NATURAL RESOURCES

Puget Sound Intertidal Biotic Community Monitoring

2011 Monitoring Report

May 2012

UNIVERSITY OF WASHINGTON

WASHINGTON STATE DEPARTMENT OF Natural Resources
Peter Goldmark - Commissioner of Public Lands

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By

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Copies of this report may be obtained from the Nearshore Habitat Program – To get more information on the program and download reports and data, enter the search term 'nearshore habitat program' on DNR home page: http://www.dnr.wa.gov

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EXECUTIVE SUMMARY

The Washington State Department of Natural Resources (DNR) is steward of 2.6 million acres of state-owned aquatic land. As part of its stewardship responsibilities, DNR monitors the condition of nearshore habitats. Monitoring results are used to guide land management decisions for the benefit of current and future citizens of Washington State.

Intertidal habitats are an important constituent of the nearshore ecosystem, and they are vulnerable to both terrestrial and aquatic stressors. One indicator of intertidal habitat health is its biotic community - the complex of the flora and fauna living in and on the beach. DNR and the University of Washington (UW) have collaboratively monitored biotic communities since 1997.

This report summarizes intertidal biotic community monitoring program findings in 2011. In 2011, we used longstanding monitoring methods to collect intertidal data at sites of management interest to two programs within DNR's Aquatic Resources Division – the Aquatic Reserves Program and the Aquatics Assessment and Monitoring Team (AAMT). The Aquatic Reserves program manages reserves throughout the state in order to conserve and adaptively manage high-quality native aquatic ecosystems. The AAMT provides broad scientific support to DNR's Aquatics Programs. Staff from Aquatic Reserves Program and AAMT selected 5 sites for sampling to inform a broad range of objectives, including to:

- Characterize conditions at beaches in Maury Island Aquatic Reserve and Nisqually Reach Aquatic Reserve;
- Characterize conditions in areas that are candidates for restoration or protection;
- Evaluate sampling techniques that provide insight into activities on state-owned aquatic lands that are managed by DNR.

Two types of sampling took place:

- The intertidal biotic community was surveyed using 0.25 m^2 quadrats and 10 cm x 15 cm core samples. This technique captures smaller infauna, but tends to under-sample large clams;
- Assemblages of large clams were described using larger core samples (0.1 m^3).

General Discussion of Findings

Biodiversity is a widely recognized priority for protection at reserves. Our surveys underscore that substrate type is a key factor determining intertidal diversity, and begin to describe patterns in intertidal diversity within the reserves. Beaches composed of lower intertidal cobble substrates have much higher diversity because cobbles create solid surfaces, stabilize beach sediments and create complex microhabitats. Sand beaches are less predictable in their diversity, and pebble beaches tend to have very low diversity. The reserve boundaries capture among-habitat (Beta) diversity as well as within-habitat (Alpha) diversity because they encompass a range of substrate and energy conditions.

Future collection of baseline information on intertidal species that occur within the reserves could inform long-term reserve management. To minimize cost, sampling could take place at representative habitats.

South Sound - Areas Sampled and Key Findings:
Oro Bay is located on Anderson Island within the Nisqually Reach Aquatic Reserve, adjacent to a new upland park. It was sampled to increase knowledge of intertidal biota in the reserve and to collect data in a potential restoration area. We sampled 3 beaches (named North, Mid, and South) along an energy gradient that increased to the south. We focused additional sampling effort on large clams because they are often a valued resource at public access sites. Findings:

- Intertidal biotic community species richness was lowest at OroN (27), compared to 38 and 40 at OroS and OroM, respectively. Lower species richness at OroN coincided with a lower proportion of pebble/cobble substrate, a common relationship between species and habitat type. The community as a whole at OroS and OroM were more similar to the 0 ft and -2 ft MLLW communities at TrebleS and TaylorS (discussed below), than to nearby OroN.
- The Oro beaches had the most abundant large clams of all sites, and richness was also high. Common species included *Saxidomus giganteus* (butter clam), *Macoma nasuta*, *M. inquinata* and *Leukoma staminea* (native littleneck). Clam species richness at +1.5 ft MLLW was equal to or greater than richness at 0 ft.

Beaches at Taylor Bay and Treble Point represent habitat types that could be used for intertidal geoduck clam aquaculture. Taylor Bay is located on the Longbranch Peninsula, and Treble Point is located to the southeast on Anderson Island, within the Nisqually Reach Aquatic Reserve. Taylor Bay was identified by DNR as a potential intertidal geoduck clam aquaculture site. Treble Point was selected as a reference site with similar environmental attributes. At each site, we sampled two beaches (North and South). Additional effort was devoted to sample the biotic community at -2 ft MLLW, a common elevation for geoduck aquaculture, and to compare the infaunal community characterization on 1mm and 2 mm sieve mesh sizes. Findings:

- At both sites and at both tidal elevations, species richness was approximately 4 times higher at the southern transect than at the northern transect. This difference relates most directly to the unstable, predominantly sand and pebble substrate at the northern beaches. Substrate size both reflects geomorphic conditions and directly determines habitat suitability. The percentage of cobble in surface sediments is positively correlated with species richness.
- Large clam densities varied substantially. At TaylorN, no clams were found, while TaylorS had low density and richness. The two most common species were the edible *Saxidomus giganteus* (butter clam) and *Leukoma staminea* (native littleneck).The Treble beaches had low clam densities but comparatively high species richness. The most common species at TrebleN were *Macoma nasuta* and *M. secta*, and the small *Tellina modesta* (all deposit-feeding species). The most common bivalve at TrebleS was the shallow-dwelling suspension feeder *Clinocardium nuttallii* (Nuttall’s cockle).

- Results at Taylor and Treble showed that sieving to 1 mm – rather than 2 mm – did not substantially change species richness or community composition. Out of 55 infaunal species found overall, 14 species were found only on 1 mm sieves. These included 6 polychaete, 6 amphipod, and 2 molluscan species. Of these, only 2 amphipod (*Protomedeia articulata* and *Rhepoxynius pallidus*) and 1 polychaete (*Barantolla americana*) species had not been found in earlier SCALE surveys using 2 mm sieves; the rest were juveniles of previously collected species. The TrebleN transects showed the most differentiation with 1 mm and 2 mm sieve sizes, due primarily to many tiny *Rochefortia* clams and 4 amphipod species.
- Our beach surveys reported here suggest that, from a biodiversity perspective, it would be preferable to place aquaculture activities on sand beaches like those at TaylorN, which naturally have relatively low richness and diversity.

Central Sound - Areas Sampled and Key Findings
Within the Maury Island Reserve in Central Puget Sound, we sampled three beaches along Piner Point. Beaches were sampled at the point (PinerM) and to the north and south, in order to capture a gradient in habitat conditions along this stretch of shoreline. Findings:

- PinerM and PinerS had similar biotic communities and similar species richness, while PinerN was distinct, with lower species richness and a different community composition. PinerN was protected from southerly exposure by the point itself, and its sediments were pebble dominated. PinerN had few epibiota on larger pebbles (barnacles), and few infauna of any kind. PinerM, in contrast, had the most cobbles and the highest species richness. Characteristic species found at PinerM and PinerS are cobble associates, *Dendraster* sand dollar juveniles, and *Spiochaetopterus* polychaetes. PinerS had small patches of *Zostera marina* (eelgrass) at 0 ft MLLW.
- No large clams were found at the Piner beaches.

Also within the Maury Island Reserve, we sampled adjacent to a recently closed gravel mine at three beaches (named Maury Mine - North, Mid, and South). The site is a candidate for restoration because defunct gravel loading structures remain on the beach. Findings:

- Species richness was very low; fewer than 10 species were found at these beaches with unstable sediments. Species found include *Spiochaetopterus, Hemipodus*, juvenile sand dollars, and juveniles of the invasive varnish clam *Nuttallia.* Some of these taxa were found only at Maury MineS, making it distinct in terms of community composition. Maury MineN (a steep beach with sand and pebbles) was depauperate, with only 2 species – green algae and one Nereid worm.
- The only large clam species found was the non-native varnish clam *Nuttallia obscurata*.
- Our lower intertidal sampling at Maury Mine did not capture the before/after conditions that would be most relevant to the restoration under consideration. At Maury MineM, the pier structure does not appear to substantially reduce longshore drift or shade intertidal vegetation. Subtidal sampling might capture changes related to structure removal, especially of hard substrate and creosote. At Maury MineN, sampling that focused on substrate and habitat conditions in upper intertidal and backshore areas would be more relevant to restoration effects.

1 Introduction

1.1 Intertidal Biotic Community Monitoring Program Overview

The overall goal of the Intertidal Biotic Community Monitoring Project is to assess the condition of intertidal biota in greater Puget Sound. This work supports the mandate of the Washington State Department of Natural Resources (DNR) to ensure environmental protection of the 2.6 million acres of state-owned aquatic lands that it stewards (RCW 79.105.030). Additionally, this work supports the Puget Sound Partnership's effort to protect and restore Puget Sound through tasks that are defined in the Puget Sound Action Agenda (Puget Sound Partnership 2009), and in the monitoring plans by its predecessor, the Puget Sound Action Team (Puget Sound Action Team 2007).

Intertidal and shallow subtidal habitats are an important constituent of the nearshore ecosystem. They are highly diverse and productive, harboring extensive populations of algae and seagrasses that contribute to food webs (both nearshore and in deeper water) and provide habitat for many other organisms (e.g., Duggins et al. 1989). Invertebrates that live in intertidal habitats are important in recycling of detritus (e.g., Urban-Malinga et al. 2008) and reduction of water turbidity (e.g., Peterson and Heck 1999), as well as providing food for shorebirds, nearshore fishes, commercially important invertebrates such as crabs, and humans. Intertidal and nearshore communities also serve as useful 'indicators' of ecosystem health. Because most organisms in these habitats are relatively sessile and thus unable to move away from stressors, they are vulnerable to both natural and anthropogenic stressors from terrestrial and aquatic sources. Demonstrated examples include sensitivity to changes in rainfall (Ford et al. 2007), ocean temperatures (Schiel et al. 2006), local pollution (Hewitt et al. 2005), and larger-scale factors such as the North Atlantic Oscillation index (Labrune et al. 2007).

DNR and the University of Washington (UW) have collaborated to monitor biotic communities since 1997. The intertidal biotic community sampling design and statistical analyses have been described in peer-reviewed publications (Schoch and Dethier 1995, Dethier and Schoch 2005, Dethier and Schoch 2006) and multiple technical reports (available through DNR at http://www.dnr.wa.gov/ResearchScience/Topics/AquaticHabitats/Pages/aqr_nrsh_publications.aspx).

1.2 2011 Monitoring Objectives

This report summarizes activities and findings in 2011. In June 2011, longstanding monitoring methods were used to collect intertidal data at sites of management interest to DNR. The goal of the sampling was to provide preliminary information to two groups within DNR's Aquatic Resources Division that are exploring nearshore habitat assessment approaches – the Aquatic Reserves Program and the Aquatics Assessment and Monitoring Team (AAMT).

DNR's Aquatic Reserves Program manages reserves throughout the state in order to conserve high-quality native ecosystems in freshwater and marine environments (Bloch and Palazzi 2005). Aquatic reserves are lands of special educational or scientific interest, or of special environmental importance (WAC 332-30-151). The reserve program was designated in 2004. As of 2011, a total of 7 aquatic reserves have been designated. Each reserve is managed according to goals defined in an individual management plan. Within its statutory authority, DNR approves new uses within a reserve that are demonstrated to be consistent with the reserve's goals, objectives and management actions. Research and monitoring data will be used in an adaptive management framework to ensure that management actions support the objectives of each reserve. The program seeks to work collaboratively with other organizations to monitor key habitat elements and indicators of condition.

The AAMT provides broad scientific support to all of DNR's Aquatics Programs, including leasing activity, Wildstock Geoduck Fishery management, intertidal aquaculture, policy development, planning, marine reserves, sediment management, and nearshore habitat assessment.

Aquatic Reserves Program and AAMT staff selected five sites for sampling within Central and South Puget Sound (Figure 1-1), with 2-3 beaches within each site. Sites were selected to address a broad range of objectives, including to:

- Characterize conditions in aquatic reserve areas;
- Characterize conditions in areas that are candidates for restoration and protection;
- Evaluate sampling techniques that provide insight into activities on state-owned aquatic lands that are managed by DNR.

Sites were selected based on two different research questions:

1) To provide reasonable replicates of each other in terms of physical characteristics, especially substrate, a physical parameter that is known to strongly control the biotic community (Dethier and Schoch 2005).
2) To characterize communities in areas with known gradients in physical characteristics, especially substrate and exposure to waves and currents.

Figure 1-1. Areas sampled during The Nearshore Habitat Program's 2011 intertidal biotic community monitoring. Yellow dots represent beaches sampled within each site. At the *Maury Mine, Piner* and *Oro* sites, three replicate beach segments were sampled per site. At the *Treble* and *Taylor* sites, two segments were sampled per site.

The sites sampled are described below, including individual sampling objectives associated with each site. Detailed methods are provided in the next section.

In South Sound, three beaches within Oro Bay were selected as candidates for protection and restoration (named OroN, OroM and OroS, corresponding to the northern, middle and southern locations). This area lies within the Nisqually Reach Aquatic Reserve (DNR

2011). The uplands were recently purchased by the Anderson Island community for a park (Hill 2012), and debris from previous activities were evident near OroN. At Oro Bay, we adopted a standard approach to assessing the entire biotic community at only 1 tidal height (0 ft MLLW), and focused additional effort at characterizing intertidal clam populations at multiple intertidal heights because clams are a valued ecosystem component that could be of particular interest at a public access site.

