

**The Nature Conservancy of Washington
Woodard Bay Native Oyster Habitat Enhancement Project**

2007 Shell Enhancement

**Final Report
December 2008**

Prepared by



**Puget Sound
RESTORATION FUND**

Introduction

This report to The Nature Conservancy of Washington (TNC) is a draft final report on the Woodard Bay Oyster Habitat Enhancement Project, Phase 2 Implementation. We will describe the steps taken to prepare the project area in Woodard Bay, implement the enhancement and monitor the outcome. The habitat enhancement phase of this project follows the baseline environmental monitoring (2005) and enhancement procedure experiments (2006) that were conducted within Henderson Inlet and Woodard Bay, specifically. The project area is shown in Figure 1 below, and includes tidelands within the Washington DNR Woodard Bay Natural Resource Conservation Area (NRCA) and adjacent subtidal bedlands leased to TNC.

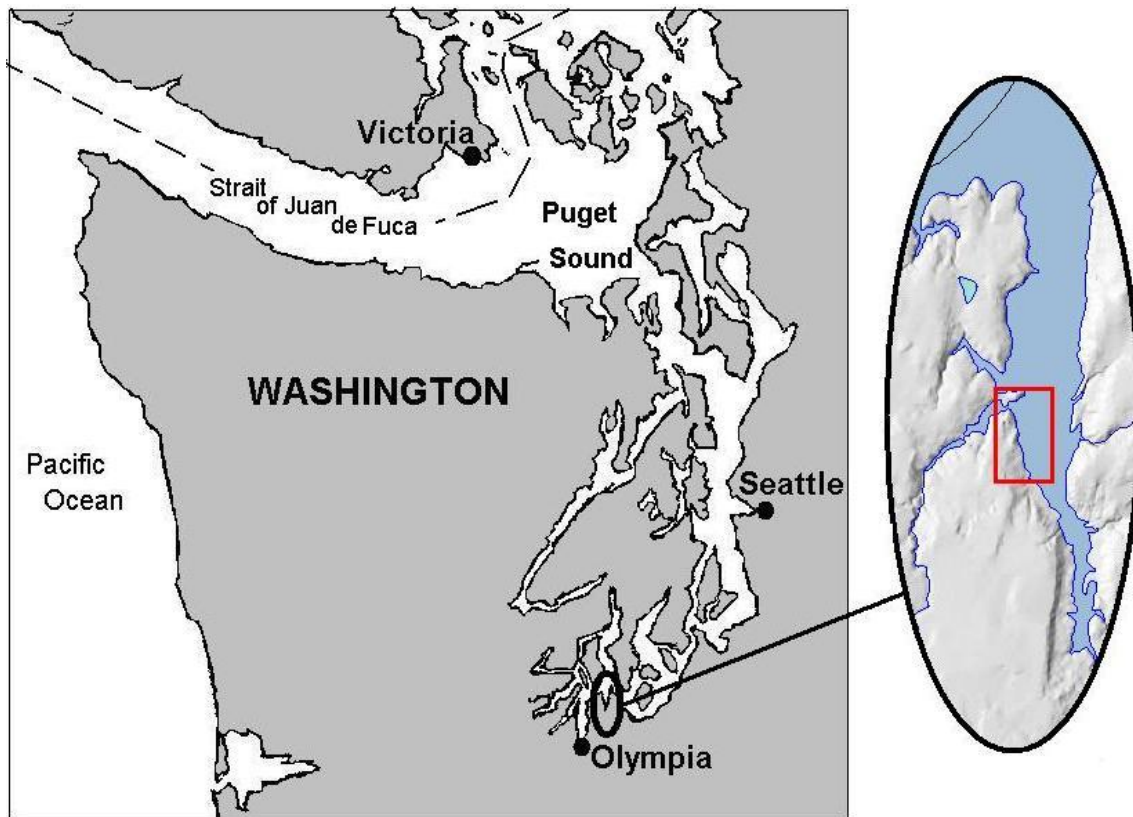


Figure 1. The Woodard Bay project area (red rectangle) within Henderson Inlet, southern Puget Sound is shown in the inset. The inset image is courtesy of the Washington Dept. of Ecology.

The baseline and experimental work prior to this phase of the project was used to inform our design of two discrete habitat enhancement plots in Woodard Bay. The enhancement material is whole Pacific oyster shell which is intended to provide the native Olympia oyster, *Ostrea conchaphila*, an attractive setting surface and encourage the recruitment of this species within the project area.

Before the habitat enhancement began, some additional baseline assessment and characterization was completed in spring 2007. The objective of these preparatory steps was to complete a close evaluation of the existing marine habitat features and community organisms in the planned enhancement plot prior to any manipulation; this included a population census of the existing Olympia oyster resource within the NRCA tidelands.

Later in the summer of 2007 the habitat enhancement was completed in two areas. The primary enhancement is called Shell Area #1, and was located on the NRCA tideland. A second and smaller shell enhancement, identified as Shell Area #2, spans the transition from intertidal to subtidal elevations and was located within and adjacent to the TNC lease area, south of Woodard Bay proper. Once the enhancements were in place, a series of monitoring efforts began in the project area starting in fall 2007; these have continued through 2008. The following report will provide a detailed account of the work completed to date in this enhancement phase of the project. Included within are recent data collections in 2008, a discussion of project efficacy as a stock-rebuilding enhancement and scheduled activities for late 2008 and 2009.

Site Preparation

The 2005 and 2006 work in the intertidal and subtidal areas of Woodard Bay collected a host of baseline information on native oyster recruitment and shell enhancement potential as well as habitat and community fauna data. The additional preparation we completed in spring 2007 focused our effort specifically in the planned shell enhancement plots, as these particular locations fell between or extended outside our previous study sites in Woodard Bay. The work involved detailed mapping exercises, habitat characterizations and oyster population assessments within the new enhancement areas.

Project Proposal

The proposed habitat enhancements in Woodard Bay were divided into two separate areas, see Figure 2. Shell Area #1 incorporates portions of the area surrounding the 2006 study site #1.5 on the NRCA tidelands and follows a contour of favorable habitat toward the mouth of Woodard Bay. We estimated this potential area to be between 1.25 and 1.5 acres. The elevation range here is from mean lower low water (MLLW) to -3.5 MLLW. The plot was designed to follow the main water feature draining this tideland from within Woodard Bay out to Henderson Inlet. To protect the natural oyster aggregation discovered within the west end of the plot, we proposed a hand-placement of bagged cultch material at the west end. These bags can be opened and the material carefully scattered by hand to avoid any damage to the existing oyster resource. The remainder of the area was to receive a bulk shell treatment.

Shell Area #2 was designed as a rectangular band of shell habitat that spans the intertidal area starting at the lower edge of 2005 study site #3 to approximately the middle of the subtidal area in the TNC lease area (2005 study site #4). This area was proposed to be 1 acre. The elevation range here is from -3 MLLW to -5 MLLW. This second shell area was intended as an examination of the potential for subtidal habitat enhancement.

Based on the performance of the 2006 experimental shell plots, Puget Sound Restoration Fund (PSRF) recommended an application of shell between 4 to 6 inches deep. This would require between 1,300 and 2,000 cubic yards of whole pacific shell to complete the proposed maximum 2.5 acre collective enhancement.

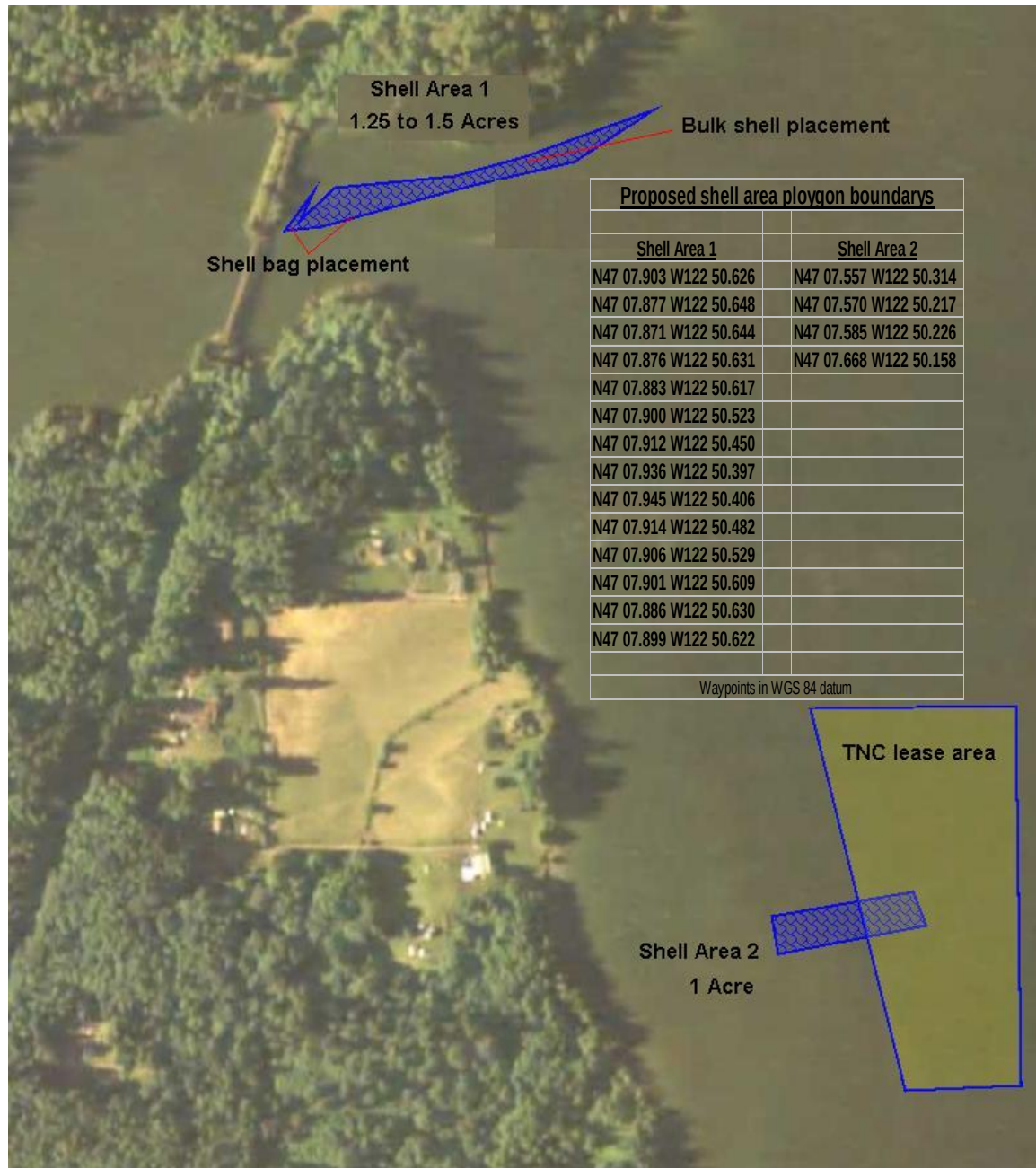


Figure 2. The proposed habitat enhancement areas are shown with blue polygons. Shell Area 1 spans the lower intertidal east of the trellis bridge in the NCRA between 2006 study site #1.5 and 2005 study site #2. Shell Area 2 begins in the lower intertidal below 2005 study site #3 and ends in the subtidal TNC lease. The aerial image was provided courtesy of the Washington Dept. of Ecology.

