDFW), does not consider subtidal areas the most appropriate restoration sites based on his knowledge of historic and current populations, predation and a lack of flow leading to sediment deposition. Predators in the subtidal area include rock crabs, graceful crabs, moonsnails (in soft areas), and sea stars – all known predators of Olympia oysters. Particularly, in the South Sound, rock crabs and graceful crabs are voracious predators in subtidal environments.

One of the reasons intertidal areas are thought to be better for Olympia oyster restoration is because they get flushed by currents at higher tides and hit by winds during lower tides. As small, flat oysters, Olympia oysters are much more vulnerable to silt than larger and more deeply cupped oysters, such as the Pacific. The regular flushing that occurs in intertidal areas may effectively scour the areas of silt and prevent the build up of sediment that results from the decomposition of algal blooms. The subtidal areas where

one might expect to find Olympia oysters would be in channels where there is water flow that prevents the build up of sediment.

While some restoration practitioners share his views others disagree. Some scientists have indicated that establishment of a significant subtidal population of Olympia oysters is key to maintaining their long-term viability (Allen Trimble pers. comm.). Periodic episodes of extreme hot or cold periods and desiccation can cause intertidal populations to be completely wiped out. However, these could be reestablished if there were nearby subtidal populations that were not susceptible to such events.

Most native oyster restoration conducted to date has been intertidal; very little is known about the subtidal limit of successful restoration beyond anecdotal observations of mortality below -2' MLLW. Conducting our habitat enhancement along an elevation gradient spanning intertidal to subtidal habitats will allow us to examine recruitment and survival at various elevations and monitor the effects of exposure, predation, siltation, and fouling. This pilot project will further our knowledge of oyster restoration, particularly in the subtidal area, and allow for scientifically sound comparative monitoring to evaluate our success over time.

Given that there was 0% spat survival in the 2005 field study conducted by Brian Allen, in spite of successful recruitment at multiple elevations, the primary purpose of the 2006 pilot study is to determine whether or not we can get recruitment AND survival at different tidal elevations without investing a lot of shell/time in the process. The proposed experimental design will allow us to test out shell placement in several moist areas to see if one area is, perhaps, more suitable than another, as is often the case on beaches throughout Puget Sound. For instance, in some tidal channels, the water may move too quickly for recruitment to occur. Future monitoring or more refined experiments could be done to help provide more information.

Location of habitat enhancement

Elsewhere in Puget Sound, seeding and enhancement projects have succeeded at multiple intertidal locations where live oysters indicate both recruitment and post-settlement survival (Puget Sound Restoration Fund and WDFW). For this reason, it was strongly recommended that Woodard Bay/Henderson Inlet habitat enhancement activities be conducted along a gradient that includes both intertidal and subtidal environments.

Based on the above recommendation and results of preliminary oyster recruitment and survival studies at eight sites in the vicinity of Henderson Inlet, we identified four areas as high priority areas for enhancement. *(Note: Site numbering is consistent with the plot numbers from the preliminary oyster recruitment and survival studies, conducted by Brian Allen in 2005, with the exception of the addition of site "1.5".)*

<u>Site #1</u>

This site contains the channel area where live Olympia oysters were found and is within the boundary of the NRCA. Flushing within the channel will help to reduce siltation and ensure continuous water coverage. The elevation of this channel is between -0.5' and -1'

MLLW. This is similar to other sites in the South Puget Sound where oyster seeding and habitat enhancement activities have succeeded (Betsy Peabody, pers. comm). The substrate of the channel bottom is also fairly firm, which could reduce the amount of shell necessary for enhancement. Some uncertainty exists with regard to the rate of flow at this site. Fast flow may affect recruitment.

A strong indicator of conditions suitable for successful restoration is the live Olympia oyster set on riprap rocks at the base of the Woodard Bay trestle. The abundance of oysters in this area otherwise dominated by soft substrate suggests that the general conditions are favorable for Olympia oyster recruitment and survival, but that structure may be limiting. Increasing the amount of suitable structure available in this area should lead to an increase in natural recruitment and post-settlement survival.