Also in South Sound, beaches at Taylor Bay and Treble Point were selected to represent habitat types that could be used for intertidal geoduck clam aquaculture. Taylor Bay was identified by DNR in response to direction by the state legislature to explore the potential of a geoduck aquaculture program on state-owned aquatic lands (Wa. State Dept. of Natural Resources 2012). Currently, there is no intertidal geoduck aquaculture activity at the site. Treble Point was selected as a reference site with similar environmental attributes. Treble Point is located on Anderson Island, within Nisqually Reach Reserve, where uses are limited based on consistency with reserve management criteria (Wa. State Dept. of Natural Resources 2011).

At Taylor Bay we sampled two beaches (N and S) approx. 0.4 km apart and differing somewhat in physical conditions (Figure 1-2). TaylorN is a relatively steep beach with pebble substrate overlying sand. Relatively little epibiota was present in the intertidal zone, presumably due to high substrate movement. In contrast, TaylorS has a lower slope. The mixed coarse substrate in the lower intertidal is composed predominately of cobbles overlying sand. Substantially more invertebrates and green algae were found in the intertidal. In the shallow subtidal, prostrate kelp and the non-native brown alga *Sargassum* were abundant.

At Treble Point we sampled one beach to the north of the point and one south, avoiding the broad sand flat that characterizes the point itself. These beaches also differed markedly in their intertidal substrate composition at similar elevations (Figure 1-3). At TrebleN, pebble substrate was confined to the upper intertidal. The middle and lower intertidal was a broad sand flat. At TrebleS, the intertidal beach was composed of mixed coarse substrate to a depth of approximately -3 ft MLLW, where the substrate abruptly changed to sand.

Our field evaluation of the Treble and Taylor sites led us to conclude that the sites were less similar and less homogenous than suggested by the previous reconnaissance surveys. While the subtidal sediments at the sites were predominately sand, the ‘beach break’, where sand transitioned to larger substrate sizes, varied within and among sites.

At Oro Bay, a more protected location than either of the other South Sound sites, we sampled 3 beaches along 0.4 km of shoreline in order to characterize habitat characteristics along the axis of the embayment (Figure 1-4). The beach segments were placed along an energy gradient, from the relatively protected head of the bay in the north, to the south which was more exposed. The segment characteristics strongly reflect this gradient. OroN had an upper intertidal marsh and a beach face composed of muddy sand. OroM and OroS were more physically similar to each other, with mixed coarse beach substrate, moderate slope and other similar geomorphological characteristics.

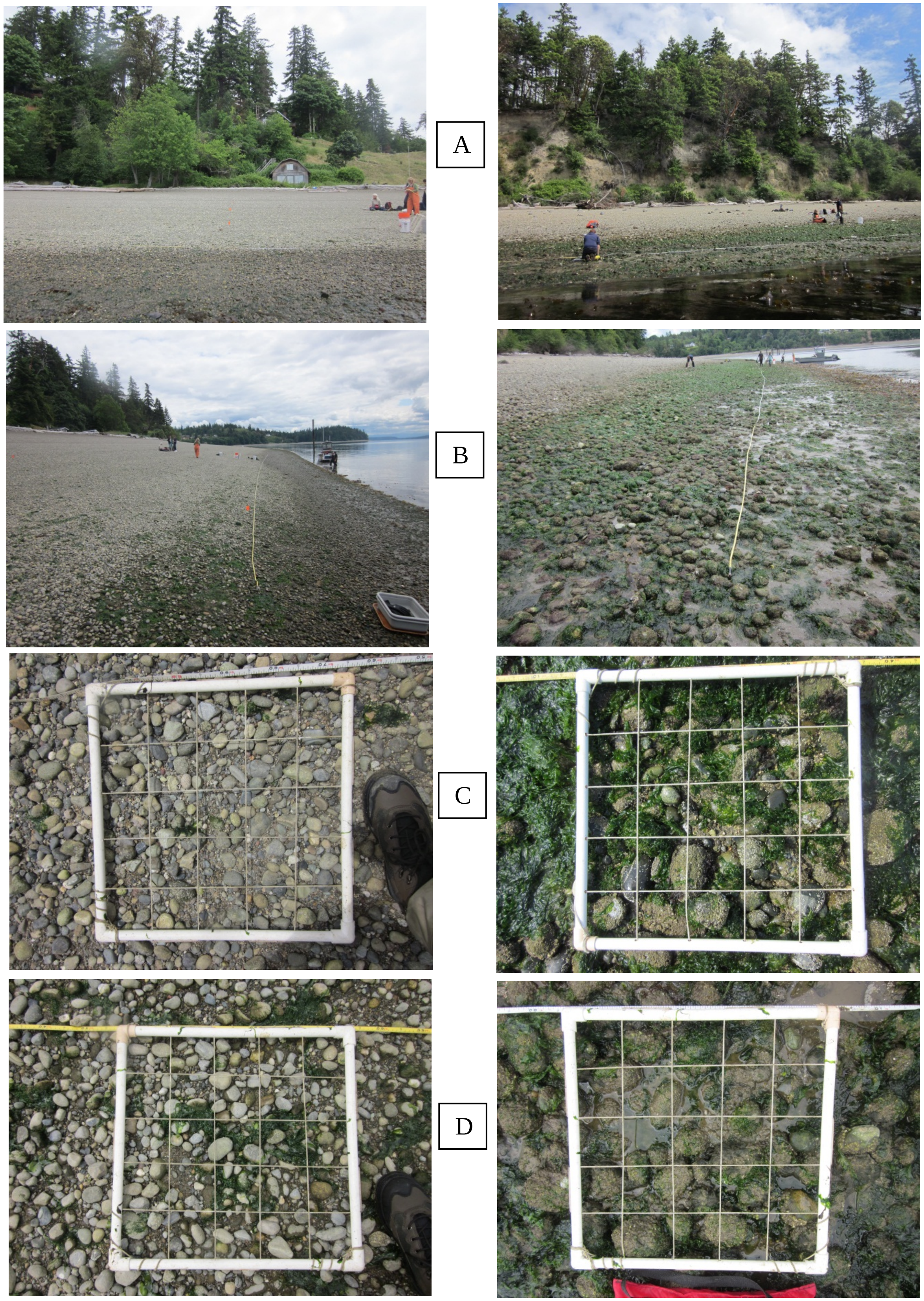

Figure 1-2. Site Photos of TaylorN (left) and TaylorS (right). A: site front; B: alongshore view with tape laid along -2 ft MLLW tidal height; C: quadrat at 0 ft MLLW; D: quadrat at -2 ft MLLW. Note that thick algae have been removed within the quadrat to uncover substrate at TaylorS.

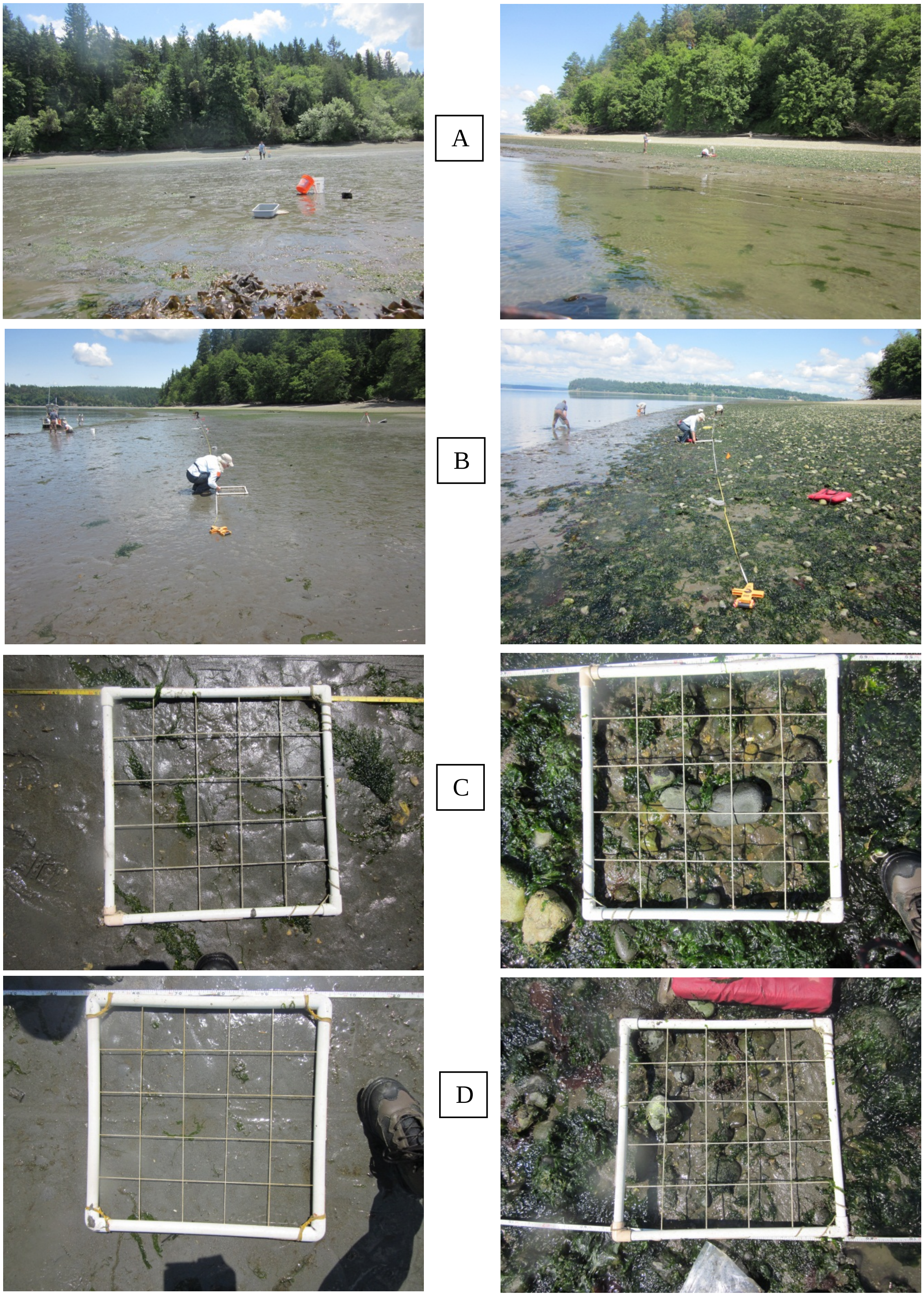

Figure 1-3. Site Photos of Treble North (left) and Treble South (right). A: site front; B: alongshore view with tape laid along -2 ft MLLW tidal height; C: quadrat at 0 ft MLLW; D: quadrat at -2 ft MLLW. Note that thick algae have been removed within the quadrat to uncover substrate at Treble South.

Figure 1-4. Site Photos of OroN (left), OroM (middle) and OroS (right). A: site front; B: alongshore view with tape laid along 0 ft MLLW tidal height; C: quadrat at 0 ft MLLW. Note that thick algae have been removed within the quadrat to uncover substrate.

In Central Sound, we focused sampling on the east and south sides of Maury Island, within the Maury Island Aquatic Reserve (Wa. State Dept. of Natural Resources 2004). On the southeastern tip of Maury, we sampled three beaches, one at Piner Point and one on either side of the point (Figure 1-5). These beach segments captured a strong gradient in exposure. PinerM was the most exposed, and composed of cobble overlying sand in the lower intertidal. PinerS was slightly less exposed, with accumulations of algae on the lower intertidal sand and cobble flat. Because the prevailing wave fetch at this site is from the south, the northern beach was in the lee of the point and thus was more wave protected. However, the intertidal beach slope and predominantly pebble substrate suggest that substrate movement associated with currents and waves occurs regularly.

Also on Maury Island, the Maury Mine site was located adjacent to Glacier Northwest's recently gravel mining site, where mining activities took place from the 1940's until 2010. Current mining activities consist of sand and gravel extraction in a portion of the 235 acre property. A dock and a portion of a conveyor system are present on the beach. However, removal of gravel from the site has not occurred via the existing dock and conveyor system for over 20 years (Wa. State Dept. of Natural Resources 2004).

One potential restoration action is to remove old marine structures (pilings and shoreline armoring) from this site. The purpose of our survey was to provide 'before' data relevant to such construction. All three sampled beaches were moderately-exposed and east-facing, but they varied in slope, substrate type, and nearshore bathymetry (Figure 1-6). Maury MineN, especially, was characterized by a steep drop-off just below MLLW, which probably contributed to the beach face being steeper and coarser than the other sites.

Figure 1-5. Site Photos of PinerN (left), Mid (middle) and PinerS (right). A: site front; B: alongshore view with tape laid along 0 ft MLLW tidal height; C: quadrat at 0 ft MLLW. Note that thick algae have been removed within the quadrat to uncover substrate at PinerS.

Figure 1-6. Site Photos of Maury MineN (left), Maury MineM (middle) and Maury MineS (right). A: site front; B: alongshore view with tape laid along 0 ft MLLW tidal height; C: quadrat at 0 ft MLLW.

2 Methods

2.1 Sampling Methods

The intertidal biotic community sampling design and statistical analyses have been described in previous peer-reviewed publications (Schoch and Dethier 1995, Dethier and Schoch 2005, Dethier and Schoch 2006) and technical reports (available through DNR at http://www.dnr.wa.gov/ResearchScience/Topics/AquaticHabitats/Pages/aqr_nrsh_publications.aspx). General methods are summarized here, followed by detailed methods for each site sampled in 2011 (Table 2-1).