Habitat and Community Characterization

An account of the benthic and epibenthic community was completed in the 2005 work in the location where Shell Area #2 was proposed. The habitat here was also well characterized in the 2006 study. The following is a supplemental habitat and community characterization for the area surrounding Shell Area #1, which fills in the data gap for the proposed shell plot. The tideland of concern lies at elevations ranging from MLLW to -3.5 MLLW and is comprised of soft sediments with little complex structure. The primary features in this area are the main creek drainage and associated standing water, seeps and the large woody debris found at the -1 MLLW elevation. The areas of pooling water are maintained by the slight sediment burms created by both the large woody debris and the meandering secondary drainages (see Figure 3) associated with the main drainage channel. There is an amount of small rock cobble and mussel clusters providing the only emergent structure in the soft sediment, though these structures are few and at low densities.



Figure 3. This photo is of the area near the 2006 site #1.5 viewed from below the trestle bridge and looking southeast out to Henderson Inlet. The main drainage is beyond the wood debris in the foreground.

The emergent species observed in this area are associated with the same habitats as the native oyster found here: relatively firmer sediment, standing or flowing water and some amount of emergent structure refuge. The mollusks observed included the bubble shell, *Haminaea vesicula*, and the native whelk, *Nucella lamellosa*, both species are associated with egg masses on emergent structure. The small snail *Astysis gausapata*, is present in relatively high densities on emergent structure. Blue mussels, *Mytilus sp.*, and barnacles, *Balanus sp.*, are also present and form clusters in the intertidal in addition to fouling other emergent structures. Other mollusks found here include the pacific oyster, *Crassostrea gigas*, the nudibranch *Phidiana crassicornis*, and the moon snail, *Polinices lewisii*, which is the dominant bivalve predator here and likely preying on the abundant Bent-nose clam, *Macoma nasuta*. Another intertidal predator observed here is the False Ochre star, *Evasterias troschelli*, though only a few were encountered. The arthropods found in this

area include various hermit species from the *Pagurus* genera, the hairy shore crab, *Hemigrapsus oregonensis*, and Cancer crabs *C. productus* and *C. gracilis*. We also observed the Ghost shrimp, *Neotrypaea californiensis*. The algal community here is limited, perhaps due to the riparian shading in effect here or brackish water flowing from Woodard Bay. Some drift algae is present in the intertidal and is primarily from the genera *Ulva* and *Enteromorpha*. There are also some hydroid colonies present here fouling emergent structure, though these are more closely associated with the intertidal area to the west and beyond the trestle bridge.

Natural Olympia Oyster Aggregation

The native oysters in the Woodard Bay area are concentrated in the west end of Shell Area #1 and are associated with pooling and flowing water in that area. The ground is also firmer in this spot and includes some emergent gravel. Oysters are observed outside of the wet areas but the majorities are concentrated with wet conditions or are partially or fully imbedded in the soft sediment surface. The oysters here are nearly exclusively found as single oysters, unassociated with a settlement substrate. It is unclear whether these oysters were transported here by some physical process after recruiting and cleaving from another spot or whether these animals recruited to this area and the wet conditions and firm ground facilitated their survival. Either way, it is clear that a unique combination of factors allow these oysters to thrive in this small area. Consistent habitat factors include a lack of significant predation, tidal elevations below MLLW, associated standing or flowing water, firmer ground and the emergent structure maintained by these wet conditions.

To conduct the population assessment, we used a population census instead of an extrapolated subsample protocol. This technique was used because of the relatively small survey area and the ample volunteer personnel available during this field effort. Surveyors organized themselves shoulder-to-shoulder, completely scouring the benthic surface for native oysters (see Figure 4). All observations of native oysters were recorded and a subsample of oysters were measured for shell length.



Figure 4. Native oyster census on the west end of the proposed Shell area #1.

The size distribution for this population can be found in Figure 8. This appears to be a normally distributed size structure, which can indicate several year-classes of recruits. This can be misleading, however, as particular microhabitats can greatly effect oyster growth rates. There are different year classes represented in these aggregations, though no recent (2006) natural recruitment was observed.

The primary aggregation of native oysters found in the west end of Shell Area #1 is at the -1 MLLW elevation (see Figure 5). This area is defined by flowing and pooling water at low tide, and is immediately adjacent to the main drainage channel. 214 oysters were observed in this primary census area centered on the following WGS 84 position: N47.13134 W122.84387. The oysters here are well distributed throughout the range of the census area, oriented southwest to northeast.



Figure 5. The primary native oyster aggregation is in the foreground. Photo position WGS 84 N47.13119 W122.84407 oriented at 29 degrees magnetic north. The 2006 seed production bags are visible in the center of the area.

A second discrete census focused on the immediate area surrounding the experimental shell plots in the 2006 site #1.5 and continued out to the primary census area. This area is shown in Figure 7 as the northern projection of the census survey area. All of the oysters encountered in this census were located in a small portion of the area (shown in black in Figure 7), adjacent to the experimental shell plots and around an area of pooling water created in part by the large woody debris found in this spot. 26 oysters were observed in this secondary census area centered on the following WGS 84 position: N47.13160 W122.84383.



Figure 6. Secondary oyster aggregation. Photo position WGS 84 N47.13136 W122.84397 oriented at 3 degrees magnetic north. The large woody debris is visible in the right side of the frame along with the 2006 experimental shell plots.

The native oyster aggregations are organized into two separate patches, thus the separate census efforts. The primary aggregation covers a tideland area of approximately 7,500 Ft² or 696 m². The oysters are well distributed in this area and using the census numbers, we estimate their density at 0.30 oysters m⁻². The secondary aggregation, near the 2006 experimental shell plots in Site #1.5 are distributed over a smaller area of approximately 2,250 Ft² or 209 m². These oysters are closely associated with the standing water in the area and occupy a smaller portion of the census survey area. We estimate the density of oysters in this secondary aggregation at 0.12 oysters m⁻². No sub-samples were collected to generate these density estimates; therefore there is no reported confidence interval for these estimates.

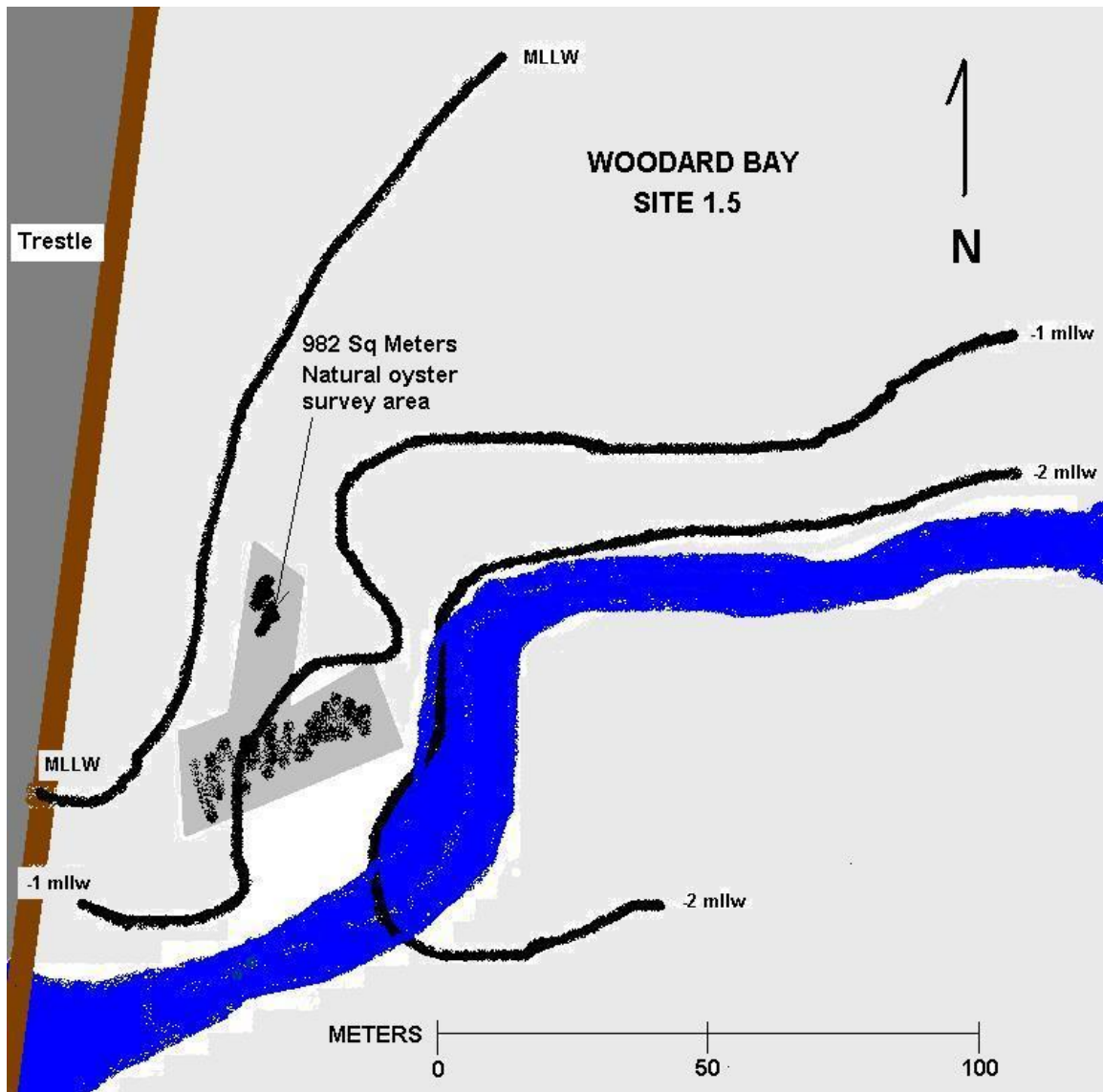


Figure 7. Scaled schematic showing the census area, primary drainage and regional elevation contours for the natural native oyster aggregations near site #1.5. The distribution of the oyster aggregations within the dark grey census area are characterized in black.