Site #1.5

This site is located within the NRCA just east of the trestle bridge on the north side of Woodard Creek. It is an ideal location for intertidal restoration because it is characterized by seeps, a gentle slope and mixed substrate of sand/mud/gravel/shell. It was also selected based on field reconnaissance which revealed numerous live Olympia oysters scattered throughout the site between from roughly 0 to -2 ft. MLLW.

Site #3

This site is also located within the NRCA along the western shore of Henderson Inlet just south of the mouth of Woodard Bay proper and due west of the lease site. This site was recommended by Brady Blake (WDFW) as an ideal location for intertidal restoration because it is characterized by seeps, a gentle slope and mixed substrate of sand/mud/gravel/shell.

Site # 4

The Conservancy is currently leasing this subtidal site for the purpose of Olympia oyster habitat restoration. It is located east of Site #3, and combined, these sites provide a continuous elevation gradient from the intertidal to subtidal. Initial oyster recruitment and survival studies found this site to have the second highest level of larval recruitment of all the sites studied.

At the subtidal lease site successful recruitment alone may not result in establishment of a viable Olympia oyster population as predation and siltation may have a marked effect on post-settlement survival. The recent analysis, done by our contract biologist Brian Allen, indicates that lower elevations may experience higher recruitment, but we do not yet know enough about post-settlement survival in subtidal locations to risk larger-scale implementation. This test placement should provide more information on the likely success of subtidal oyster restoration at this site.

The exact location for placement of bulk and bagged shell along the stated elevation gradients will be determined through a site reconnaissance visit in early spring 2006. We intend to contract with the Puget Sound Restoration Fund to implement the proposed enhancement pilot project. We request that staff from the Natural Areas Program

accompany the Conservancy and Puget Sound Restoration Fund to ensure that the proposed locations are acceptable.

Location, orientation, width and depths of substrate enhancement
Parameters guiding bulk and bag cultch placement will include:
- Tidal elevation
- Moisture (seeps)
- Substrate
- Depth and configuration of shell

Cultch placement design

A total of 5 cubic yards of bulk shell (equivalent to 126 bags) will be distributed between 21 uniform patches among the four sites at varying elevations (see Tables 1 and 2). In TNC's oyster recruitment and survival study, better recruitment was found at all sites at the -1' and -3' MLLW elevations compared to +1' MLLW, hence the starting elevation of 0' MLLW.

Table 1. Cultch Configuration and Replication

	# Patches (1 sq. m.)	# Bags (3'x1'x1')
Site 1	3	18
Site 1.5	3	18
Site 3	9	54
Site 4	6	36
TOTAL	21	126

Table 2. Tidal Elevations per Site

Elevation	Sites Locations
0' MLLW	Site #3 (east of lease site)
-1' MLLW	Site #1 (channel in Woodard Bay); Site #3 (east of lease)
-1.5' MLLW	Site #1.5 (east of trestle bridge)
-3' MLLW	Site #3 (east of lease)
-5' MLLW	Site #4 (TNC lease site)
-7' MLLW	Site #4 (TNC lease site)

Three replicate patches (1 sq. m.) will be established at each site/elevation combination. We estimate 6 bags will be needed for each patch for a total of 126 bags. This will result in an average of 6-8 inches of shell coverage. Depth of cultch placed will vary among intertidal and subtidal plots.

Square patches were selected for all sites based on strong recommendations from NOAA staff who have been involved with similar enhancement projects completed by the Puget Sound Restoration Fund. Uniform patches make good sampling units because they can be divided up into even grids and quantitatively monitored using statistically sound sampling techniques.

Surface Area of Enhancement
Approximately 21 square meters of intertidal and subtidal ground at four sites within Henderson Inlet/Woodard Bay will be enhanced with approximately 5 cubic yards of whole Pacific oyster shell to increase native oyster spat settlement. Within these four sites a total of 21 shell patches (1 sq. m. each) will be established.