Sampling took place during low tides between June 13 and June 17, 2011. A surveying level and stadia rod were used to locate the appropriate transect elevation relative to the predicted tide at the time of the measurement. This approach has been compared to the actual tide within this region, locations were typically within $\pm$ 0.15 m of the target elevation (Dethier and Schoch 2005). Each day, tidal heights were marked at all beaches simultaneously to ensure that the same levels were used at each. Other tidal levels were located (relative to the marked level) using a surveyor's transit and rod.

Biotic sampling followed the standard SCALE protocol used annually in the Nearshore Habitat Program/University of Washington shoreline monitoring work. At each site and each elevation, we placed a 50 meter (m) transect tape running parallel to the water's edge. Along each transect, 10 locations were intensively sampled for intertidal organisms using 0.25 m^2 quadrats. Prior studies have shown that approximately 95% of the richness per transect is captured in 10 samples (see Dethier and Schoch 2005). Quadrat locations were placed at pre-determined random distances along each transect. Five quadrats were placed on the landward (high) side of the tape and five on the waterward (low) side. All macroscopic surface flora and fauna (and percent cover of cobbles, defined as >10 cm diam, and sand <2 mm diam) were identified and enumerated for each quadrat and recorded on field sheets. Whenever possible, field identifications were made down to the species level. To quantify infauna (primarily polychaete worms and bivalves), a 10 centimeter (cm) diameter x 15 cm deep core was collected at each of the 10 sampling locations on the opposite side of the transect line from where surface flora and fauna were enumerated. Infaunal cores were sieved on two millimeter (mm) sieves; smaller meshes completely clog with this pebble-sand sediment type (but see below for additional mesh-size experiment). Infauna from cores were stored in vials filled with 7% formalin, and later enumerated and identified down to species level at the UW Friday Harbor Laboratories.

Separate sampling was conducted to estimate populations of large clams; these longer-lived organisms can constitute better 'integrators' of long-term conditions than most of the other, shorter-lived infauna (e.g. worms). Additional 0.1 m^3 (0.3 m per side and 0.3 m deep) box core samples were collected and sieved using 1 cm mesh to characterize adult clam abundance and size distribution. These larger core samples are targeted to adequately sample large clams, but they are prohibitively large for sampling smaller infauna. At each of the selected elevations we dug 4 holes at random locations along the transects (Table 2-1).

Temperatures and salinities were measured during each sampling day both along the transects and in the nearshore waters. Temperature and salinity of the porewater in the beach sediment was measured in 3 of the randomly-sampled holes along each transect line using a YSI Model 30 Conductivity Meter. Nearshore data were taken in ca. 1 m water depth just offshore of the transects.

At each site, one or more tidal elevations were selected for sampling (Table 2-1) based on the site-specific research question, target species and the available tidal sampling window. Specific rationale for selecting certain tidal elevations for sampling was:

- 0 ft MLLW – the most frequently sampled elevation for both epibiota/infauna and adult clams. This is the lowest elevation that can be fully sampled at a number of nearby locations during most spring tide sampling windows. MLLW is preferred over higher tidal elevations (which provide longer sampling windows) because more organisms generally live at this elevation than higher on the shore. At MLLW, organisms are submerged ca. 90% of the time.
- +1.5 ft MLLW – clam samples were additionally collected at this elevation because previous surveys found clam abundances to be high at this level, and comparative data exist.
- +3.0 ft MLLW – represents the approximate mean low water (MLW) datum. This tidal level is selected to represent the mid-intertidal community, especially populations of large clams. The biota tends to be less diverse and abundant than at MLLW. Sampling at similar levels has been conducted at Seahurst Park, at Point Wells in King County, and in San Juan County embayments.
- -2.0 ft MLLW - the lowest intertidal level that can be readily sampled using our sampling techniques. Relatively few transects can be sampled because sampling windows are severely restricted by tides. We sampled this tidal level at Treble and Taylor in order to document communities in areas where clam aquaculture might take place.

Region	Site Name	# of Shore Segments (Segment Names, if applicable)	Elevations Sampled for Epibiota/Infauna (ft MLLW)	Elevations Sampled for Clams (ft MLLW)	Sieve Size for Epibiota/Infauna Samples
South Sound	Oro	3 (North, Mid, South)	0	+3.0 (N only) +1.5 0	2 mm
South Sound	Taylor	2 (North, South)	0 -2	+1.5 0 -2	1 mm, 2 mm
South Sound	Treble	2 (North, South)	0 -2	+3.0 (N only) +1.5 0 -2 -3.3	1 mm, 2 mm
Central Sound	Piner	3 (North, Mid, South)	0	+1.5 0	2 mm
Central Sound	Maury Mine	3 (North, Mid, South)	0	+1.5 0	2 mm

Table 2-1. Summary of Locations and Tidal Elevations Sampled in 2011.

To test the effectiveness of the standard SCALE method of sieving samples to 2 mm rather than smaller mesh sizes (as are often used for soft-sediment surveys), we double-sieved the 80 samples from the Taylor Bay and Treble Point transects with both 2 and 1 mm sieves; the two sieves were nested, the sample was sieved in sea water as usual, and the organisms retained on the two sieves were picked off and preserved separately.

The finest taxonomic resolution used in field sampling and laboratory identification was species level, although some difficult taxa were only identifiable to genus or higher levels (e.g. *Pagurus* spp., Phylum Nemertea). Taxonomic references were Kozloff (1996) for invertebrates and Gabrielson et al. (2000) for macroalgae.

2.2 Analyses

Multivariate statistical analyses of the entire community (species present and abundances) at each elevation were conducted in PRIMER6 to test how the communities differ among beaches and tidal elevations (Clarke and Gorley 2001). The data matrix of taxon abundances was square-root transformed to downweight the importance of highly abundant species in relation to less abundant ones in the calculation of similarity measures. We used the ordination technique of non-metric multidimensional scaling (MDS) to group communities based on the Bray-Curtis similarity metric. Graphic plots of ordination results for the two axes explaining the greatest proportion of the variance were examined for obvious sample groupings. Analysis of similarity (ANOSIM) tested the significance of hypothesized differences among sample groups. Similarity percentage (SIMPER) analyses identified the variables (species) that contributed the most to different groupings seen in the MDS plots. In addition, spatial and temporal patterns of species richness were evaluated among the sites and elevations.

To examine the similarities of the biotic communities at the sampled sites and compared with other regional beaches, we contrasted the transect data for the south Sound sites (Oro, Taylor, and Treble) with data collected using the same methods at nearby Case Inlet from 1998 to 2007. Similarly, we contrasted the Piner Point and Maury Mine data with other beaches surveyed on Maury Island in 2001 and 2002.

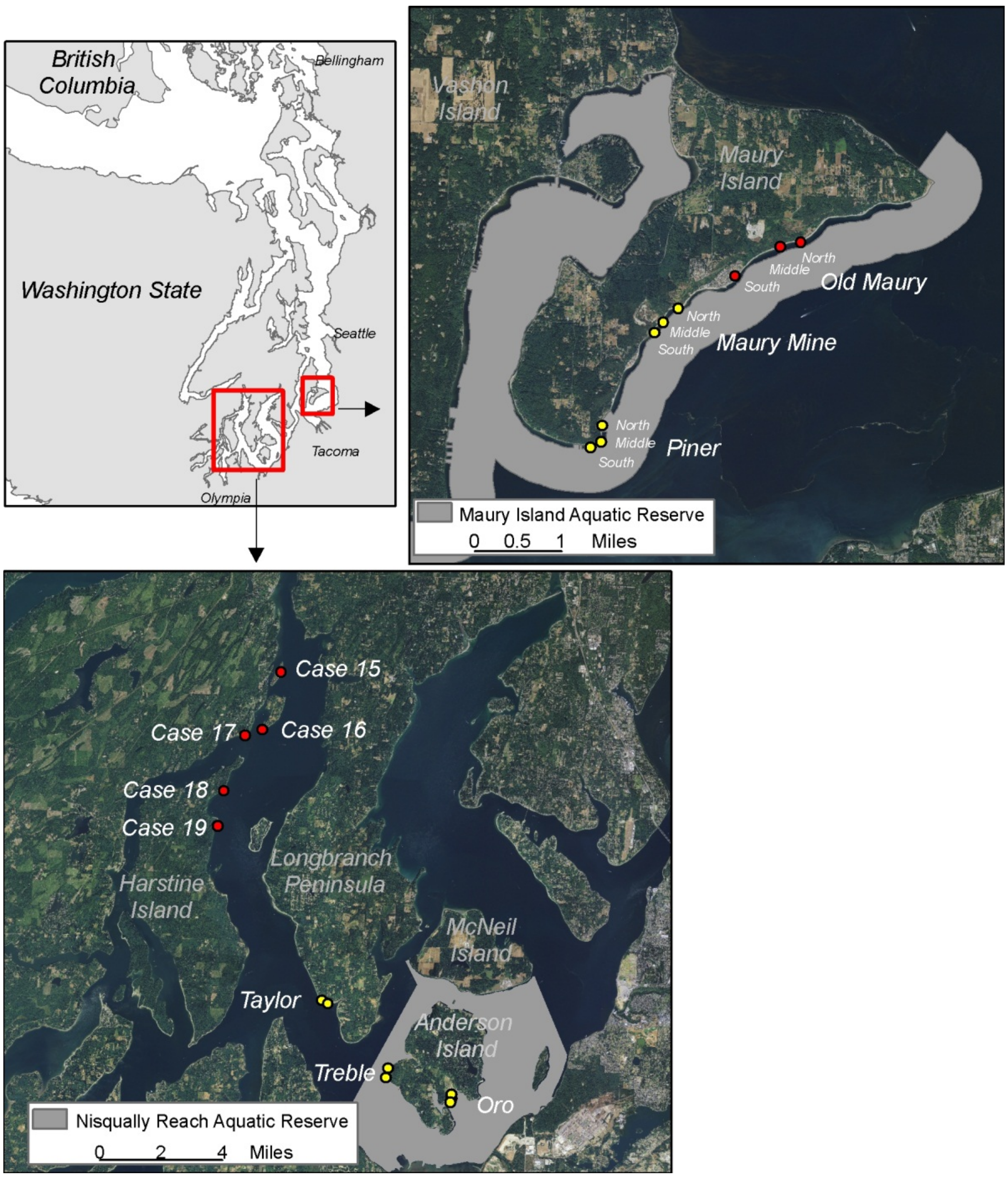

Figure 2-1. Location of beaches in used multivariate statistical analysis. Red dots represent beaches sampled in previous years. Yellow dots represent beaches sampled in 2011.

3 Results

3.1 *South Puget Sound Beach Communities*

Appendices A, B and C summarize the organisms found on the beaches sampled in South Puget Sound in 2011, and Appendix F provides detailed abundance information. The biota of the three sites sampled was different both from each other and from beaches sampled in Case Inlet in 1998 to 2007. Figure 3-1 illustrates this variation with a multidimensional scaling plot of the biota from all the beaches and dates analyzed. All the Case data were from 0 ft MLLW, whereas the Taylor and Treble points include biota from -2' as well. Each point represents the biota from one transect; points closer together indicate that the biota overall (both the species and their abundances) were more similar than for points farther apart.

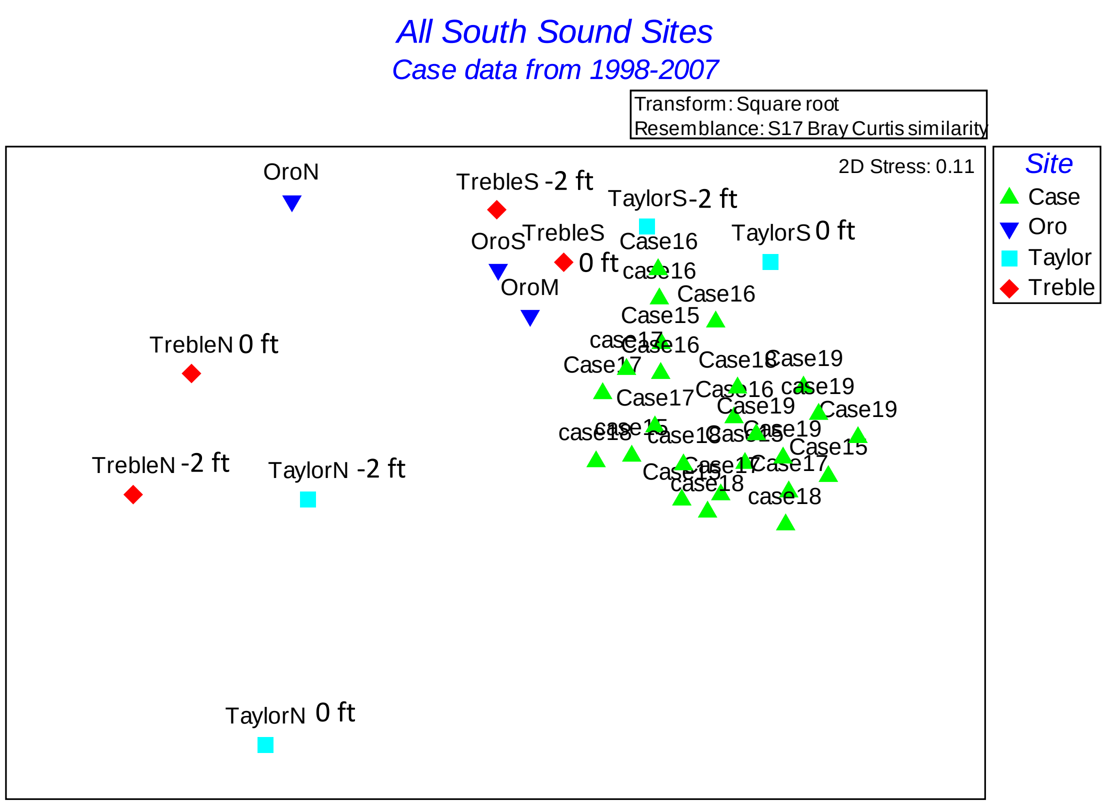

Figure 3-1. Non-metric multidimensional scaling (MDS) plot of the biota at the transects at 0' (all sites) and -2' (Taylor and Treble only). Each point represents mean biota from a transect in a given year, with abundances squareroot transformed.