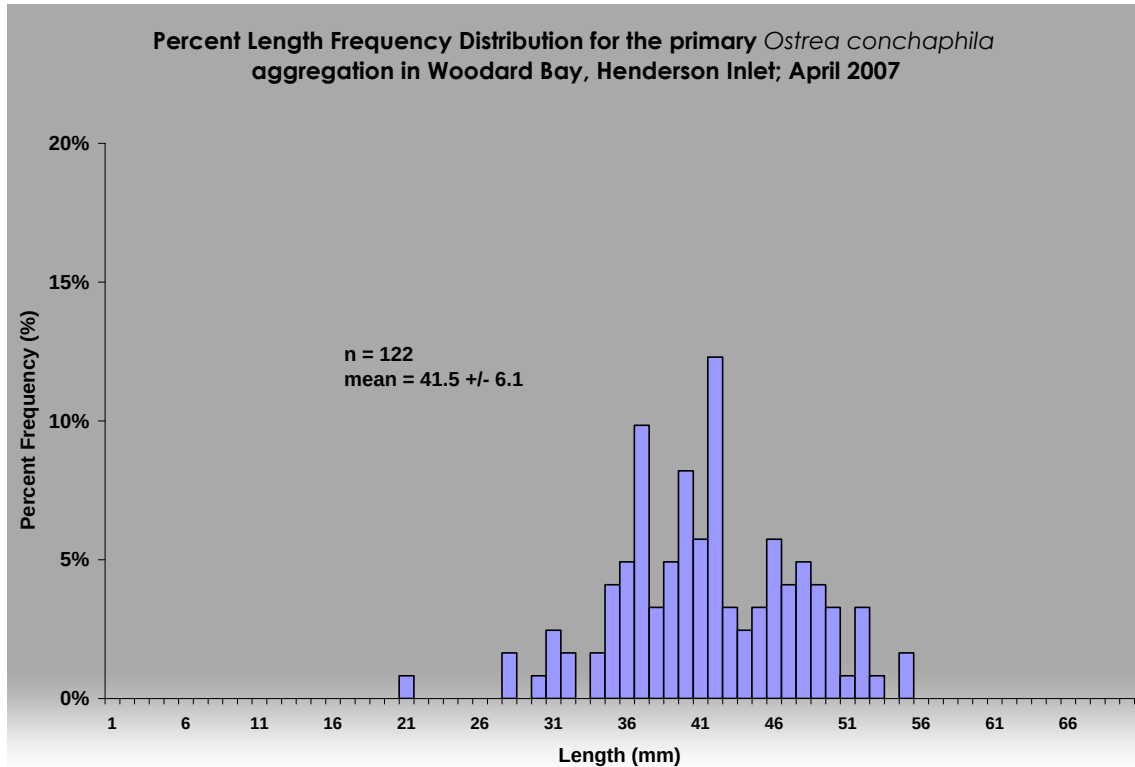


Figure 8. Percent length frequency distribution from an April 2007 population census of naturally-occurring native oysters in Woodard Bay at the west end of Shell Area #1.

Benthic Community Diversity

The 2005 effort in Woodard Bay integrated several pre-enhancement environmental measures that included assessments of the benthic infauna in each of the study sites. Surveys of the benthic infauna were conducted at the four Woodard Bay sites (2005 site #'s 1-4) and the one biological control site on the east shore of Henderson Inlet (2005 site #5). In 2006, an additional site (#1.5) was added to the project. This report is a supplement to the suite of benthic community data collected in 2005 and includes benthic core data and results for samples collected in June 2007. Site #'s 1.5 and 3 were selected for benthic core transects as these locations were the proposed enhancement locations in 2007.

Methods

Benthic core samples were collected on June 12th, 2007 at the selected Woodard Bay sites (#'s 1.5 and 3). Methods for biological sample collection were borrowed from Dethier & Schoch (2005). Ten core samples (10cm core at 15 cm depth) were collected from each site. Sample locations were selected using a random number table to specify core locations along a 50-meter transect oriented parallel to shore. Transects were located at the MLLW elevation for Site #3 and at the -1 MLLW elevation for Site #1.5, as this

location does not offer the elevation specified in the protocol. Core samples were sieved at 2mm and the samples fixed in 10% Formalin for identification in the lab.

In the laboratory, samples were processed and identified to species when possible. The biomass from the benthic samples was represented largely by a variety of worms from the phylum Annelida, class Polychaeta. In the case of polychaetes, species were delineated and keyed to Order or Family when practical. Species diversity was calculated using standard biodiversity indices. First is Species Richness (S') which reports the number of different species observed. The second is Relative Abundance which is calculated using the Shannon-Weiner Index (H'), where:

$$H' = - \sum p_i \ln p_i$$

Examples of each organism not identified to species remain catalogued and stored in 10% Formalin. These specimens are available for future comparisons or identification efforts.

Results

21 species were observed in benthic cores from site #1.5 and 16 species from site #3. Species richness and evenness indexes results are shown in Figure 9. The bentnose clam (*Macoma nasuta*), an unknown Nemertean and three species of Polychaete worm (2 unknown species and 1 species from the family *Glyceridae*) were the most common and found from surveys of each site. The identification of most marine worms (Nemerteans and Annelids) proved to be beyond the scope of this project and was not necessary to calculate biodiversity. Simply identifying the number of species was adequate to complete the analysis; survey data is included in the Appendix. The following is a list of organisms recorded during the processing of benthic core samples:

Animals keyed to genus or species

- Bentnose clam (*Macoma nasuta*)
- Native Littleneck clam (*Protothaca staminea*)
- Tube-dwelling Amphipod (*Corophium salmonis*)
- Tube-dwelling Amphipod (*Corophium acherusicum*)
- Shrimp (*Pandalus* sp.)
- Bubble Shell (*Haminaea vesicular*)
- Butter clam *Saxidomus giganteus*

Animals keyed to Order or Family and Unknowns:

- Brachyuran Crab, 1 species
- Polychaete, 11 species
- Polychaete species family *Glyceridae*, 1 species
- Nemertean species, 1 species
- Nematode species, 2 species
- Unknown Bivalve, 1 species
- Unknown Worm, 1 species
- Unknown Shrimp, 1 species

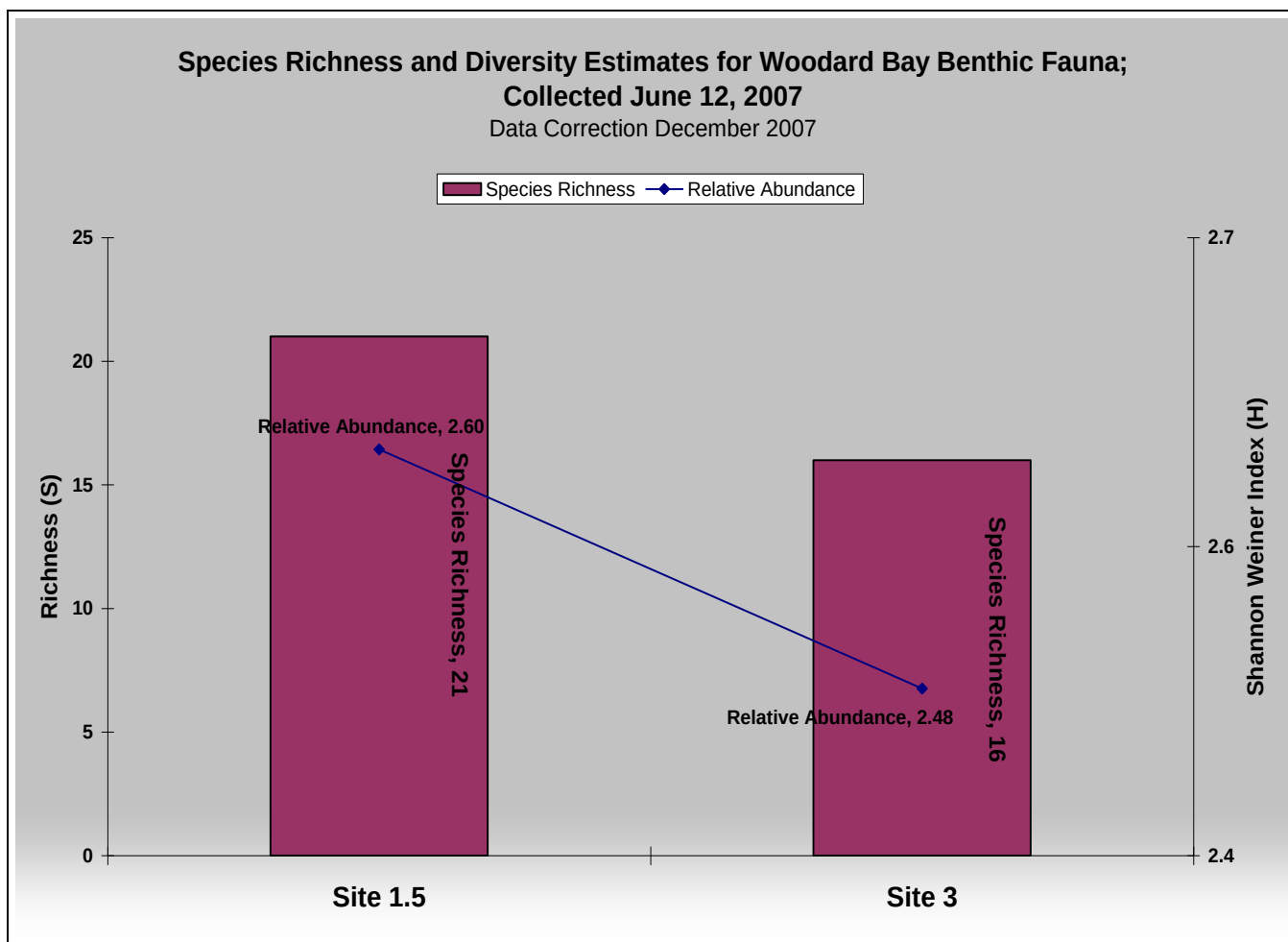


Figure 9. Benthic community biodiversity results from 2007 Woodard Bay benthic survey.

Discussion

Species richness can be useful in comparing geographic areas, but their usefulness is largely dependent on sample size. Pilot studies referenced in Dethier and Schoch (2005) showed that 10 sample units accounted for 95% of the diversity per transect, with approximately 80% accounted for by the first six sample units. Therefore, additional sample units would not appreciably increase the overall estimates of diversity.

By themselves, species richness (S) numbers can be misleading. Think about two communities, each with the same number of species but where one has one very common species with only a few individuals of the other species while the other community has equal numbers of each species. Intuitively we recognize that the community where the individuals are spread out equally among the species is a more diverse community than the one where almost all of the individuals belong to one species. To correct for this we need to consider relative abundance or equitability. The Shannon-Weiner Index takes into account the evenness of the species distribution as well as the absolute number of species.

The benthic sediment is more complex at Site #1.5 offering a range of substrate that includes shell, gravel, sand and mud. The shell component of the substrate appears to be barnacle shell hash, likely washed into the survey area from the rocky areas in the adjacent higher elevations. The complexity of sediments here may be a factor in the resulting biodiversity increase over Site #3.

Habitat Enhancement

In the spring of 2007, when the final design of the proposed enhancements was completed, the scale of each shell enhancement was adjusted. The footprint of each shell area was reduced from the proposed size to realize particular objectives in each plot. For Shell Area #1, we wanted the enhancement to follow defined habitat features on the NRCA tideland. These included elevation contours at or below -0.5 MLLW and a close association to the main drainage. For Shell Area #2, we decided a pilot-scale enhancement was merited to examine our technique in the transitional elevations from low intertidal to below extreme low water and into the subtidal area leased by TNC. Logistic restraints of moving the shell material also caused a reduction from the original proposal. The final design for the two shell enhancements had Shell Area #1 as a 0.75 acre shell plot that spanned 650 feet of shoreline in the NRCA and Shell Area #2 as a 0.25 acre band of shell, oriented perpendicular to the contour and 425 feet long. The following section describes the implementation of the collective 1-acre habitat enhancement in Woodard Bay.