Substrate Type
Whole Pacific oyster shell
Based on its availability, recommendations of shellfish biologists and a recently completed University of Washington study (White 2004), Pacific oyster shell is strongly recommended as the best available substrate for habitat enhancement activities in Puget Sound and is proposed for use in this project. Whole Pacific oyster shell is readily available in bag and bulk form and is large enough to remain on top of soft substrates. It forms an effective underlayer for a reestablished native oyster reef, and provides lots of cryptic space where spat can settle away from emergent surfaces that are likely to be fouled by barnacles and off the bottom.

The University of Washington sponsored investigation (White 2004) indicated that Olympia oyster spat had a settlement preference for live Olympia oysters (#1 preference), followed by Olympia oyster shell (#2 preference) and whole Pacific oyster shell (#3 preference), although these results were not statistically significant. The whole Pacific oyster used in this project will be purchased from Taylor Shellfish Company under Transfer permits issued by WDFW indicating that the shell is free of fine sediments and potentially harmful marine organisms.

Other substrates considered
While other materials have also been suggested as possible cultch material, a brief analysis of various options confirms Pacific oyster shell as the only practical, natural option for habitat enhancement. Some artificial substrates, such as concrete coated structures, may be available, but were not considered for use in this project since they would likely be unacceptable for use within the NRCA.

> Live Olympia oysters
> While live Olympia oysters are the #1 preference for settlement, perhaps due to the periostracum covering the surface of live oysters, it would be impractical in terms of availability and cost and detrimental to the host populations to transport live Olympia oysters from another location to Henderson Inlet. There is also concern about the appropriateness of brining in oysters of unknown genetic stock into the NRCA.
>
> Olympia oyster shell
> As with live Olympia oysters, Olympia oyster shell is unavailable in sufficient quantities to support its use in restoration projects. Puget Sound Restoration Fund has investigated the collection of Olympia oyster shell from several sources over the years to determine the practicality of its use in substrate enhancement projects.

The Olympia Oyster Company, while seeming to be a likely source of shell, is unwilling to part with Olympia oyster shell. The company uses the shell for cultch bags. J.J. Brenner Shellfish Company, another longtime oyster company, seemed another likely source of Olympia oyster shell. The Company volunteered shell on their beaches for use in restoration, but predicted that there were probably no more than 50 or so bags of shell available – not enough to support large-scale enhancement nor merit time-intensive collection.

Any attempt to gather enough native oyster shell for a large-scale enhancement project would deprive remnant oyster populations in other parts of Puget Sound of hard structure necessary for settlement.

Mussel Shell

While not included in White's 2004 study of substrate preference, mussel shell has been suggested as a possible cultch material for Olympia oyster recruitment. Taylor Shellfish Company has offered material for collection off its mussel floats and the quantities are sufficient to support enhancement. However, there are two major drawbacks to the use of mussel shell: 1) It is not readily available in bag or bulk form for transport and would therefore need to be collected off mussel rafts and transported by barge to enhancement sites and 2) the shell material is too fragile for use in soft substrate conditions. During collection and transport, the mussel shell would likely break into tiny pieces and become buried in the soft sediments that are characteristic of the project site, proving altogether unsuitable as an underlayer.

Collection of oyster seed

Placement of adult brood oysters or seed on top of shell piles is thought to increase spat settlement through chemical cues emitted into the water by live oysters (Bill Taylor pers. comm.) We propose placing approximately 20 bags of cultch at site 1.5 and/or suspending some from the pilings in Chapman Cove /or Woodard Bay in summer of 2006 to collect local oyster seed. Site 1.5 is ideal for collection of oyster seed because we found numerous live oysters in the area and know there is good larval supply, and due to ease of access by foot. The seed would be grown out for use during the larger-scale restoration in 2007. Although anecdotal evidence from TNC's contract biologist, Brian Allen, suggests that flatworms are not likely to be a major problem in Henderson Inlet, it may be necessary to husband the oyster seed for a year. This would entail keeping the bags of cultch off the bottom. Periodically, the bags would be inspected and freshwater dipped at 6 months post-settlement if necessary to kill any flatworms (or drills).