Figure 3-2 shows that the Case biota are distinctly different from the new sites. Overall, the Case beaches are biotically rather uniform, as opposed to the new sites which vary substantially among themselves. The outlier points (e.g. TaylorN point at the bottom) are not the lower-elevation (-2') transects (as might be expected since beach biota differ by tidal height) but rather some of the 0 ft MLLW transects.

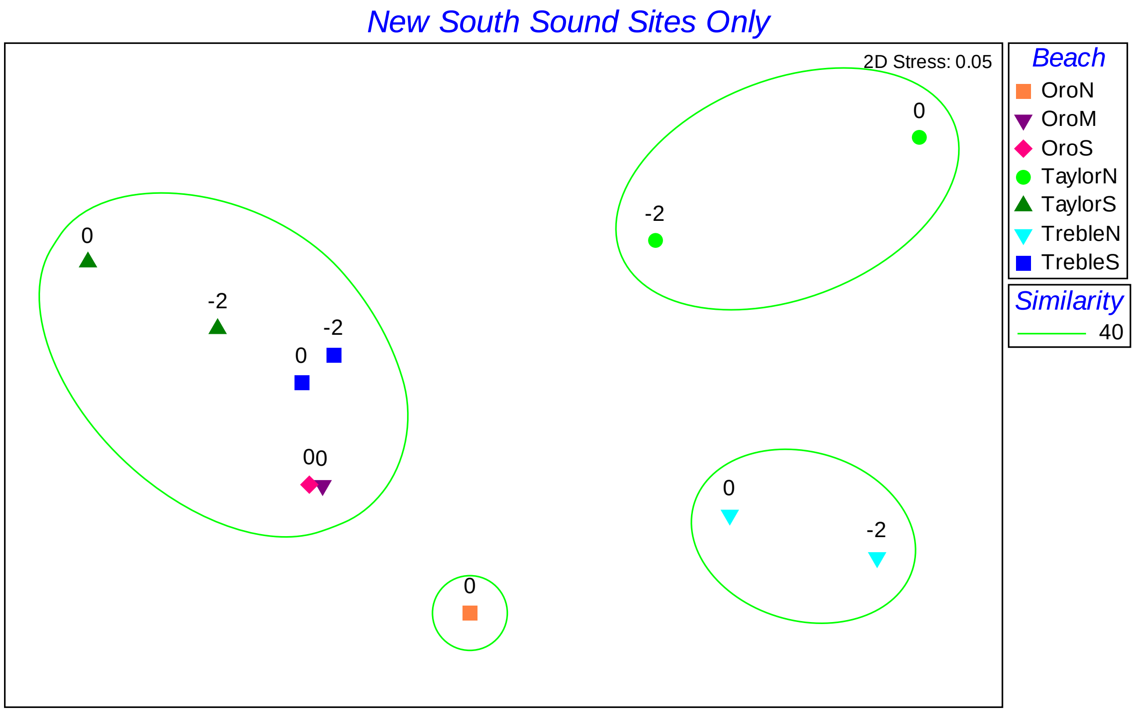

Figure 3-2. MDS plot of the biota at the transects at 0' (all sites) and -2' (Taylor and Treble only). Circles are drawn around the clusters of transects for which biotic similarity is >40%.

Removing the Case data, it is possible to see that biota group together by beach rather than by elevation; the -2' biota are generally rather similar to the 0' biota at that location. This clustering can be quantified with an ANOSIM test, which showed that the factor "beach" is highly significant ($R = 0.804$, $p = 0.001$), i.e. the biota of different beaches are distinctly different. Another pattern visible is that while the biotas at the 3 Oro Bay beaches are quite similar, TaylorN and TaylorS are very distinct from each other, as are TrebleN and TrebleS; i.e. points do not cluster well by Site (Taylor vs

Treble vs Oro), and the ANOSIM test for this contrast gives only R = 0.12[1], p = 0.18. These clear differences within and among sites can also be seen in the overall number of species per transect (Figure 3-3).

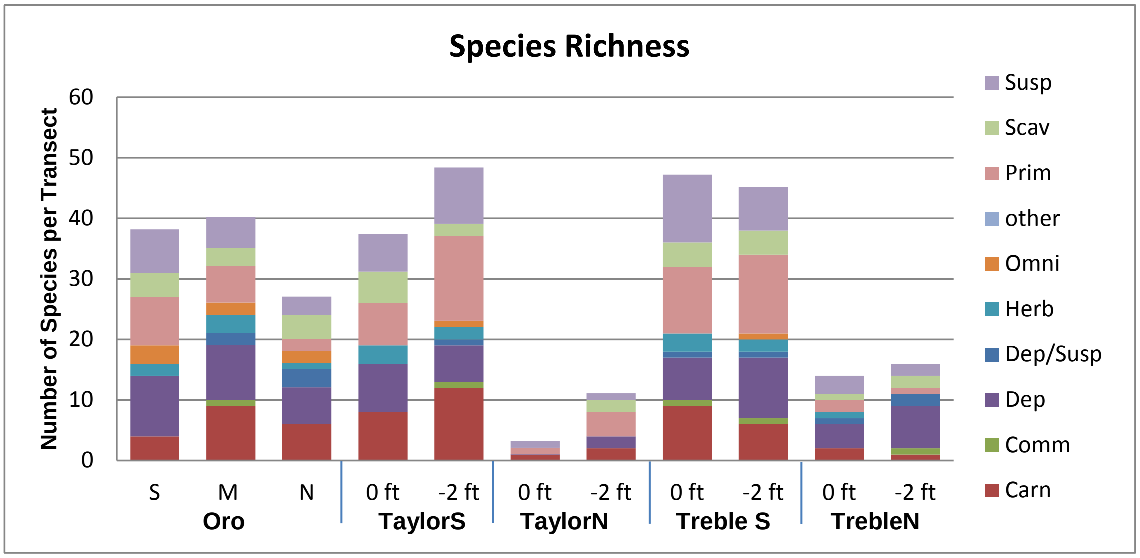

Figure 3-3. Overall species richness per transect at each of the beaches and elevations sampled. Species are subdivided by trophic group: Susp(ension Feeder), Scav(enger), Prim(ary Producer), other, Omni(vore), Herb(ivore), Dep(osit)/Susp(ension), Dep(osit), Comm(ensal), Carn(ivore). Appendix L lists all species and trophic group designation.

Much of the biotic difference within and among sites is probably driven by sediment types, as we have found throughout Puget Sound (i.e., Dethier and Berry 2010, Dethier and Berry 2011). Figure 3-4 shows the average percent covers of the two surface sediment types that we quantified, sand (<2 mm grains) and cobble (>10 cm rocks). Other grain sizes were not quantified, but the remainder (out of 100%) for most quadrats was generally pebbles (2 mm to 6 cm), as shown in Figures 1-2 through 1-4.

[1] R values, which usually fall between 0 and 1, are a measure of the degree of discrimination between (user-defined) groups. If similarities among groups are approximately equal to similarities within groups, R will be close to 0; visually, this would occur when it is impossible to draw non-overlapping circles around groups in an MDS plot. R = 1 occurs when *all* samples within a group are more similar to each other than all samples from different groups, i.e. the groups are totally distinct on a plot. This comparative measure is more meaningful than the p value from the ANOSIM test which may indicate "significance", even with very small R values, when sample sizes are large; even when groupings are weak (with little ecological relevance), if there are many samples within a group, there are likely to be some dissimilarities among groups, causing R to be significantly different from zero.

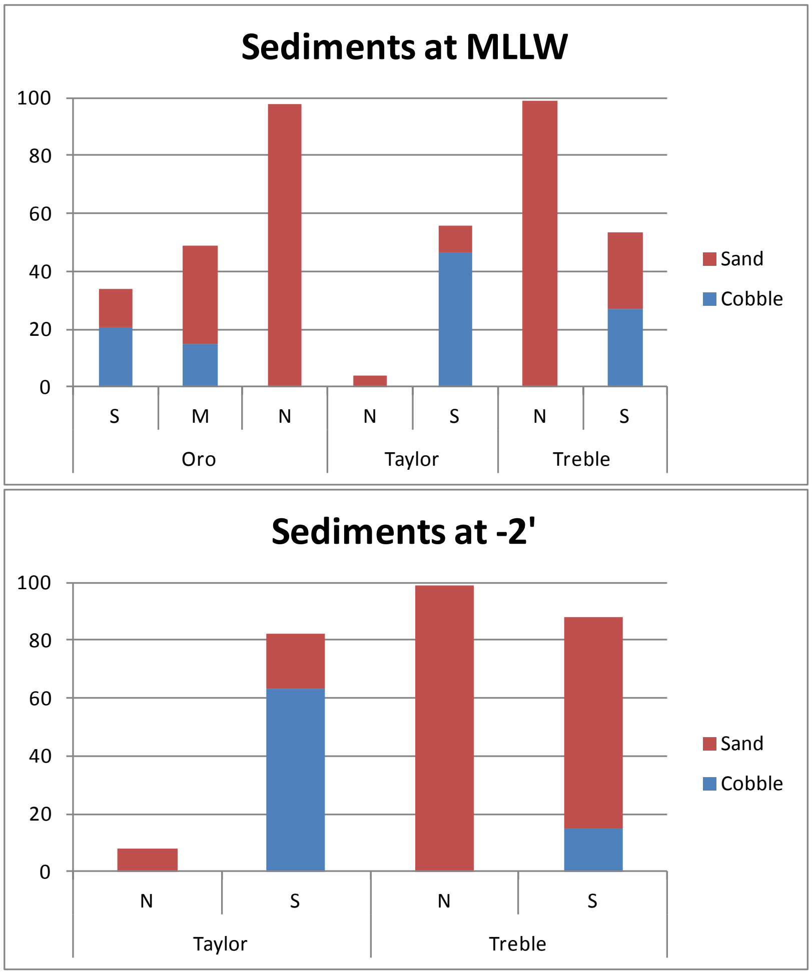

Figure 3-4. Percent cover of two key surface sediment types along each transect. Values are means from 10 quadrats. Remaining percents (not recorded in the field) could be mud, granules, pebbles, shell hash, boulders, or bedrock.

Our studies throughout Puget Sound have documented the importance of these two grain sizes to the beach biota. Cobble generally provides not only attachment surface for algae and sessile or slow-moving invertebrates (such as limpets), but also a relatively stable environment for infauna living under the cobbles and in the sediment between them. High cobble abundance thus often correlates with high species richness, as is seen for these sites in Figure 3-5. High proportions of sand, in contrast, can result in relatively low species richness (although not consistently, as seen in Fig. 3-5), probably both because of the inherent instability of this substrate type and because of the absence of microhabitats in which different organisms can live. Sand flats stabilized by eelgrass often have higher diversity, but no *Zostera* was recorded in the quadrats at these 7 beaches. The four transects with the lowest diversity were the two elevations at Treble N, both of which were sand dominated, and the two elevations at Taylor N, where we the transects were mostly comprised of pebbles, which are not quantified (Figure 1-2).

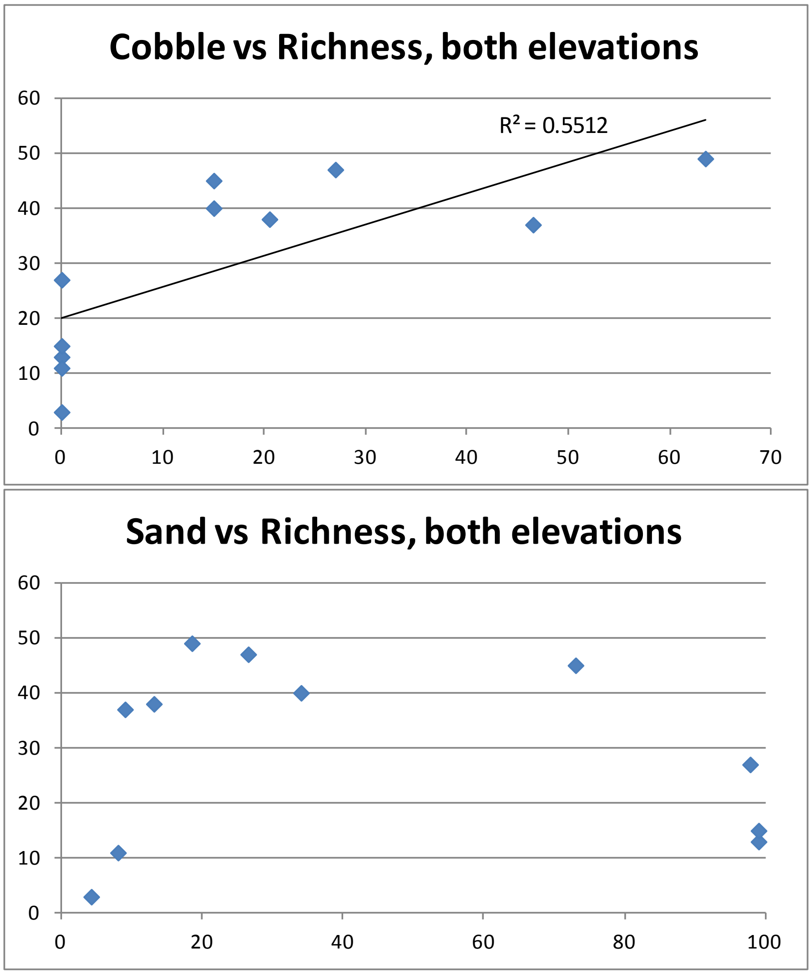

Figure 3-5. Correlations of percent cover of Cobble or Sand (x axis) and species richness on each of the 2011 South Sound transects.