Enhancement Shell Plots

The enhancement plots, described as Area #1 and #2 (see Figure 10), both bulk shell and hand-placed shell enhancement areas. Approximately (0.2 Acres) in the west end of Shell was enhanced by hand-placing the shell from 150 bags, purchased from Taylor Shellfish Farms in Shelton; delivered the load to Woodard Bay for spreading at low tide. The shell spread out on August 14th during a -0.4 foot low tide. The result was a 1 to 2 inch cultch layer between the 0 and -2 MLLW contour.

Figure 10. 2007 shell enhancement areas in Woodard Bay.

The hand-placement in the west end of the plot was intended to avoid harming the natural aggregation at the site, estimated at 240 oysters in May 2007.



Shell include
9,000 Ft²
Area #1
cultch
the
PSRF
by barge
was



Figure 11. Taylor Shellfish crew spreading shell in Shell Area #1.

The remaining portion of Shell Area #1 covers 23,000 Ft² (0.5 acre) of tideland between the 0 and -4 MLLW contours. The footprint of the plot follows the main water feature east of the trestle bridge, a weaving channel that cuts through the tideland across 650 feet of shoreline. Five scow loads, of approximately 60 yards³ of cultch each, were spread here by the Taylor Shellfish Farm crew between August 6th and 12th (Figure 11). The 300 yard³ application of cultch was inspected by PSRF staff on September 24th and estimated to provide approximately 3 inches of emergent shell above the substrate.

There is an additional 10,000 Ft², approximately ¼ acre, of available habitat adjacent to Shell Area #1. This extends to the east from the shell area and captures an expanse of tideflat at the -2 MLLW elevation; the eastern edge of the enhancement plot in Shell Area #1 includes a portion of this same feature. The boundaries for each completed enhancement are defined by the position information found in Table 1 below.

Shell area #2 is farther south, at the lease site, and covers 12,600 Ft² (acre) between the -3 Ft and -5 Ft (MLLW) elevation. In 2005, this consistently reported above average spatfall on shellstrings. plot was designed specifically to investigate the gradient, if any, in efficacy of a cultch enhancement spans the gap over the lower intertidal and shallow subtidal in Woodard Bay. By August 12th, yards³ of cultch was spread here by Taylor crew over a 425 foot long of subtidal ground. The enhancement is oriented perpendicular to the elevation contour and is on a line drawn the 2006 Site #3, -3 station

<u>Shell Area Ploygon Boundarys</u>			
<u>Shell Area 1</u>		<u>Shell Area 2</u>	
N47 07.911 W122 50.501		N47 07.561 W122 50.317	
N47 07.896 W122 50.506		N47 07.557 W122 50.314	
N47 07.900 W122 50.551		N47 07.572 W122 50.218	
N47 07.897 W122 50.583		N47 07.567 W122 50.218	
N47 07.877 W122 50.617			
N47 07.861 W122 50.637			
N47 07.877 W122 50.644			
N47 07.890 W122 50.620			
N47 07.903 W122 50.592			
N47 07.902 W122 50.537			
Waypoints in WGS 84 datum			

TNC
(0.3
area
The
the
that

180
the
strip

from
Table

1. Position information for shell areas #1 and #2.
to the Site #4, -5 MLLW middle

station. PSRF staff visited the plot post-placement and estimate the emergent shell height at 3 to 4 inches. There are a handful of locations within the plot that have a shell height closer to 6 inches. Table 2 below summarizes the quantity of each discrete application.

Plot	Total Area	Application	Quantity	Shell Height
Shell Area #1	8,700 Sq Ft	hand placement	150 bags $\approx$ 3.75 yards ³	2"
Shell Area #1	22,700 Sq Ft	bulk spreading	300 yards ³	3"
Shell Area #2	12,600 Sq Ft	bulk spreading	180 yards ³	4"
Total 44,000 Sq Ft (1 Acre)				

Table 2. Enhancement descriptions for the August 2007 project.

No remedial actions are required for this effort. The application of cultch shell in these areas accurately replicates our designs for the enhancement. Marker stakes were removed on September 24th. An initial assessment was scheduled for winter 2007.

Monitoring

To monitor the performance of the enhancement material, the forecasted native oyster recruits and the reaction of the community organisms to the enhancement we recommended a standardized-random sample protocol and associated community-level data recording methodology. This protocol would randomly select independent $\frac{1}{4}$ m² sample positions to the frequency required to estimate population parameters within an established precision for confidence intervals. This protocol is similar to the Campbell protocol used by the Washington Department of Fish & Wildlife to assess clam and oyster populations in Puget Sound.

The population of concern in this case is that of the native oyster; therefore sample sizes will be based on this population's variability within the enhancement plots and determined to generate density means approaching a +/- 30% relative error for confidence intervals. Initially these enhancement plots are expected to have low densities of oysters as they begin to colonize the enhancement shell; this fact makes our confidence interval goals impractical likely until continued recruitment increases density and decreases population variability over time. Separate surveys will be conducted for each shell area. The population will be defined as those oysters occurring within the footprint of each contiguous shell area. The data collection methodology used for monitoring surveys will focus on descriptions of the survey area, live oyster counts and length frequency observations for native oysters. We will also make observations of the amount, condition and fouling community associated with the emergent oyster substrate. Predator and competitor species for the native oyster will be quantified and other emergent macro invertebrate species recorded to generate relative species richness estimates. This methodology was developed specifically to assess the community-level response to this restoration practice and the roll of complex biogenic structure (oysters) and shell in the intertidal.

Enhancement Assessment

The 2007 shell enhancement of Woodard Bay tidelands was intended to present available substrate for recruiting native oysters during the next available reproductive season. PSRF has shown an expected range for the initial seasonal spawning event can be estimated by finding where the ambient seawater temperature exceeds a published threshold (Baker, 1995); see Figure

12. This occurred during the first week of June in 2007. PSRF forecast the peak settlement events to begin, therefore, during the neap tide on or about 30 days following the spawning event. There was such a neap tide in 2007 between July 6th and 8th.

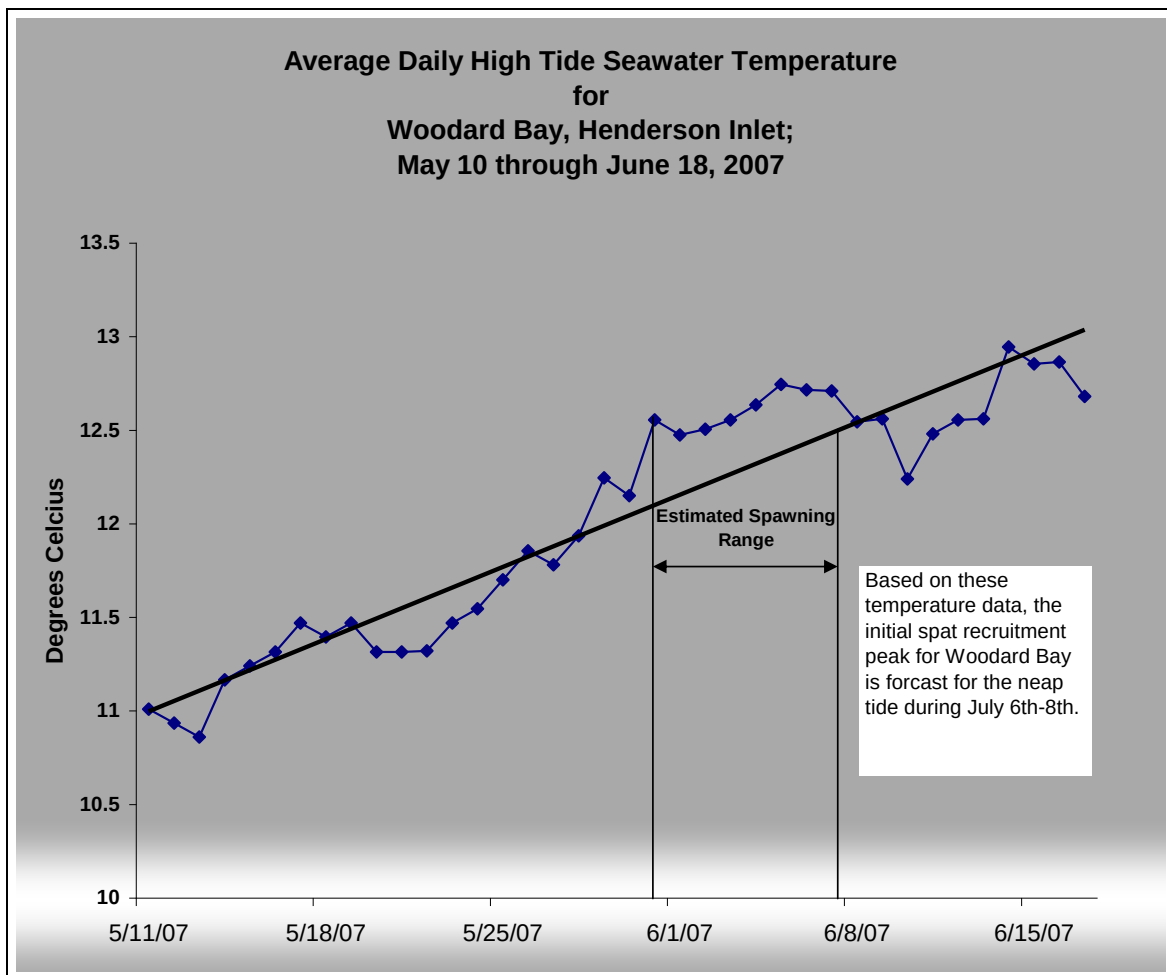


Figure 12. This chart was generated using temperature logger data and shows the daily average high tide water column temperature in degrees Celsius. The estimated timing for native oyster spawning is shown.

Trials in 2006 demonstrated that Pacific oyster shell substrate in Woodard Bay will attract native oyster spat settlement. The 2007 spat recruitment period in Henderson Inlet likely had begun at least by the first week of July. In conversations with Tim McMillin, the proprietor of the Olympia Oyster Company in Totten Inlet, he echoed our assessment of the spatfall timeframe and commented that majority of the spatfall this year occurred during the month of July. The shell enhancements in Woodard Bay, completed on August 12th, were conducted with the understanding that the material would likely arrive after the spat recruitment period.

Shell Area #2, being nearly entirely subtidal does not lend itself to standard low tide survey. A modified protocol using SCUBA was necessary to survey within this shell plot to collect samples congruent with the intertidal methods. Because there was likely no oyster recruitment to the shell plots in 2007, an underwater survey of Shell Area #2 was reserved for November 2008, which followed the first reproductive season available to these enhancements. Discussed below

are the two monitoring efforts of the intertidal shell plot in Shell Area #1 that occurred prior to the enhancements exposure to native oyster recruitment; one in December 2007 and one in April 2008. This is followed by reports of the surveys conducted after the 2008 reproductive season in both shell areas.