Construction timing, methods and equipment

The Pacific oyster cultch used in this project should be spread in mid-June to early July to avoid barnacle set (Bill Taylor pers. comm.). The fresher the shell, the more the oysters will be attracted to it. The exact timing of the placement should be as close to the time of set as possible, as determined by temperature/tidal method used by Brian Allen during the recruitment and survival studies. The shell should be placed just prior to the neap tide that occurs approximately 30 days after average water temperatures reach 12.5° C. At lease

one temperature logger will be placed at each site in early-May and monitored until the temperature approaches 12.5° C (likely in mid-June).

At the 0', -1', 1.5' and -3' MLLW tidal elevations shell can be spread by hand at low tide. However, at the -5' and -7' MLLW elevations, shell will need to be spread by boat. We were unable to find biodegradable shell bags so, shell will be transported in bags (3'x1'x1') for convenience of handling and measurement, but shell will be removed from the bags when placed on site. Each bag is approximately 3 feet long by 1 foot wide and 1 foot tall.

Monitoring

The size and distribution of replicable shell patches will facilitate monitoring for oyster spat recruitment and survival over a range of habitat types and tidal elevations. Monitoring will quantitatively document the recruitment of oyster spat at various tidal elevations, in addition to the survival of spat over the course of the summer.

Monitoring measures will include:

- Water temperature (for timing of cultch placement)
- Oyster spat recruitment
- Quantity of oyster spat recruiting to enhanced habitat
- Quantity of oyster spat surviving on enhanced habitat
- Stability of cultch (height above bottom; maintenance of shape)
- Salinity
- Presence of competitors/predators
  - Quantity of competitors/predators (high, medium, low cover classes) on enhanced habitat
  - Presence/absence of flatworms on collected seed

Table 3. Timing of monitoring events

Monitoring event	Approximate Date Range
Temperature (for cultch placement)	May 1- June 15, 2006
Spat recruitment	June 1- Sept. 30, 2006 (low and neap tides)
Quantity of spat	June 1- Sept. 30, 2006 (low tides)
Spat survival	July 1- Sept. 30, 2006; April 1, 2007
Cultch Stability/Depth	Sept. 30, 2006 and April 1, 2007
Salinity	July 1-Sept. 2006
Competition/Predation- on shell patches	July 1- Sept. 30, 2006; April 1, 2007
Competition/Predation- on collected seed	Aug. 30- Dec. 30, 2006; April 1, 2007

Random sampling of cultch shell within each of the 21 patches will demonstrate whether native oysters are more successful in recruiting to and surviving on cultch shell across a range of intertidal and subtidal elevations. Approximately 100 shells will be collected from each patch, mound or reef. Oyster spat and the number of predators/competitors will be enumerated in the field and shells returned to their respective locations. Routine monitoring (approximately bi-weekly as tides allow) will begin once oyster spat are large

enough to be observed (August) and will continue through the end of September. This monitoring captures important data on initial survival and growth.

In anticipation of expanded restoration in 2007 and to assess survival over the winter, spat survival and predation will be monitored at the beginning of April 2007. By coupling oyster and predator monitoring we can gather information to help determine whether there is a threshold density above which oyster populations can withstand predation. This will be valuable for designing and advancing expanded shellfish restoration projects in Henderson Inlet and at other sites through the Sound.

Cultch bags used to collect local oyster seed will be periodically examined between August and December. If flatworms or drills are present, the bagged cultch will be freshwater dipped and then re-examined prior to use in 2007.

COST ESTIMATE:

Table 4. Estimated budget for 2006 Pilot Enhancement

Expense Category	**Estimated Cost**
Contract expenses (planning, implementation and monitoring)	$ 8,500
Temperature loggers	$ 1,000
Cultch (bagged and bulk, including delivery and spreading	$ 1,000
Boat rental	$ 1,500
Diving	$ 1,500
Misc. supplies	$ 1,000
TOTAL COST	$ 14,500

Note: TNC staff time not included.

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