The species recorded at each of these beaches (Appendices A, B, C, and F), and that separate the beaches from each other in the MDS plot, are generally those we expect to see associated with their dominant substrate type: cobbles, sand, and pebbles (based on previous SCALE work). Beaches and elevations with substantial amounts of cobble (OroS and M, TaylorS, Treble S; which all clustered together in Fig.3-1), have a variety of algae (ulvoids and a few red algae), barnacles, limpets, littorinid snails, shore crabs, and hermit crabs, plus abundant and diverse polychaetes in the sediment beneath the cobbles. Beaches that are primarily sand (OroN, Treble N) contain few surface species and moderate numbers of sand-dwelling clams (*Macoma*, *Tellina*; see Clams section), plus *Spiochaetopterus* polychaete tubes, sand-dwelling opisthobranchs (*Haminoea*), and burrowing anemones (*Edwardsia*) and cucumbers (*Leptosynapta*). Beaches characterized by pebbles, such as Taylor N, have the fewest species, in this case gammarid amphipods and glycerid polychaetes (which are both highly mobile and move around among the shifting pebbles), barnacles (which colonize the larger pebbles but do not live long), and small amounts of opportunistic algae such as ulvoids and *Acrosiphonia*.

3.2 Central Sound Beach Communities

Appendices D and E summarize the organisms found on the beaches sampled in Central Puget Sound in 2011, and Appendix G provides detailed abundance information. We sampled three beaches around Piner Point on the southeast corner of Maury Island, and three beaches on the relatively wave-exposed southeast side of Maury Island, adjacent to a gravel mining site. We contrasted the biota on these beaches with two years of data (2001 and 2002) from 3 beaches to the northeast of Maury Mine, referred to here as Maury Old. All 9 beaches were sampled at 0 ft MLLW only (except for clams, see below).

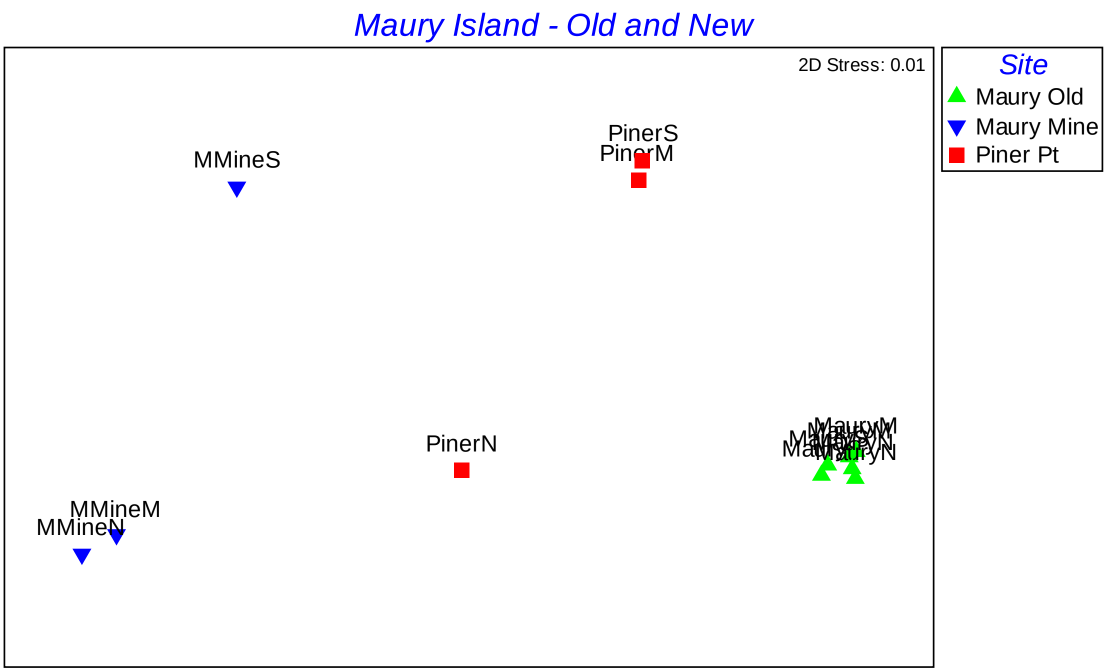

Figure 3-6. MDS plot of the biota at the transects at 0 ft MLLW in Central Sound (all sites). Maury Old data are from 2001 and 2002.

Figure 3-6 shows that as for the South Sound sites, the biota of the beaches varied substantially. While beaches varied somewhat within sites (e.g. PinerN separate from PinerM and PinerS), there was a significant pattern of biota varying at the Site level (ANOSIM of Sites, global $R = 0.93$, $p = .001$). Beaches also differed greatly in species richness (Fig. 3-7).

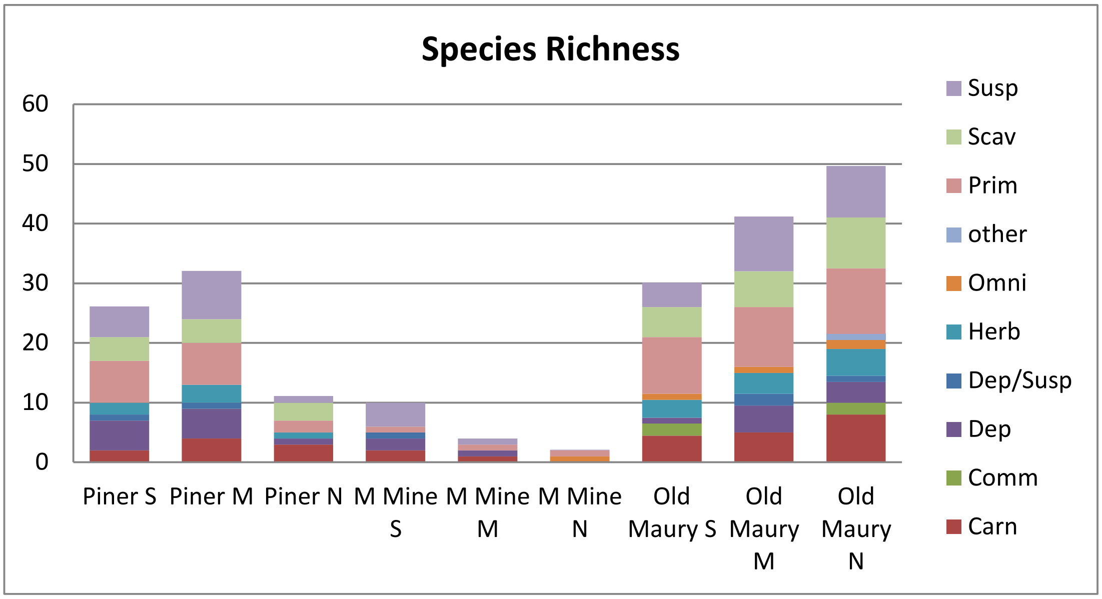

Figure 3-7. Species richness at 0 ft MLLW at each of the beaches sampled in 2011 (Piner and Maury Mine) and in 2001 and 2002 (Old Maury).Species are subdivided by trophic group: Susp(ension Feeder), Scav(enger), Prim(ary Producer), other, Omni(vore), Herb(ivore), Dep(osit)/Susp(ension), Dep(osit), Comm(ensal), Carn(ivore). Old Maury values are averages. Appendix L lists all species and trophic group designation.

Maury Mine beaches differed both from each other (S very distinct from M and N, Fig. 3-6 and 3-7) and from the other sites. Similarity of biota among Mine beaches was low, 44%. Similarity of the 3 Mine beaches to the 3 Maury Old beaches was only 18%. The Mine beaches had very low species richness, as seen above. As for the south Sound beaches, many of these patterns can be understood in terms of the sediment types, illustrated in Figure 3-8. The Mine beaches were characterized by large amounts of sand, no cobble, and some pebbles. Species found at these beaches were the polychaetes *Spiochaetopterus* and *Hemipodus*, juvenile sand dollars, and juveniles of the invasive varnish clam *Nuttallia*. Some of these taxa were found only at Maury MineS, making it stand out on the MDS plot. Maury MineN (a steep beach with sand and pebbles) was extremely depauperate, with only 2 species – a small amount of Ulva, and one Nereid worm.

Piner beaches were also variable among themselves, with overall similarity among beaches of 47%. Similarity to the Maury Mine beaches was low at 22%. Characteristic species found at Piner are cobble associates, some *Dendraster* sand dollar juveniles, and *Spiochaetopterus* polychaete tubes. One site (PinerS) had a small amount of *Zostera*. The northernmost of the three beaches (PinerN) was very different. It was protected from southerly exposure by the Point itself, and its sediments were pebble dominated, causing the very low species richness characteristic of such beaches. PinerN had only a few epibiota on the larger pebbles (barnacles), and few infauna of any kind. PinerM, in contrast, had the most cobbles and the highest species richness.

The Maury Old beaches were much more uniform (since they were chosen to be replicates in terms of sediment and wave energy); the biotic similarity among the three beaches was 63%. They were also much more similar to Piner beaches (47%) than to the Maury Mine beaches (18%). Characteristic species were again cobble associates (cobble was present in the quadrat photos, although it was not counted as part of our sampling protocol in those years), and a variety of worms.

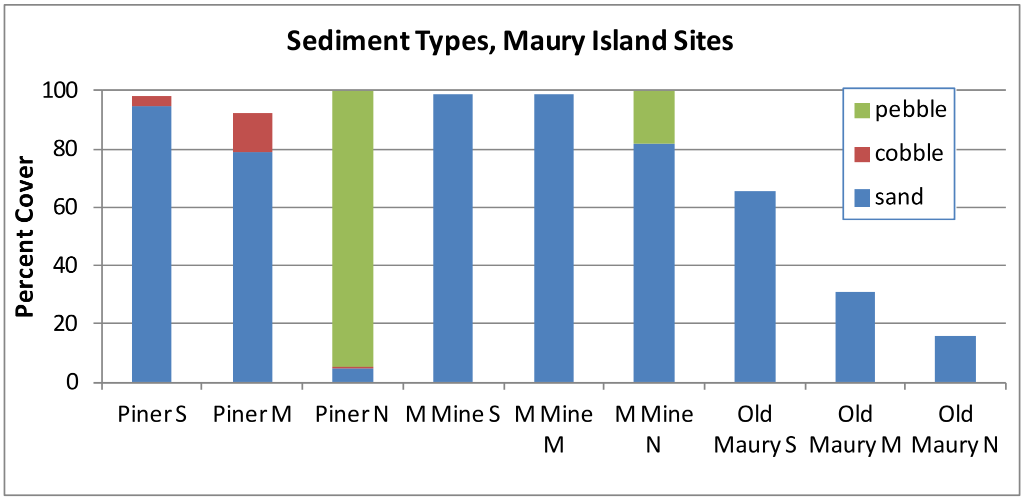

Figure 3-8. Sediment types at the 6 beaches sampled in central sound in 2011, and sand cover at the Old Maury beaches. Cobble percent covers were not recorded until 2005, so cobble cover at the Old Maury beaches is not known.

3.3 Clam Populations at all Sampled Sites

Appendix H provides detailed information on the large clams found at South Sound and Central Sound beaches. Abundances and species of clams varied widely among the sites sampled, as expected given the large variation in sediment types. In South Sound, the Treble Point beaches had low clam densities at all tidal elevations but rather high species richness except at +1.5’, where no clams were found (Fig. 3-9). The most common species at TrebleN were *Macoma nasuta* and *M. secta*, and the small *Tellina modesta* (all deposit-feeding species). The most common at TrebleS was the shallow-dwelling suspension feeder *Clinocardium*. The Oro beaches had by far the most abundant clams, and richness was also high. The most common species there were *Macoma nasuta* and *M. inquinata*, but there were also numerous *Leukoma (=Protothaca*). The TaylorN beach had no clams in any of the cores. TaylorS had low densities and clam richness, but the two most common species were the edible *Saxidomus* (butter clams) and *Leukoma* (native littlenecks).