To achieve our assessment objectives, we used a method developed in 2007 by PSRF, “Intertidal *Ostrea conchaphila* Population Assessment Procedures; Applications for surveying natural populations and restoration areas”. This document and supporting material is available from the PSRF. This procedure borrows from the WDFW standardized-random approach for sample density (Campbell, 1996). The protocol was altered slightly to reduce sample size, as the presumed absence of oysters precluded a population estimate.

Shell Area #1 Assessment Results, winter 2007

A winter assessment of the enhancement shell, conducted by PSRF staff and volunteers on December 21st, was able to confirm the absence of young-of-the-year native oysters on the cultch substrate. The objectives outlined for this initial assessment of the 4-month old enhancement were therefore the following:

- Make an initial assessment of the amount and condition of the shell habitat in each enhancement plot relative to the amount and condition at deployment.
- Confirm presence or absence of native oyster recruits.
- Establish a permanent transect within the plot and collect preliminary population statistics for native oysters, if present, to facilitate future population assessments.

In December 2007, the plot in Shell Area #1 was found to be intact and providing a continuous emergent substrate over the entire original enhancement footprint. The original delineated plot was reported as 2,917 m² or 0.72 acres (combined bulk and hand-placed shell) to TNC in progress report #1. This estimate was generated from the GPS positions of the original marker stakes used to guide the shell spreading crew. The December survey estimated the plot area to be 3,745 m² or 0.92 acres. This survey estimate is generated through a combination of direct measures of plot dimensions; this will always be more accurate than estimates from GPS. The apparent growth of the plot area is an affect produced by the inherent error in using hand held GPS and possibly in the application of the shell outside the plot boundary.

The emergent cultch shell averaged 1.9 inches in height above the benthic surface and covered an estimated 70% of the beach within samples. This enhancement plot was specifically located within the primary drainage of this tideland in order to capture the empirical benefit to oyster habitat; this area presents a soft and silty benthic sediment, so it was no surprise to

Shell Area #1 Corner Positions	
Map Position	WGS 84 GPS Position
1	N47 07.870 W122 50.634
2	N47 07.875 W122 50.643
3	N47 07.909 W122 50.515
4	N47 07.898 W122 50.494

observe an estimated 37% average silt cover within the shell area.

Table 3. Surveyed corner positions for Shell Area #1 in December 2007; see Figure 13.

Position 1, in red text, is the established start position monument for the permanent survey baseline.

Based on the oyster populations found in other shell areas, the siltation experienced by this location would not appear to limit the development of effective populations of native oysters. There was no significant animal or algal fouling of the emergent shell.

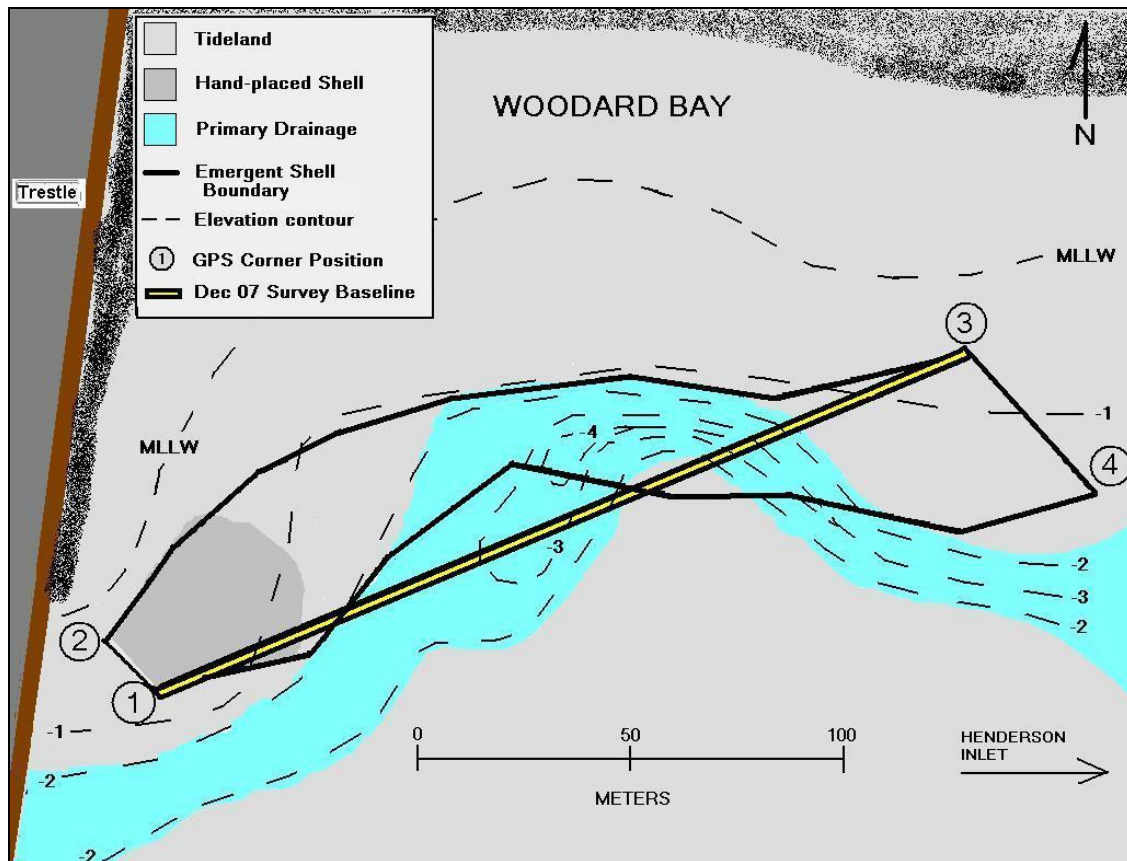


Figure 13. A scaled schematic showing Shell Area #1 in Woodard Bay. Corner positions are shown above in Table 3.

The shell habitat arrived to this location late in the season for most fouling organisms, which was confirmed by the empirical low densities. Fouling organisms reported in samples include the competitor species *Crepidula fornicata*, *Pododesmus cepio* and a *Mytilus* species; these were all estimated to be below densities of 1 m⁻². Other fouling organisms encountered include the bryozoan *Schizoporella unicornis*, and the green algae *Ulva fenestrata*. The remaining emergent fauna observed in samples are likely pre-enhancement residents or immigrants from adjacent unstructured habitat; the relative emergent species richness for this plot was estimated at 30 species.

The plot is entirely below the MLLW elevation. At a -2 ft. tide, 75% of the emergent shell is in standing or flowing water. Figure 13 shows the plot as it follows the path of the primary drainage over nearly 1 acre of tideland. A summary of the December 2007 survey results can be found in the Appendix. The absence of native oysters within the

enhancement plots is no surprise at this stage of the project post-enhancement. The shell was simply not available to larval oysters in early July when they were in the area. The goals of this initial assessment were met by collecting good baseline measures for the emergent substrate amount, quality and associated community organisms for comparison to subsequent assessments.

The emergent shell height and area were well preserved in Shell Area #1; indications of biological manipulation (loss to bioturbation) to the plot would have been expected by the December assessment. There was no loss of the plot area observed in the December survey. Also, the estimated 38% reduction in emergent shell height tracks well with the rate of loss experienced by the 2006 experimental shell plots. PSRF anticipated this plot was well positioned to encourage native oyster spat recruitment in 2008. If this area continues to provide oyster substrate in good condition and native oysters recruit here in subsequent years, estimates of the oyster population parameters will become available.

Shell Area #1 spring 2008

PSRF staff and a dedicated group of volunteers from TNC conducted another survey of Shell Area #1 on April 9th, 2008. The absence of young-of-the-year native oysters on the shell substrate was confirmed in the December 2007 survey, but there was an interest in tracking the changing condition of the emergent oyster substrate and community organisms. A summary of the 2008 (fall and spring) survey results can be found in the Appendix. The objectives outlined for the second assessment of the 9-month old enhancement were therefore the following:

- Track of the amount and condition of the shell habitat in the enhancement plot relative to the amount and condition at the previous survey.
- Collect another series of observations of community organisms as they begin to exploit the new habitat.

In April 2008, Shell Area #1 continued to provide emergent substrate over the entire original enhancement footprint. The updated area estimate for Shell Area #1 was 3,667 m² or 0.91 acres, a negligible decrease in total area from December 2007.

The amount of emergent cultch remained unchanged since the last survey, with shell height above the benthic surface averaging 1.8 inches and covering an estimated 70% of the beach within samples. Observations of silt cover, however, increase since the December survey from 37% to 84% average silt cover of emergent shell. Algal fouling was minor at 15% cover; barnacle fouling was reported at 5%. Though the shell habitat was 9 months old at the time of this survey, it had not endured an entire summer growing season when significant fouling would be expected. Other emergent organisms reported in samples mirror the December survey and include the competitor species *Crepidula fornicata*, *Pododesmus cepio* and a *Mytilus* species; there was a slight increase in *Crepidula* and *Mytilus* densities from December reports. Other fouling organisms encountered include again the bryozoan *Schizoporella unicornis*, and the green algae *Ulva fenestrata*. The relative emergent species richness for this plot was recorded at 25 species.

The enhancements in Woodard Bay were 9 months old by spring 2008, but this alone would not negatively affect the ability of the plot to attract native oyster set. Brady Blake (pers. comm.), WDFW Biologist, suggests that oyster cultch not only continues to remain effective the longer it stays on the tideland, but improves as a settlement catalyst.

Shell Area #1 fall 2008

This last survey of the intertidal enhancement in Shell Area #1 was conducted 15 months post-placement on November 13th, 2008 and followed on the heels of the 2008 reproductive season. Again, this was the first exposure to potential native oyster spat settlement since the implementation of the enhancement. Based on measured spatfall from the Woodard Bay shellstrings in 2008, we expected to observe native oyster juveniles during the fall survey. The objectives outlined for this third assessment of the enhancement on the NRCA tidelands were the following:

- Track of the amount and condition of the shell habitat in the enhancement plot relative to the amount and condition at the previous survey.
- Collect another series of observations of community organisms as they begin to exploit the new habitat.
- Confirm natural recruitment of native oyster juveniles to the enhancement plot and if present, make density and population estimates.

The shell plot in the NRCA continued to provide emergent substrate over the entire original enhancement footprint, but there were marked changes observed since the last survey, 7 months previous. Generally, the shell is less dense and covers slightly more area than reported in the last assessment. Plot area estimates increased 9% to 4,013 m² or approximately 1 acre and shell coverage decreased 48% from April to an estimated 22.6% average cover; emergent shell density was reported at 46 shells m⁻². Shell height decreased 30% to an average 1.3 inches. Surprisingly, observations of silt cover decreased 56% since the April survey to a reported 28% mean cover of emergent shell.

A single native oyster recruit was observed in the November sample. While measurable amounts of oyster larvae and spat were observed during the recruitment window (see the following section on 2008 recruitment), it was a relatively poor recruitment year for this species in Henderson Inlet; possible contributing factors are discussed below. While it was rewarding for the volunteer surveyors to find a 2008 oyster recruit, the single observation precludes a meaningful estimate of population size or density.