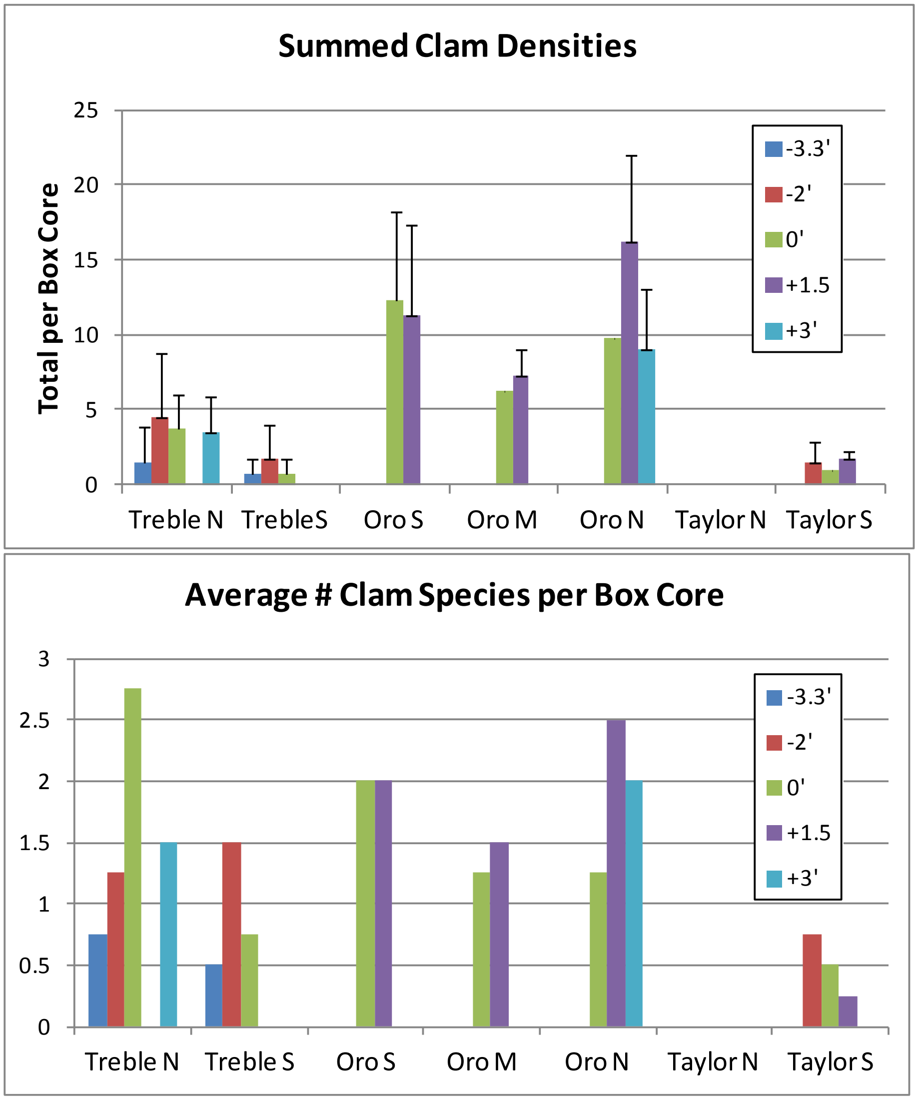

Figure 3-9. Abundances and species richness of clams in box cores at all sampled tidal elevations at South Sound beaches. Error bars in upper panel are one s.d. Only TrebleN and OroN were sampled at +3'; only TrebleN and TrebleS were sampled at -3.3'.

In the Central Sound sites (Maury Island), no clams were found in any of the 24 box cores at the Piner beaches, and only 5 clams were found in 24 cores at the Maury Mine beaches (clam data were not collected at Old Maury). These consisted of one small *Saxidomus* (12 mm) and 3 adult *Nuttallia* (38-67 mm) at Maury MineS, and 1 adult *Nuttallia* (35 mm) at Maury MineN. Thus the following plots do not contain clam information for Maury or Piner except for the *Nuttallia* size information in Fig. 3-10.

Sizes of clams found in the cores are shown in Figure 3-10 for the more abundant species. The large error bars denote high variance in sizes per site; for example at Taylor Point we found *Saxidomus* ranging from 20 to 90 mm. Harvestable size for *Saxidomus* and *Leukoma* is ~38 mm (1.5"); only 4 legal *Leukoma* were found at any of the sites, but many of the *Saxidomus* were large enough to be harvestable. Few of the other clams are harvested recreationally, except for *Clinocardium* (cockles) and *Tresus* (horse clams), both of which were uncommon at all sites.

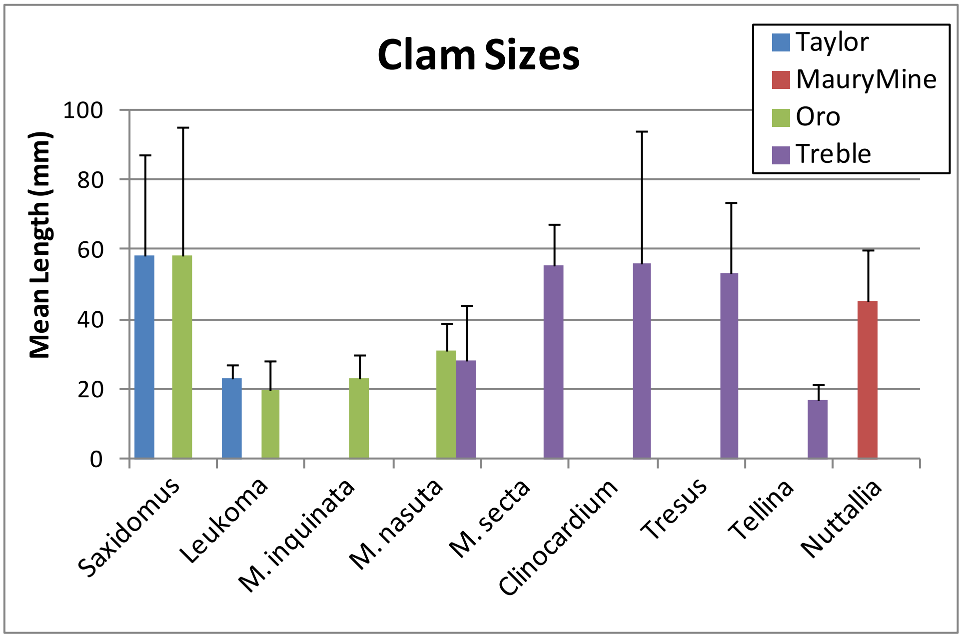

Figure 3-10. Mean sizes of clams found at each of the sites; error bars are one s.d. Data are given only for species for which >3 individuals per site were found.

3.4 Sieve Size Test

Organisms retained on 2 mm and 1 mm sieves were compared to quantify what kinds of species and how many individuals are "missed" by only using larger mesh sieves; these data are summarized in Figure 3-11. Appendices I and J summarize species found with the two mesh sizes at each transect, and Appendix K lists abundances.

Out of 55 infaunal species found overall, 14 species were found only on the 1 mm sieves (comprising 26 individuals); these included 6 polychaete, 6 amphipod, and 2 molluscan species. Of these, only 2 amphipod (*Protomedeia articulara* and *Repoxynius pallidus*) and 1 polychaete (*Barantolla americana*) species had not been found in earlier SCALE survey using 2 mm sieves; the rest were all juveniles of species seen at other places and times. The polychaete *Barantolla americana* was collected previously during a special survey that used 1 mm mesh sieves in Browns Bay in 2008. For most (9) of the 14 species, only 1 individual was found, indicating that they are probably rare taxa. 18 additional species (268 individuals) were found in the 1 mm sieves but were also present in the 2 mm samples (549 individuals) for those sites. In this case, also, the 1 mm sieve contained juveniles (or pieces) of species found as larger individuals in the larger sieves.

Taxonomic Group	# Individuals Collected		# Species Collected		Comparison of # Species Found On Each Mesh Size		
	1 mm	2 mm	1 mm	2 mm	1 mm only	2 mm only	Both 1 mm and 2 mm
amphipod	8	2	7	2	6	1	1
anemone	12	56	1	1	0	0	1
bivalve	170	31	6	8	2	4	4
crab	0	2	0	2	0	2	0
isopod	0	4	0	1	0	1	0
nemertean worm	0	12	0	1	0	1	0
polychaete worm	103	487	17	24	6	13	11
sand dollar	1	39	1	1	0	0	1
sea cucumber	0	21	0	1	0	1	0
TOTAL	**294**	**654**	**32**	**41**	**14**	**23**	**18**

Figure 3-11. Infaunal species collected using 1 mm and 2 mm mesh sizes.

A total of 948 individuals in 55 species were found in these 80 infaunal samples on both sieve sizes. Of these, 33% of the individuals were on the 1 mm sieves. While this sounds like a relatively large proportion, most (58%) of the 1 mm sieve individuals were one species of small clam, *Rochefortia (=Mysella) tumida.* This species rarely reaches 2.5 mm in size; 2 (of 155 total) were caught on the 2 mm sieves, and it is regularly seen in SCALE samples elsewhere. When that clam is excluded, 15% of the total infaunal individuals were found on the 1 mm sieves. It appears that the capitellid *Barantolla* (3 individuals) may be the only species “caught” that is less than 2 mm as an adult and thus is unlikely to be seen if only the larger mesh size is used. Thus overall, some small individuals but very few species are ‘missed’ with the 2 mm sieve size relative to 1 mm.

On a per transect basis, species richness in core samples increased by a median of 21% with 1 mm mesh size, as compared to 2 mm (Figure 3-12). At beaches that weren’t depauperate, the 1 mm sieve size had the greatest effect on infaunal richness at TrebleN, where richness increased by 50% at both intertidal heights (0 and -2 ft MLLW). Other sites showed smaller per-transect changes in richness with the addition of 1 mm samples (Figure 3-12).

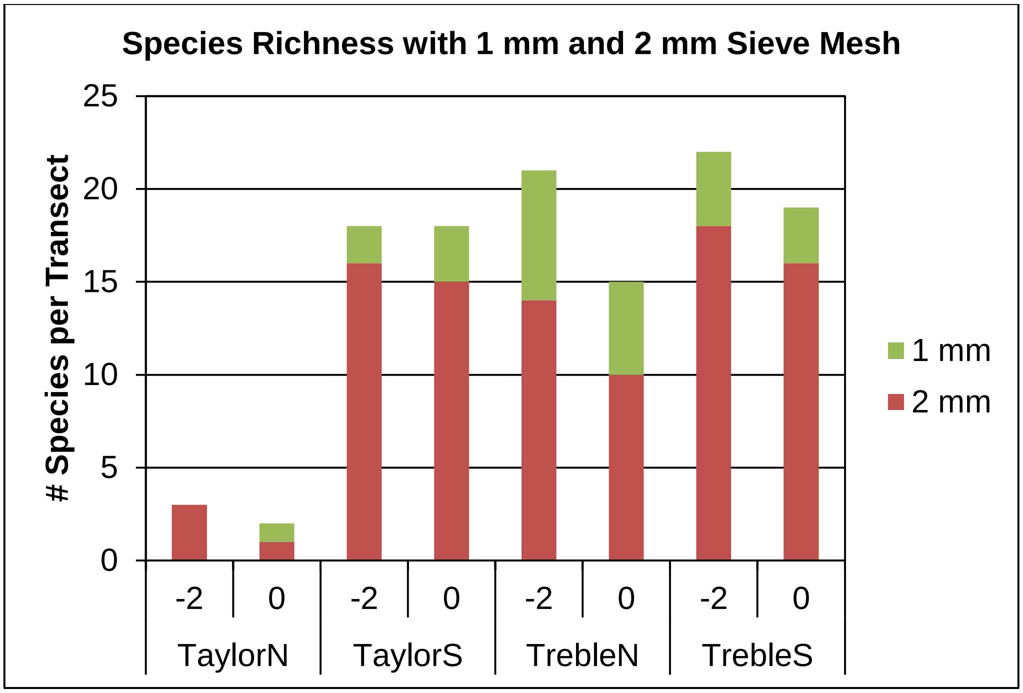

Figure 3-12. Species richness in core samples at Taylor and Treble transects (0 and -2'), where each core sample was sieved with 2 and 1 mm sieves. Species richness for 1 mm sieve includes all species along a transect that were not collected on the 2 mm sieves.

An MDS plot (Fig. 3-13) compares the whole community found using each method; for this analysis, the "1 and 2" points include all the species found in the quadrats as well as in both sieve sizes, whereas the "2 only" excludes the individuals (all infauna) found on the 1 mm sieves for that site. Overall, adding in the 1 mm fauna makes very little difference to the community as a whole; this is not surprising since there were few species that were found exclusively in the 1 mm samples, and very few individuals of those. The TrebleN transects showed the most differentiation in these paired comparisons. At both the 0' and -2' elevations, at this beach we found many *Rochefortia* in the small sieves as well as single small individuals of rare species, including 4 amphipod species not seen elsewhere. These transects were both sand-dominated (see above), differentiating their biota overall from the other beaches. The biota of TrebleN were also unusual in having many of the burrowing anemone *Edwardsia,* with adults in the 2 mm sieves and juveniles in the 1 mm. When the relative abundances of species are eliminated from consideration by analysis of simple presence/absence data, the resulting MDS plot was virtually identical.

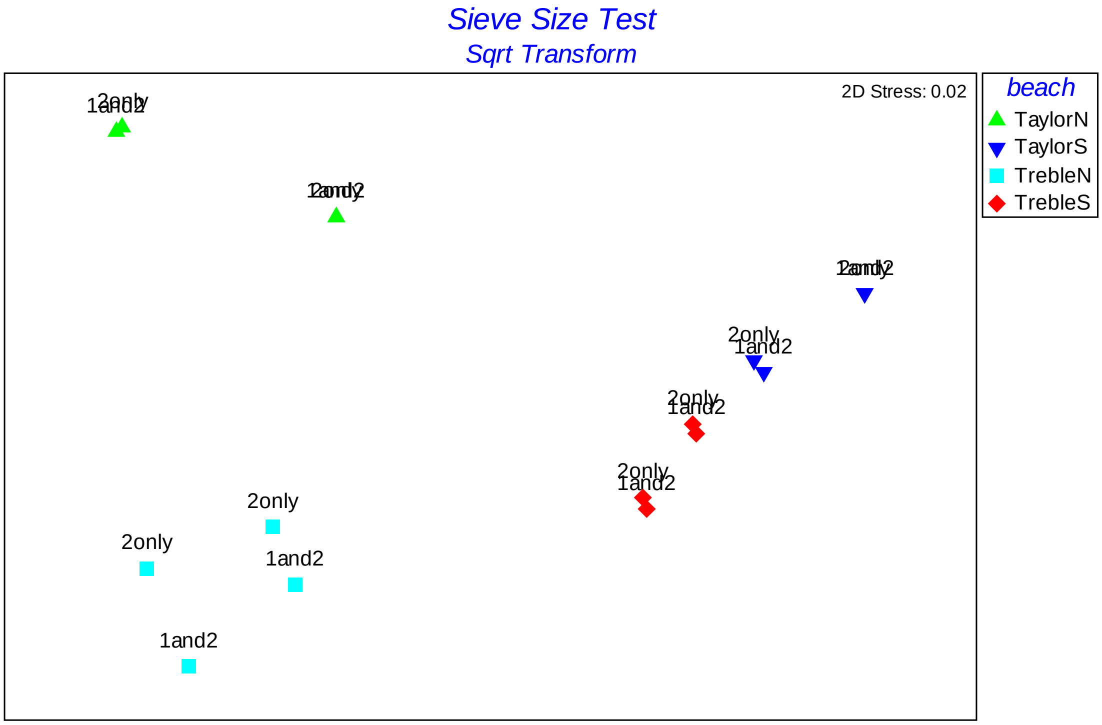

Figure 3-13. MDS plot of the biota at the Taylor and Treble transects (0 and -2'), where each core sample was sieved with 2 and 1 mm sieves. The two left TrebleN points are -2', two right are 0'.

In conclusion, in terms of characterizing overall community structure and biodiversity, little information is lost by using only 2 mm sieves at these beach segments. Much more important in determining the biota is the choice of sites, substrate types, and tidal elevations.

4 Discussion and Conclusions

4.1 General Intertidal Biodiversity Patterns

A primary objective of both the Maury Island and Nisqually Reach Reserves is to conserve native intertidal ecosystems and species. The management plans for both reserves place special emphasis on habitat for forage fish, salmonids, and migratory birds Some other intertidal ecosystem characteristics that are commonly perceived to be important to protect include overall biodiversity (Bloch and Palazzi 2005), and abundant and diverse clam populations (Dethier 2006).

The surveys we completed in the reserves underscore that substrate types are a key factor determining intertidal biodiversity. Beaches that contain cobble substrates, especially near or below 0 ft MLLW, have much higher overall biodiversity than other types of Puget Sound beaches, including pebble, sand, and mud. The solid surfaces of cobbles, as well as the stability they impart to the beach as a whole, create a complex set of microhabitats that lead to high biodiversity. Algae and sessile or slow-moving invertebrates attach to the tops and sides of cobbles, while other invertebrates and even fishes live under the cobbles or in the sediment between them. Throughout Puget Sound we have found a consistent pattern of species richness being linked to the abundance of cobble present, whether the beaches are relatively protected (like Oro Bay) or exposed (like TaylorN or TrebleN). Sand beaches are less predictable in their biodiversity although none are as species-rich as cobble beaches. Some high-energy (wave exposed) sand beaches we have surveyed have very low richness and abundances of species, while others are much more diverse. Beaches exposed to substantial wave action tend to be too unstable for eelgrass to recruit and survive, but lower-energy beaches often harbor beds of eelgrass. Species diversity of beaches with eelgrass is higher than unvegetated areas, and valued organisms such as Dungeness crab are more likely to be present (Mumford 2007). The third major substrate type, unstable pebbles, has very low diversity.

Our analyses have illustrated intertidal diversity within beaches, and how beaches vary. It is important to note an additional factor relative to overall biodiversity; the species found in different substrate types are almost entirely different from each other. Thus the best way to capture high or representative biodiversity for a region is to create reserves where several different beach types are present – referred to as

Beta (among-habitat) diversity, as opposed to Alpha (within-habitat) diversity. The current reserve boundaries generally capture among-habitat diversity by encompassing multiple substrate types as well as energy regimes, which also are likely to support different species. Reserve sites that contain several habitat types are also likely to contain more species that people care about, such as seals, shorebirds, eagles, and herons, since such sites provide a diversity of food resources for these predators.

Of the areas we sampled in the Maury Island Reserve, the Maury Mine sites had relatively low intertidal Alpha and Beta diversity. PinerN also had low Alpha diversity, but stronger Beta diversity when considered along with the adjacent habitats at PinerM and PinerS. While biodiversity is an important concern, we also recognize that intertidal community biodiversity is not the only rationale for placing an area in reserve status. For example, this stretch of shoreline along Maury Island stands out as a relatively undeveloped portion of shoreline in a highly altered area of Central Puget Sound. While we do not know all the ramifications of shoreline development (i.e. houses and/or armoring near the beach), it is likely that undeveloped shorelines serve ecosystem functions that are important to capture within a Reserve system.

Clams were targeted in our study with a separate sampling methodology because they are “valued ecosystem components” but are not effectively quantified in the relatively small and shallow cores taken for other infauna. Some of the most valued species, such as butter clam, horse clam, and geoduck, are hard to quantify in any sampling scheme because they dig so deeply into the substrate. Our box cores appear to do an effective job quantifying littleneck, soft shell, and other shallow-dwelling clams, however, and at least a moderate job quantifying butter clams. As with most other marine organisms, clam species (and densities) are closely tied to both tidal elevation and substrate type (Dethier 2006). Clams of most species, including littleneck and butter clams, are far more abundant in cobble-sand mixed substrates than elsewhere. This pattern may be driven by the difficulty that predators have in reaching clams living among and under cobbles. Aquaculturists routinely spread coarser sediment onto sand or mud beaches to encourage both settlement and survival of clams there. The site with the largest clam populations in our 2011 study was Oro Bay, which has both this optimal mixed substrate and may have low human disturbance. TaylorS had relatively low numbers of clams, but the species found were the highly valued littlenecks and butter clams. At all sites, clams were found over a wide tidal range, with little evidence for an optimal height for any of them.

Primary productivity is another factor that affects both biodiversity and habitat usage. Primary productivity varies highly among Puget Sound beaches. Submerged aquatic vegetation – eelgrass and kelp populations – constitute the habitats of highest nearshore productivity but were not surveyed in our study; these are important to food webs in the Sound as a whole, as well as providing critical feeding and rearing habitat for various fish and shellfish species. Eelgrass extends into the low intertidal zone on many Puget Sound beaches, especially in areas that are not fully wave-exposed. Kelps and other macroalgae are also more common in the shallow subtidal zone than the intertidal, but cobble-dominated beaches do support some kelps and are the areas of greatest intertidal productivity (as well as diversity).

4.2 Some Factors To Consider During Reserve Monitoring

The Aquatic Reserves Program plans to develop a network-wide reserve monitoring program (Betty Bookheim, pers. comm. 2012). In addition to future monitoring activities, we recommend conducting sampling that establishes a baseline of intertidal species that occur within the reserve. Given limited funds, sampling could take place at representative habitats that are identified based on existing beach characterizations. Parameters could include basic physical information, such as beach profile, and community characterization.

Another focus of concern within the aquatic reserves is to understand the effects of overwater structures, bulkheads, and marinas on nearshore resources (DNR 2011). As part of a separate project funded by Washington Sea Grant, we are currently collecting mid-to- upper intertidal data in Central Puget Sound that links armoring to nearshore processes by comparing conditions at pairs of armored and unarmored beaches (Dethier, unpub. data). These data include type and location of armoring and a series of upper intertidal habitat characteristics including wrack presence, talitrid abundance, and insect abundance. This project will provide some information on the Maury Island Reserve, as six of the existing sites fall within it. The project may also establish additional sites in the South Sound within the Nisqually Reach Aquatic Reserve. The results from this study could be used to understand patterns along unarmored and armored shorelines, and to inform future monitoring methods within the reserve.

4.3 Comparison of 1 mm and 2 mm sieves

Results at Taylor and Treble showed that sieving to 1 mm – rather than 2 mm - did not substantially change the species richness or community composition. Given that much greater field and laboratory resources are required for using 1 mm sieves, using 2 mm sieves can decrease the resources required for beach characterization, with only minor loss of site-level detail. This consideration should be weighed with other individual project considerations in determining sieve mesh size choice, such as trade-offs between the number of areas sampled and the degree of detail per site, target species, and comparison to other datasets. For very fine substrates (mud or fine sand), where much of the infauna comprises very small organisms, use of finer sieve sizes is a logical choice.

4.4 Observations related to Potential Restoration at Maury Mine

Two of the beaches at Maury Mine that we sampled have potential for restoration - removal of the remaining pier structure at Maury MineM and removal of the backshore concrete structure at Maury MineN. Our lower intertidal sampling at these sites did not capture the before/after conditions that would be most relevant to such restoration efforts. At Maury Mine M, the remaining pier structure does not appear to be substantially reducing longshore drift or shading intertidal vegetation. Additional subtidal sampling might capture changes related to structure removal, especially of hard substrate and creosote. At MauryN, the primary impact of the structure is in the upper intertidal and backshore, so sampling that focused on substrate and habitat conditions in that zone would capture restoration effects. Parameters could include sediment size, beach profile, forage fish spawning, talitrids, insects, and wrack.

4.5 Observations Related to the Habitat Types for Potential Geoduck Aquaculture

One environmental concern related to geoduck and other types of aquaculture is disruption of the local natural community from planting and harvesting disturbances, and from structural changes caused by tubes and nets. Our beach surveys reported here suggest that from a biodiversity perspective, it would be preferable to place such activities on sand beaches like those at TaylorN, which naturally have relatively low richness and diversity. These higher-energy beaches also are less likely to suffer from sedimentation by fine particles that are stirred up into the water column during aquaculture activities, both because there are fewer fines in high-energy beaches, and because waves and currents are likely to sweep them away. Cobble beaches are poorer choices for shoreline aquaculture, both because the logistics of establishing tubes and nets among cobbles is difficult, and because loss of native communities is more of a concern in these higher-diversity habitats.

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APPENDICES

Appendix A. Summary of Organisms Found at Oro Bay

Organisms found in 0.25 m^2 quadrats and 10 cm x 15 cm deep cores (sieved with 2 mm mesh). 10 random samples collected along a 50 meter transect.

OroN (0 ft MLLW)	OroM (0 ft MLLW)		OroS (0 ft MLLW)	
Anthopleura elegantissima	*Acrosiphonia* spp.	*Nereis procera*	*Acrosiphonia* spp.	*Nereis procera*
Diatoms, chain-forming	*Alia* spp.	*Nicolea zostericola (?)*	*Axiothella rubrocincta*	*Notomastus tenuis*
Edwardsia sipunculoides	*Ampharete labrops*	*Notomastus tenuis*	*Capitella capitata*	*Pagurus* spp.
Gammarid amphipods	*Aphelochaeta multifilis*	*Odostomia* sp.	*Caulleriella ?pacifica*	*Platynereis bicanaliculata*
Glycera americana	*Capitella capitata*	*Pagurus* spp.	*Cirratulus multioculatus*	*Podarke pugettensis*
Glycinde picta	Dead barnacles (Class Cirripedia)	*Phyllodoce* spp.	*Crepidula dorsata*	Polynoid
Haminoea vesicula	Diatoms, chain-forming	*Pinnixia schmitti/occidentalis*	Dead barnacles (Class Cirripedia)	*Porphyra* sp.
Harmothoe imbricata	*Edwardsia sipunculoides*	*Podarke pugettensis*	Diatoms, chain-forming	*Rochefortia tumida*
Leito/Scoloplos	Fleshy crust	*Polydora cardalia*	*Euclymene spp.*	Sabellid
Leptochelia dubia	*Glycera americana*	Polynoid	Flatworm	*Saxidomus giganteus* juv.
Lucina tenuisculpta	*Glycinde picta*	*Polysiphonia* sp.	*Fleshy crust*	*Scytosiphon simplicissimus*
Macoma nasuta	*Haminoea vesicula*	*Rochefortia tumida*	*Hemigrapsus oregonensis*	*Spiochaetopterus costarum*
Macoma nasuta juv.	*Hemigrapsus oregonensis*	*Saxidomus giganteus* juv.	*Hemipodus borealis*	Ulvoids
Mediomastus californiensis	*Hemipodus borealis*	*Spio filicornis*	*Leito/Scoloplos*	
Nassarius sp.	*Leito/Scoloplos*	Ulvoids	*Leptochelia dubia*	
Nemertean	Live barnacles (Class Cirripedia)		*Leukoma staminea*	
Nephtys caecoides	*Lophopanopeus bellus bellus*		*Leukoma staminea juv.*	
Nicolea zostericola (?)	Lottid limpets		Live barnacles (Class Cirripedia)	
Notomastus tenuis	*Lucina tenuisculpta*		Lottid limpets	
Pagurus spp.	*Macoma inquinata*		*Macoma inquinata* juv.	
Platynereis bicanaliculata	*Macoma inquinata* juv.		*Macoma nasuta*	
Podarke pugettensis	*Macoma nasuta* juv.		*Mastocarpus jardinii*	
Polydora cardalia	*Mastocarpus papillatus*		*Mastocarpus papillatus*	
Pseudopolydora kempi japonica	*Mediomastus californiensis*		*Mediomastus californiensis*	
Spiochaetopterus costarum	*Mopalia lignosa*		*Megamoera subtener*	
Spiophanes bombyx	*Nassarius* sp.		*Mopalia lignosa*	
Tellina modesta	Nemertean		Nemertean	
Ulvoids				

Appendix B. Summary of Organisms Found at Taylor Bay

Organisms found in 0.25 m^2 quadrats and 10 cm x 15 cm deep cores (sieved with 2 mm mesh). 10 random samples collected along a 50 meter transect.