Algal fouling of the shell continued in 2008, but remains relatively low at 11% cover. Barnacle recruitment increase in 2008 and now covers an estimated 49% of emergent shell, however the barnacle cover is limited to the top surfaces of the shell and avoids the cryptic surfaces preferred by the native oyster. Other species reporting successful recruitment in 2008 include, most notably, *Mytilus* species (estimated at 35 mussels m⁻²) and the native whelk *Nucella lamellosa*, while not quantified, juveniles were observed in every sample in November. The *Crepidula fornicata* density estimate increase slightly, with the help of an observed 2008 set, to an estimated 10.6 m⁻². The Jingle shell, *Pododesmus cepio*, a tough space competitor in previous pilot enhancements has yet to show a serious presence in Shell Area #1, reporting a density of 0.1 m⁻², a negligible change from previous assessments. The relative emergent species richness for this plot increased to 31 recorded species and included some interesting species not previously observed, including:

- *Nucella lamellosa*, snail
- Hydrozoan polyps
- *Onchidoris bilamellata*, nudibranch
- *Mopalia* sp., chiton
- Unkn Cottid sp., fish
- Unkn adult Salmon

Shell Area #2 fall 2008

PSRF conducted the first survey of the subtidal shell plot, Shell Area #2, which cuts across the lower intertidal elevations and into the subtidal depths of the TNC lease area in November 2008. We had to develop an appropriate subtidal survey protocol for this plot to conduct the sample collection via SCUBA. In preparation for such, PSRF became an organizational member of the American Academy of Underwater Sciences to certify its staff and qualified volunteers as scientific divers under this nationally recognized diver safety program. The survey protocol was modified from the standardized-random sample placement to a haphazard placement to facilitate rapid sample collection in the low-visibility conditions. Data collection duties were split between the dive team, which made some observations of shell quality and observed species, and the surface team, which made direct observations of the emergent shell samples.

The emergent substrate within the habitat enhancement is a stark contrast to the surrounding benthos in Shell Area #2; now that the enhancement is 15 months old, the effect of available hard substrate is readily apparent as floral and faunal succession has altered the once barren sediment into a reef, diverse with kelp and other animal species not previously observed in this area.

The shell plot itself is a narrow strip, approximately 25ft wide, which crosses between the center of the 10-acre TNC lease at the -5 ft. MLLW elevation to the low edge of the 2006

experimental Site #3, at the -3 ft. elevation MLLW (see Figure10). The sediment here is quite soft, which is why the application of shell was targeted at 3 to 4 inches emergent. In November 2008, the shell height was estimated an average 1.8 inches, covering 66% of the benthic surface within the plot; emergent shell density was reported at 280 shells m^{-2} . The fouling community consists primarily of algae, estimated at 39% mean cover, and barnacles which were estimated to cover 56% of the emergent shell. Again, barnacles tend to foul the upper surfaces of the shell, leaving the interstitial surfaces relatively bare. Silt was estimated to cover 44% of the shell surface.

A single native oyster recruit was also the only observed specimen in the November samples from this plot. While the native oyster recruited to the plot in 2008, the single observation again precludes a meaningful estimate of population size or density. A summary of the survey data is available in the Appendix.

The only recognized oyster predator observed during the survey were the robust numbers of *Cancer gracilis*, estimated at 1.3 m^{-2} for samples. These crabs were only noticed within the shell plot, not in the adjacent unstructured area. *Crepidula fornicata* also recruited to the shell enhancement, since the placement in August 2007, and were estimated from samples at 0.4 m^{-2} . Of note were observations of the hooded nudibranch, *Melibe leonine*, a species typically associated with eelgrass or kelp structure.

2008 Native Oyster Recruitment

Temperature loggers were deployed in south Puget Sound from May 7th to June 19th, 2008 to track seasonal increases in seawater temperature and to forecast the oyster spawn and subsequent spatfall. Spring 2008 was relatively late, about a month, to warm up to oyster spawning temperatures. In fact, the daily high tide mean temperature in south Puget Sound remained under 12°C in late June, where in 2007 this mean exceeded 12°C by late May. A temperature trend extrapolation (similar to that found in Figure 12) forecasted the native oyster spawn on or about July 3rd in 2008. This pushed the spatfall forecast to begin during the neap tides of July 26th or August 8th.

Three shellstring stations were established in Shell Area #1 and monitored for spatfall during the forecasted initial settlement period. This has empirically been the best time to record natural set in Henderson Inlet and was repeated in the summer of 2008 to qualify the relative juvenile recruitment potential for the enhancements that year. Three shellstrings, containing 11 Pacific oyster shells each, were mounted on wires and positioned at the benthic surface within the shell plot. The position information can be found in Table 4. Station #1 was located in the east part of the plot, station #2 in the middle, and station #3 was at the western part of the plot, near the old trestle bridge.



Figure 14. Shellstring station

The initial series of shellstrings were deployed on July 24th to soak during the neap tide, centered on July 26th. A second series was deployed on August 4th to capture the spatfall during the August 8th neap tide. Oyster spat settlement was recorded from shellstrings in Woodard Bay and the results are shown in Table 5.

Table 4. 2008 shellstring station positions (WGS 84)

	Station #1	Station #2	Station #3
Elevation	-2Ft MLLW	-2.5 MLLW	-2.5 MLLW
Latitude	N 47 07.900	N 47 07.903	N 47 07.885
Longitude	W 122 50.520	W 122 50.594	W 122 50.627

The oyster spat that were observed on shellstrings appears to settle consistently throughout the monitoring period. This collection was intended to simply confirm spat settlement within the plot area in 2008.

Table 5. Shellstring reports for Woodard Bay, Summer 2008

Shellstring	Elevation	Deploy Date	Collection Date	Spat Count
1	-2	24-Jul	4-Aug	4
2	-2.5	24-Jul	4-Aug	3
3	-2.5	24-Jul	4-Aug	4
1	-2	4-Aug	15-Aug	9
2	-2.5	4-Aug	15-Aug	1
3	-2.5	4-Aug	15-Aug	3

Larval Retention Pilot

Habitat enhancement using Pacific oyster cultch has been a successful stock-rebuilding technique in locations around Puget Sound. With each enhancement, we attempt to learn more about the efficacy of the practice. One question we hoped to look at in 2008 was how effective enhancement shell is at attracting and retaining native oyster larvae in the plankton. PSRF attempted to measure this effect with plans for a pilot larval retention experiment. Originally intended for the Frye Cove project in Eld Inlet, ultimately the location of the pilot was changed to focus on the Woodard Bay shell enhancement.

We scheduled an experiment to coincide with the forecasted initial recruitment period. The plan was to collect 100-liter plankton samples, near the substrate surface, in two locations: one within the enhanced shell plot of Shell Area #1, and one in an adjacent unstructured portion of tideland in Woodard Bay. We planned to examine the samples to determine if more larvae were observed in the shell plot as compared to unstructured benthos, indicating that the shell habitat may retain larvae.

Four plankton collections were made between July 24th and August 15th during the predicted spat settlement when oyster larvae. The results of those collections can be found in the Appendix.

Each sample was collected during daylight flood tide conditions, 6 to 12 inches off-bottom, pre-filtered at 300µm and collected at 75µm then preserved in 70% Ethanol. The two stations were separated by 500 feet. Two sample periods focused on neap tides and two on spring tides, which spread the collections approximately a week apart. Native oyster larvae were observed in samples, primarily from the latter two collections on August 7th and 15th, respectively. These data are found in the below in Figure 15.

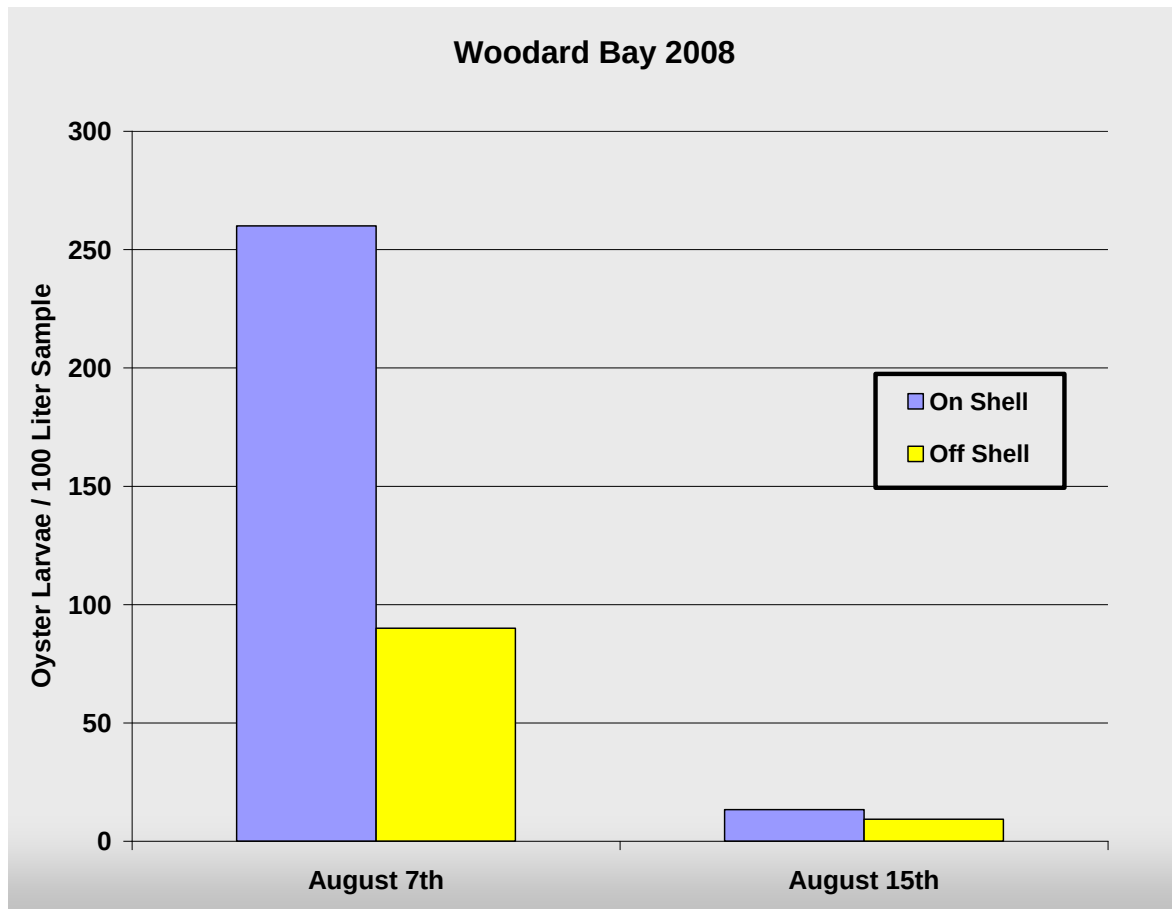


Figure 15. Results from the last two dates of plankton collections in Woodard Bay when oyster larvae were observed in samples.

Sample replicates and frequencies were not intended to support statistical comparisons of abundance for this pilot effort; however, the results do indicate a trend toward greater abundance of oyster larvae found within the complex shell habitat in the enhancement as compared to the adjacent unstructured littoral space.

Discussion

The 2006 experimental plots in this area, which are a year older, still remain emergent above the benthic surface. What we have seen happen in those small experimental plots is much the same as was noticed this fall in the larger 2007 enhancement. The shell is both sinking to some degree into the sediment, as expected, and becoming less dense as some shell is transported along the

tideland. Physical disturbance and sediment transport will continue to affect the amount of emergent shell within the enhancements.

While the density of shell may be decreasing as shell sinks or is scattered, the amount and quality of emergent shell available for oyster settlement remains high. Some scattering and sedimentation is to be expected and was certainly indicated by the pilot experimentations, however the enhancement is currently meeting expectations regarding providing the opportunity for natural oyster settlement.

Shell Area #2 looks to be in great shape regarding quantity and quality of emergent oyster substrate, now 15 months post-placement. As discussed, in the 2005 assessment of this area, any available hard substrate will very quickly be utilized by subtidal species in this unstructured benthic condition. Many species encountered in this area are only found associated with hard, emergent substrate that facilitates refuge, foraging or access to the water column.

While the spatfall reports from shellstrings in Woodard Bay seemed to indicate the potential for juvenile recruitment, 2008 was shown to be a poor recruitment year in Henderson Inlet. Robust juvenile recruitment, as was measured here in 2005 by TNC and measured elsewhere in Puget Sound in 2008, appears to be a less frequent occurrence in Henderson Inlet. Regardless, the 2007 enhancement plots continue to provide high quality oyster settlement habitat in good condition for subsequent recruitment events.

The cold temperatures measured in spring 2008 likely affected the reproductive and column conditions for native oysters in south Puget Sound. This was the sentiment of Tim McMillin, proprietor of the Olympia Oyster Co. in Totten Inlet, while other oyster growers commented on robust juvenile recruitment observed in Totten Inlet later in 2008. There are certainly localized conditions within Puget Sound that would create differences between the inlets in regards to native oyster settlement and juvenile recruitment. This could be the result of the differences in the parent population abundance within each inlet; this lends to the theory that the larval retention of the native oyster in south Puget Sound inlets is significant. If this is the case, then the success of the Woodard Bay enhancements as stock-rebuilding projects is linked directly with the population abundance and reproductive success of the parent population of native oysters in Henderson Inlet. To date, no substantial populations have been encountered in Henderson Inlet beyond the population that fouls the commercial Pacific oyster farm to the south of Woodard Bay (approximately 2 miles away). The management cycles (planting and harvest of Pacific oysters) on this farm are likely major factors that affect the annual juvenile recruitment potential in Woodard Bay.

Next Steps

Benthic core samples were collected in spring 2007 prior to the placement of the habitat enhancements. Now that the enhancement plots have been in place for each of the four seasons (fall, winter, spring and summer), the time is right to collect another series of benthic cores. The goal is to examine the change in the benthic community as a result of the addition of shell material. Since previous collections in Woodard Bay are collected in June, it is important to maintain the timing of these collections to avoid a seasonal bias to any comparisons. PSRF plans to conduct these benthic samples in June 2009.

References

- Baker, P. 1995. Review of ecology and fishery of the Olympia oyster, *Ostrea lurida*, with annotated bibliography. *Journal of Shellfish Research* Vol. 2, No. 2: 501-518
- Campbell, W.W. 1996. Procedures to determine intertidal populations of *Protothaca staminea*, *Tapes philippinarum*, and *Crassostrea gigas* in Hood Canal and Puget Sound, Washington. Washington Department of Fish and Wildlife, Procedures Manual MRD96-01.
- Kozloff, E.N. 1993. *Seashore life of the northern pacific coast; An illustrated guide to northern California, Oregon, Washington and British Columbia*. Seattle: University of Washington Press.

Appendix

Shell Area #1 – winter 2007

PSRF Native Oyster Survey Results Page

Survey Information			Survey Area	
Date:	12/21/07		Start Position	
Area:	Woodard Bay		Latitude:	N47 07.870
Site:	Shell Area #1		Longitude:	W122 50.634
Enhancement Date:	8/1/07		Elevation:	-0.5
Surveyor:	B. Allen		Baseline Orientation:	52 °Magnetic
Surveyor Contact:	PSRF		Area Estimate	
			Baseline Length:	189.0 meters
			Mean Width:	19.8 meters
			Total Area:	3745 Sq meters
Survey Results			Emergent Oyster Substrate Results	
Sample Size:	16		Amount	
Sample mean:	0.0		Mean Emergent Substrate Height:	1.9 inch
Mean oysters m⁻²:	0.0		Mean Emergent Substrate Area (%):	69.8%
Population est:	0		Emergent Substrate Density m ⁻² :	287.0
Sample s² =	0.0		Condition	
SE =	0.00		Wet Emergent Substrate (%):	93%
CV =	-		Anoxic Benthic Condition (%):	0%
relative precision:	-		Fouling	
% Single Oyster:	NA		Mean Algal Cover (%):	0%
			Mean Silt Cover (%):	37%
			Mean Barnacle Cover (%):	0%
			Mean Mussel Cover(%):	0%
			Mean Bryozoan Cover (%):	0%
			Mean Hydroid Polyp Cover (%):	0%
			Mean Poriferan Cover (%):	0%
			Mean Colonial Ascidian Cover (%):	0%
			Total animal fouling cover (%):	0%
Mortality Information			Oysters on Substrate	
	<u>Sample Mean</u>	<u>% of Total</u>	Mean Oyster Count per Substrate Piece:	0.0
Unknown Mortality:	-	-	Mean Mortality per Substrate Piece:	0.0
Drill Mortality:	-	-	Setting Substrate	Percent
Crab Mortality:	-	-	Native Oyster (live)	-
Silt Mortality:	-	-	Native Oyster shell	-
			Pacific Oyster (live)	-
			Pacific Oyster shell	-
			Other Shell	-
			Rock	-
			Other Substrate	-
Predator / Competitor Results			Community Information	
	<u>Sample Mean</u>	<u>est. m⁻²</u>	Relative Species Richness:	30
<i>C.productus</i>	-	-	Next Survey	
<i>C. gracilis</i>	0.4	1.8	<u>Minimum Sample Size for next survey</u>	
<i>C.inornatum</i>	-	-	Nmin @ +/-20% for next survey:	-
<i>N.lamellosa</i>	-	-	Nmin @ +/-30% for next survey:	-
<i>P.brevispinus</i>	0.1	0.3		
<i>P.ocraceas</i>	-	-		
<i>E.troschelli</i>	-	-		
<i>P.ceprio</i>	0.2	0.8		
<i>Mytilus sp.</i>	0.1	0.3		
<i>C.fornicata</i>	0.3	1.0		
<i>C.gigas</i>	-	-		
	-	-		
	-	-		
	-	-		
	-	-		

Shell Area #1 – spring 2008

PSRF Native Oyster Survey Results Page				
Survey Information			Survey Area	
Date:	4/9/2008			Start Position
Area:	Woodard Bay		Latitude:	same as Dec 07
Site:	Shell Area #1		Longitude:	
Enhancement Date:	August 2007		Elevation:	
Surveyor:	R.Peters,TNC volunteers		Basline Orientation:	54 °Magnetic
Surveyor Contact:	B. Allen, PSRF			Area Estimate
			Basline Length:	191.0 meters
			Mean Width:	19.2 meters
			Total Area:	3667 Sq meters
Survey Results			Emergent Oyster Substrate Results	
Sample Size:	27		Amount	
Sample mean:	0.0		Mean Emergent Substrate Height:	1.8 inch
Mean oysters m⁻²:	0.0		Mean Emergent Substrate Area (%):	70.2%
Population est:	0		Emergent Substrate Density m ⁻² :	155.6
Sample s² =	0.0		Condition	
SE =	0.00		Wet Emergent Substrate (%):	93%
CV =	-		Anoxic Benthic Condition (%):	0%
relative precision:	-			
			Fouling	
% Single Oyster:	NA		Mean Algal Cover (%):	15%
			Mean Silt Cover (%):	84%
			Mean Barnacle Cover (%):	5%
			Mean Mussel Cover(%):	0%
Unknown Mortality:	-	-	Mean Bryozoan Cover (%):	0%
Drill Mortality:	-	-	Mean Hydroid Polyp Cover (%):	0%
Crab Mortality:	-	-	Mean Poriferan Cover (%):	0%
Silt Mortality:	-	-	Mean Colonial Ascidian Cover (%):	0%
			Total animal fouling cover (%):	5%
			Oysters on Substrate	
			Mean Oyster Count per Substrate Piece:	0.0
			Mean Mortality per Substrate Piece:	0.0
	Sample Mean	est. m⁻²	Setting Substrate	Percent
<i>C.productus</i>	-	-	Native Oyster (live)	-
<i>C. gracilis</i>	0.1	0.6	Native Oyster shell	-
<i>C.inornatum</i>	-	-	Pacific Oyster (live)	-
<i>N.lamellosa</i>	-	-	Pacific Oyster shell	-
<i>P.brevispinus</i>	-	-	Other Shell	-
<i>P.ocraceas</i>	-	-	Rock	-
<i>E.troschelli</i>	-	-	Other Substrate	-
<i>P.cephio</i>	0.0	0.1		
<i>Mytilus sp.</i>	0.4	1.8	Community Information	
<i>C.fornicata</i>	0.3	1.2	Relative Species Richness:	25
<i>C.gigas</i>	-	-		
	-	-	Next Survey	
	-	-	Minimum Sample Size for next survey	-
	-	-	Nmin @ +/-20% for next survey:	-
	-	-	Nmin @ +/-30% for next survey:	-

Shell Area #1 – Fall 2008

PSRF Native Oyster Survey Results Page			
Survey Information		Survey Area	
Date:	4/9/08	<u>Start Position</u>	
Area:	Woodard Bay	Latitude:	same as Dec 07
Site:	Shell Area #1	Longitude:	
Enhancement Date:	August 2007	Elevation:	
Surveyor:	R.Peters,TNC volunteers	Basline Orientation:	54 °Magnetic
Surveyor Contact:	B. Allen, PSRF	<u>Area Estimate</u>	
		Basline Length:	191.0 meters
		Mean Width:	19.2 meters
		Total Area:	3667 Sq meters
Survey Results		Emergent Oyster Substrate Results	
Sample Size:	27	<u>Amount</u>	
Sample mean:	0.0	Mean Emergent Substrate Height:	1.8 inch
Mean oysters m ⁻² :	0.0	Mean Emergent Substrate Area (%):	70.2%
Population est:	0	Emergent Substrate Density m ⁻² :	155.6
Sample s ² =	0.0	<u>Condition</u>	
SE =	0.00	Wet Emergent Substrate (%):	93%
CV =	-	Anoxic Benthic Condition (%):	0%
relative precision:	-		
% Single Oyster:	NA	<u>Fouling</u>	
		Mean Algal Cover (%):	15%
		Mean Silt Cover (%):	84%
<u>Mortality Information</u>		Mean Barnacle Cover (%):	5%
	<u>Sample Mean</u>	<u>% of Total</u>	Mean Mussel Cover(%):
Unknown Mortality:	-	-	Mean Bryozoan Cover (%):
Drill Mortality:	-	-	Mean Hydroid Polyp Cover (%):
Crab Mortality:	-	-	Mean Poriferan Cover (%):
Silt Mortality:	-	-	Mean Colonial Ascidian Cover (%):
			Total animal fouling cover (%):
			5%
<u>Predator / Competitor Results</u>		<u>Oysters on Substrate</u>	
	<u>Sample Mean</u>	<u>est. m⁻²</u>	Mean Oyster Count per Substrate
<i>C.productus</i>	-	-	Piece:
<i>C. gracilis</i>	0.1	0.6	Mean Mortality per Substrate Piece:
<i>C.inornatum</i>	-	-	
<i>N.lamellosa</i>	-	-	<u>Setting Substrate</u>
<i>P.brevispinus</i>	-	-	<u>Percent</u>
<i>P.ocraceas</i>	-	-	Native Oyster (live)
<i>E.troschelli</i>	-	-	Native Oyster shell
<i>P.cepio</i>	0.0	0.1	Pacific Oyster (live)
<i>Mytilus sp.</i>	0.4	1.8	Pacific Oyster shell
<i>C.fornicata</i>	0.3	1.2	Other Shell
<i>C.gigas</i>	-	-	Rock
	-	-	Other Substrate
	-	-	
	-	-	<u>Community Information</u>
	-	-	Relative Species Richness:
	-	-	25
	-	-	<u>Next Survey</u>
	-	-	<u>Minimum Sample Size for next survey</u>
	-	-	Nmin @ +/-20% for next survey:
	-	-	Nmin @ +/-30% for next survey:

Shell Area #2 – Fall 2008

PSRF Native Oyster Survey Results Page				
Survey Information			Survey Area	
Date:				<u>Start Position</u>
Area:	Woodard Bay		Latitude:	N 47 07.570
Site:	Shell Area 2 (TNC lease)		Longitude:	W 122 50.219
Enhancement Date:	August-08		Elevation:	-5
	Morgan,Betsy,Brian,Nolan			
Surveyor:	(UW)		Baseline Orientation:	265 °Magnetic
Surveyor Contact:	PSRF			<u>Area Estimate</u>
			Baseline Length:	
			Mean Width:	
			Total Area:	
Survey Results		Emergent Oyster Substrate Results		
Sample Size:	9	<u>Amount</u>		
Sample mean:	0.1	Mean Emergent Substrate Height:	1.8 inch	
Mean oysters m ⁻² :	0.4	Mean Emergent Substrate Area (%):	65.6%	
Population est:	-	Emergent Substrate Density m ⁻² :	280.0	
		<u>Condition</u>		
Sample s ² =	0.1	Wet Emergent Substrate (%):	100%	
SE =	0.11	Anoxic Benthic Condition (%):	100%	
CV =	100%			
relative precision:	196%			
		<u>Fouling</u>		
% Single Oyster:	0%	Mean Algal Cover (%):	39%	
		Mean Silt Cover (%):	44%	
		Mean Barnacle Cover (%):	56%	
Mortality Information		Mean Mussel Cover(%):	-	
		Mean Bryozoan Cover (%):	-	
		Mean Hydroid Polyp Cover (%):	0%	
		Mean Poriferan Cover (%):	-	
		Mean Colonial Ascidian Cover (%):	-	
		Total animal fouling cover (%):	56%	
Predator / Competitor Results		Oysters on Substrate		
		Mean Oyster Count per Substrate		
		Piece:	0.0	
		Mean Mortality per Substrate Piece:	0.0	
		<u>Setting Substrate</u>	<u>Percent</u>	
		Native Oyster (live)	-	
		Native Oyster shell	-	
		Pacific Oyster (live)	-	
		Pacific Oyster shell	-	
		Other Shell	-	
		Rock	-	
		Other Substrate	-	
Community Information				
		Relative Emergent Species Richness:	21	
Next Survey				
		<u>Minimum Sample Size for next survey</u>		
		Nmin @ +/-20% for next survey:	900	
		Nmin @ +/-30% for next survey:	400	

Benthic Infauna Survey Data

<u>SITE</u>	<u>DATE</u>	<u>SAMPLE</u>	<u>ORGANISM</u>	<u>COUNT</u>	<u>DESCRIPTION</u>
1.5	6/12/2007	1	Polychaete sp. #13	3	
1.5	6/12/2007	1	Polychaete sp. #14	1	
1.5	6/12/2007	1	Polychaete sp. #15	2	
1.5	6/12/2007	1	Polychaete sp. #4	3	
1.5	6/12/2007	1	Polychaete sp. #7	1	
1.5	6/12/2007	2	Macoma Nasuta	2	
1.5	6/12/2007	2	Polychaete sp. #16	1	tube dwelling
1.5	6/12/2007	2	Polychaete sp. #6	1	
1.5	6/12/2007	2	Protothaca staminea	1	
1.5	6/12/2007	3	Brachyuran Crab #1	1	possibly Hemigrapsus sp. (4 mm)
1.5	6/12/2007	3	Macoma Nasuta	1	
1.5	6/12/2007	3	Polychaete sp. #4	1	
1.5	6/12/2007	3	Polychaete sp. #7	2	
1.5	6/12/2007	3	Saxidomus giganteus	1	
1.5	6/12/2007	4	Nemertean sp. #1	1	
1.5	6/12/2007	4	Polychaete sp. #15	1	
1.5	6/12/2007	4	Polychaete sp. #17	4	
1.5	6/12/2007	5	Nematode #1	1	
1.5	6/12/2007	5	Nematode #2	3	
1.5	6/12/2007	5	Polychaete sp. #13	5	
1.5	6/12/2007	5	Polychaete sp. #14	2	
1.5	6/12/2007	5	Polychaete sp. #15	11	
1.5	6/12/2007	5	Polychaete sp. #18	1	
1.5	6/12/2007	5	Polychaete sp. #19	2	
1.5	6/12/2007	5	Polychaete sp. #20	2	
1.5	6/12/2007	5	Polychaete sp. #7	1	
1.5	6/12/2007	6	Macoma Nasuta	2	
1.5	6/12/2007	6	Polychaete sp. #4	1	
1.5	6/12/2007	6	Unknown Bivalve #1	1	
1.5	6/12/2007	7	Nemertean sp. #1	2	
1.5	6/12/2007	8	Macoma Nasuta	3	
1.5	6/12/2007	8	Polychaete sp. #19	1	
1.5	6/12/2007	8	Polychaete sp. #4	1	
1.5	6/12/2007	8	Polychaete sp. #7	1	
1.5	6/12/2007	8	Protothaca staminea	1	
1.5	6/12/2007	8	Unknown Bivalve #1	1	
1.5	6/12/2007	9	Polychaete sp. #14	1	
1.5	6/12/2007	9	Polychaete sp. #15	3	
1.5	6/12/2007	9	Polychaete, Glyceridae fm.	1	
1.5	6/12/2007	9	Unknown Polychaete	1	
1.5	6/12/2007	10	Nemertean sp. #1	2	
1.5	6/12/2007	10	Polychaete sp. #14	1	
1.5	6/12/2007	10	Polychaete sp. #15	5	
1.5	6/12/2007	10	Polychaete sp. #17	1	
1.5	6/12/2007	10	Polychaete sp. #19	2	

<u>SITE</u>	<u>DATE</u>	<u>SAMPLE</u>	<u>ORGANISM</u>	<u>COUNT</u>	<u>DESCRIPTION</u>
3	6/12/2007	1	Macoma Nasuta	1	
3	6/12/2007	1	Polychaete sp. #15	1	
3	6/12/2007	1	Polychaete, Glyceridae fm.	1	
3	6/12/2007	2	Macoma Nasuta	1	
3	6/12/2007	2	Nemertean sp. #1	1	
3	6/12/2007	2	Polychaete, Glyceridae fm.	1	
3	6/12/2007	3	Macoma Nasuta	1	
3	6/12/2007	3	Polychaete, Glyceridae fm.	1	
3	6/12/2007	4	Brachyuran Crab #1	1	
3	6/12/2007	4	Corophium acherusicum	1	
3	6/12/2007	4	Macoma Nasuta	1	
3	6/12/2007	4	Nemertean sp. #1	1	
3	6/12/2007	4	Polychaete sp. #14	1	
3	6/12/2007	4	Polychaete sp. #6	1	
3	6/12/2007	4	Protothaca staminea	1	
3	6/12/2007	5	Corophium salmonis	1	
3	6/12/2007	5	Macoma Nasuta	2	
3	6/12/2007	5	Polychaete sp. #7	2	
3	6/12/2007	5	Polychaete, Glyceridae fm.	1	
3	6/12/2007	6	Nematode #1	1	
3	6/12/2007	6	Nemertean sp. #1	2	
3	6/12/2007	6	Polychaete sp. #13	1	
3	6/12/2007	6	Polychaete sp. #14	1	
3	6/12/2007	6	Unknown shrimp	1	
3	6/12/2007	7	Haminaea vesicula	1	
3	6/12/2007	7	Nemertean sp. #1	2	
3	6/12/2007	7	Polychaete sp. #6	1	
3	6/12/2007	7	Unknown Pandalus sp.	1	juvenile shrimp, possibly P. goniurus
3	6/12/2007	8	Corophium acherusicum	3	
3	6/12/2007	8	Nemertean sp. #1	1	
3	6/12/2007	8	Polychaete, Glyceridae fm.	2	
3	6/12/2007	8	Protothaca staminea	1	
3	6/12/2007	9	Corophium salmonis	2	
3	6/12/2007	9	Macoma Nasuta	1	
3	6/12/2007	9	Nemertean sp. #1	1	
3	6/12/2007	9	Polychaete sp. #14	2	
3	6/12/2007	9	Polychaete sp. #6	1	
3	6/12/2007	10	Macoma Nasuta	1	
3	6/12/2007	10	Polychaete sp. #6	1	

Woodard Bay, Henderson Inlet

2008 Plankton Sampling

	On Shell Station	Off Shell Station
Treatment		
Elevation	-2.5 MLLW	-2.5 MLLW
Latitude	N 47 07.885	N 47 07.853
Longitude	W 122 50.627	W 122 50.519

Method

Notes: 100 Liter Samples collected 6-12" off-bottom.
300 micron prefilter, 75 micron collection.
Samples collected during daylight on flood tides

Date	Water Temp (°F)	Treatment	Sample Volume	SubSample (1mL)	Count	Description
24-Jul-08	58	ON SHELL	30	1		NO BIVALVES
				2		NO BIVALVES
				3		NO BIVALVES
	58	OFF SHELL	50	1		NO BIVALVES
				2	1 ??	250
				3		NO BIVALVES
4-Aug-08	59	ON SHELL	50	1		NO BIVALVES
				2		NO BIVALVES
				3		
	60	OFF SHELL	52	1		
				2		
				3		
7-Aug-08	57	ON SHELL	130	1		
				2	3	219,250,188
				3	3	235,219,282
	56	OFF SHELL	135	1		NO BIVALVES
				2	1	235
				3	1	250
15-Aug-08	67	ON SHELL	20	1	1	250
				2	1	219
				3		
	64	OFF SHELL	28	1	1	282
				2		
				3		