TaylorN -2 ft MLLW	TaylorS -2 ft MLLW		TaylorS 0 ft MLLW	
Acrosiphonia spp.	*Acrosiphonia* spp.	Nemertean	*Acrosiphonia* spp.	Nemertean
Cancer sp.	*Armandia brevis*	*Notomastus tenuis*	*Asabellides sibirica*	*Notomastus lineatus*
Dead barnacles (Class Cirripedia)	*Asabellides sibirica*	*Nucella lamellosa*	*Axiothella rubrocincta*	*Notomastus tenuis*
Diatoms, chain-forming	*Axiothella rubrocincta*	*Onchidoris bilamellata*	Dead barnacles (Class Cirripedia)	*Nucella lamellosa*
Fleshy crust	Bryozoa	*Owenia fusiformis*	*Dendraster* juv.	*Onchidoris bilamellata*
Gammarid amphipods	*Cancer productus*	*Pagurus* spp.	Diatoms, chain-forming	*Owenia fusiformis*
Hemipodus borealis	*Cryptosiphonia woodii*	*Petalonia fascia*	Flatworm	*Pagurus* spp.
Live barnacles (Class Cirripedia)	Dead barnacles (Class Cirripedia)	*Pinnixia schmitti/occidentalis*	Fleshy crust	*Polycirrus* n. sp. (L. Harris)
Notomastus lineatus	*Dendraster* juv.	*Pisaster ochraceus*	Gammarid amphipods	*Polysiphonia* sp.
Notomastus tenuis	Diatoms, chain-forming	*Pododesmus cepio*	*Glycera americana*	*Porphyra* sp.
Pagurus spp.	*Eulalia sanguinea*	*Polynoid*	*Gnorimosphaeroma oregonense*	*Saxidomus giganteus* juv.
Ulvoids	Flatworm	*Polysiphonia* sp.	*Harmothoe imbricata*	*Sphaeromid isopods*
	Fleshy crust	*Porphyra sp.*	*Hemigrapsus oregonensis*	*Tharyx parvus*
	Gelidium spp.	*Prionitis* sp.	*Hemipodus borealis*	*Tresus capax*
TaylorN 0 ft MLLW	*Harmothoe imbricata*	*Pycnopodia helianthoides*	*Hermissenda crassicornis*	Ulvoids
Dead barnacles (Class Cirripedia)	*Hemigrapsus oregonensis*	*Sarcodiotheca sp. (unid.)*	*Idotea* sp.	
Hemipodus borealis	*Hemipodus borealis*	*Saxidomus giganteus juv.*	*Leptosynapta clarki*	
Live barnacles (Class Cirripedia)	*Hermissenda crassicornis*	*Scytosiphon simplicissimus*	*Littorina* sp.	
Ulvoids	*Laminaria saccharina*	*Spio filicornis*	Live barnacles (Class Cirripedia)	
	Live barnacles (Class Cirripedia)	*Spiochaetopterus costarum*	Lottid limpets	
	Lottid limpets	*Stichaeidae*	*Mastocarpus papillatus*	
	Lyonsia californica	*Tresus capax*	*Metridium* sp.	
	Macoma inquinata juv.	*Tresus capax* juveniles	*Mytilus trossulus*	
	Mastocarpus papillatus	Ulvoids		
	Metridium sp.			
	Mopalia lignosa			

Appendix C. Summary of Organisms Found at Treble Point

Organisms found in 0.25 m^2 quadrats and 10 cm x 15 cm deep cores (sieved with 2 mm mesh). 10 random samples collected along a 50 meter transect.

TrebleN -2 ft MLLW	TrebleN 0 ft MLLW	TrebleS -2 ft MLLW		TrebleS 0 ft MLLW	
Anisogammarus pugettensis	*Dendraster* juv.	*Acrosiphonia* spp.	*Mediomastus californiensis*	*Acrosiphonia* spp.	Live barnacles (Class Cirripedia)
Asabellides sibirica	Diatoms, chain-forming	*Alia* spp.	*Metridium* sp.	*Alia* spp.	Lottid limpets
Dendraster juv.	*Edwardsia sipunculoides*	*Anthopleura elegantissima*	*Mopalia lignosa*	*Anthopleura elegantissima*	Majid crab
Edwardsia sipunculoides	*Lacuna* spp.	*Asabellides sibirica*	*Nassarius* sp.	*Cirratulus multioculatus*	*Malmgreniella nigralba*
Euclymene spp.	*Leito/Scoloplos*	*Axiothella rubrocincta*	Nemertean	*Clinocardium nuttallii juveniles*	*Mastocarpus papillatus*
Fabia subquadrata	*Leptosynapta clarki*	*Clinocardium nuttallii* juveniles	*Nereis procera*	*Cryptosiphonia woodii*	*Metridium* sp.
Glycinde picta	*Macoma nasuta* juv.	*Cryptosiphonia woodii*	*Notomastus lineatus*	Dead barnacles (Class Cirripedia)	*Mopalia lignosa*
Leito/Scoloplos	*Monocorophium* spp.	Dead barnacles (Class Cirripedia)	*Notomastus tenuis*	*Dendraster excentricus*	Nemertean
Macoma inquinata juv.	Nemertean	*Dendraster excentricus*	*Onchidoris bilamellata*	*Dendraster* juv.	*Notomastus tenuis*
Macoma nasuta juv.	*Nephtys caecoides*	*Dendraster* juv.	*Pagurus* spp.	*Diatoms, chain-forming*	*Owenia fusiformis*
Notomastus tenuis	*Polydora cardalia*	*Diatoms, chain-forming*	*Polydora cardalia*	*Edwardsia sipunculoides*	*Pagurus spp.*
Pagurus spp.	*Spiochaetopterus costarum*	*Edwardsia sipunculoides*	*Polynoid*	*Euclymene spp.*	*Pisaster ochraceus*
Polydora cardalia	*Tellina modesta*	*Euclymene* spp.	*Polysiphonia* sp.	*Eupentacta quinquesemita*	*Pododesmus cepio*
Polydora proboscidea	Ulvoids	Fleshy crust	*Porphyra sp.*	*Evasterias troschelii*	*Polydora socialis*
Tellina modesta		Gammarid amphipods	*Sarcodiotheca* sp.	Flatworm	*Polynoid*
Ulvoids		*Gelidium* spp.	*Sargassum muticum*	Fleshy crust	*Polysiphonia* sp.
		Gracilaria pacifica	*Spiochaetopterus costarum*	Gammarid amphipods	*Porphyra* sp.
		Hemipodus borealis	*Tellina modesta*	*Gelidium* spp.	*Rochefortia tumida*
		Leito/Scoloplos	*Tharyx parvus*	*Glycinde picta*	*Sabellid*
		Leptosynapta clarki	*Tresus capax*	*Gracilaria pacifica*	*Scytosiphon simplicissimus*
		Live barnacles (Class Cirripedia)	Ulvoids	*Hemigrapsus oregonensis*	*Spiochaetopterus costarum*
		Lottid limpets		*Hemipodus borealis*	*Tharyx parvus*
		Majid crab		*Lacuna* spp.	*Tresus capax*
		Malmgreniella nigralba		*Leito/Scoloplos*	Ulvoids
		Mastocarpus papillatus		*Leptosynapta clarki*	
		Mazzaella splendens			

Appendix D. Summary of Organisms Found at Piner Point

Organisms found in 0.25 m^2 quadrats and 10 cm x 15 cm deep cores (sieved with 2 mm mesh). 10 random samples collected along a 50 meter transect.

PinerN (0 ft MLLW)	**PinerM (0 ft MLLW)**		**PinerS (0 ft MLLW)**
Anthopleura elegantissima	*Acrosiphonia spp.*	Sphaeromid isopods	*Acrosiphonia* spp.
Dead barnacles (Class Cirripedia)	*Anthopleura artemisia*	*Spio filicornis*	*Alia* spp.
Eogammarus oclairi	*Axiothella rubrocincta*	*Spiochaetopterus costarum*	*Armandia brevis*
Fleshy crust	*Calliopius spp.*	*Tharyx parvus*	*Calliopius* spp.
Gammarid amphipods	Dead barnacles (Class Cirripedia)	*Tresus capax* juveniles	*Chaetozone acuta*
Hemipodus borealis	*Dendraster* juv.	Ulvoids	*Clinocardium nuttallii*
Lacuna spp.	Diatoms, chain-forming		Dead barnacles (Class Cirripedia)
Live barnacles (Class Cirripedia)	*Fleshy crust*		*Dendraster* juv.
Nemertean	*Gammarid amphipods*		Diatoms, chain-forming
Notomastus tenuis	*Hemipodus borealis*		Family Hippolytidae
Sphaeromid isopods	*Lacuna* spp.		Fleshy crust
Ulvoids	Live barnacles (Class Cirripedia)		Gammarid amphipods
	Lottid limpets		*Hemipodus borealis*
	Lucina tenuisculpta		*Lacuna* spp.
	Metridium sp.		Live barnacles (Class Cirripedia)
	Mopalia lignosa		*Lottid limpets*
	Mytilus trossulus		*Mytilus trossulus*
	Nemertean		*Notomastus tenuis*
	Nephtys caecoides		*Pagurus* spp.
	Notomastus lineatus		*Petalonia fascia*
	Notomastus tenuis		*Porphyra* sp.
	Owenia fusiformis		*Spio filicornis*
	Pagurus spp.		*Spiochaetopterus costarum*
	Petalonia fascia		*Tellina modesta*
	Polysiphonia sp.		*Tellina nuculoides*
	Porphyra sp.		Ulvoids
	Saxidomus giganteus juv.		*Zostera marina*

Appendix E. Summary of Organisms Found at Maury Mine

Organisms found in 0.25 m^2 quadrats and 10 cm x 15 cm deep cores (sieved with 2 mm mesh). 10 random samples collected along a 50 meter transect.

Maury Mine N (0 ft MLLW)	Maury Mine M (0 ft MLLW)	Maury Mine S (0 ft MLLW)
Dead barnacles (Class Cirripedia)	*Dendraster* juv.	*Dendraster* juv.
Nereis procera	*Hemipodus borealis*	*Hemipodus borealis*
Ulvoids	Ulvoids	*Nuttallia obscurata* juv.
		Pseudopolydora kempi japonica
		Sabellid
		Spiochaetopterus costarum
		Tellina modesta
		Ulvoids

Appendix F. Detailed List of Organisms Found at South Sound Beaches

Organisms and their average abundances (counts for mobile organisms, percent cover for sessile organisms) in 0.25 m^2 quadrats and 10 cm x 15 cm deep cores (sieved with 2 mm mesh). 10 random samples collected along a 50 meter transect.

Site	Oro	Oro	Oro	Taylor	Taylor	Taylor	Taylor	Treble	Treble	Treble	Treble
Beach	Mid	North	South	North	North	South	South	North	North	South	South
Elevation (ft MLLW)	0	0	0	0	-2	0	-2	0	-2	0	-2
Taxa Name											
Acrosiphonia spp.	0.7	0	0.1	0	0.5	1.4	6.4	0	0	1.7	0.1
Alia spp.	2.5	0	0	0	0	0	0	0	0	0.6	15.2
Ampharete labrops	0.1	0	0	0	0	0	0	0	0	0	0
Anisogammarus pugettensis	0	0	0	0	0	0	0	0	0.1	0	0
Anthopleura spp.	0	0.5	0	0	0	0	0	0	0	0.9	0.6
Aphelochaeta multifilis	0.1	0	0	0	0	0	0	0	0	0	0
Armandia brevis	0	0	0	0	0	0	0.2	0	0	0	0
Asabellides sibirica	0	0	0	0	0	0.5	3.4	0	0.3	0	0.3
Axiothella rubrocincta	0	0	0.1	0	0	0.1	0.1	0	0	0	0.2
Bryozoa	0	0	0	0	0	0	1.3	0	0	0	0
Cancer sp.	0	0	0	0	0.1	0	0.1	0	0	0	0
Capitella capitata	0.2	0	0.1	0	0	0	0	0	0	0	0
Caulleriella ?pacifica	0	0	0.1	0	0	0	0	0	0	0	0
Cirratulus multioculatus	0	0	0.1	0	0	0	0	0	0	0.2	0
Clinocardium nuttallii juveniles	0	0	0	0	0	0	0	0	0	0.1	0.2
Crepidula dorsata	0	0	0.8	0	0	0	0	0	0	0	0
Cryptosiphonia woodii	0	0	0	0	0	0	0.2	0	0	0.2	0.9
Dead barnacles (Class Cirripedia)	3.8	0	3.4	1	1	3.4	1.4	0	0	1	1.1
Dendraster excentricus	0	0	0	0	0	0	0	0	0	1	0.1
Dendraster juv.	0	0	0	0	0	0.1	0.3	1.1	0.4	0.8	1.2
Diatoms, chain-forming	7.8	23	33	0	4	1.5	16.5	0.8	0	11.5	6
Edwardsia sipunculoides	0.5	1.3	0	0	0	0	0	1.6	2	0.5	1.5
Euclymene spp.	0	0	0.1	0	0	0	0	0	0.1	1.2	0.5
Eulalia sanguinea	0	0	0	0	0	0	0.1	0	0	0	0

Appendix F (continued). Detailed List of Organisms Found at South Sound Beaches.

Site	Oro	Oro	Oro	Taylor	Taylor	Taylor	Taylor	Treble	Treble	Treble	Treble
Beach	Mid	North	South	North	North	South	South	North	North	South	South
Elevation (ft MLLW)	0	0	0	0	-2	0	-2	0	-2	0	-2
Eupentacta quinquesemita	0	0	0	0	0	0	0	0	0	0.1	0
Evasterias troschelii	0	0	0	0	0	0	0	0	0	0.1	0
Fabia subquadrata	0	0	0	0	0	0	0	0	0.1	0	0
Flatworm	0	0	0.1	0	0	0.8	0.1	0	0	0.3	0
Fleshy crust	1.3	0	1.2	0	0.1	4.8	2.6	0	0	4.6	0.8
Gammarid amphipods	0	0.1	0	0	0.7	0.1	0	0	0	0.1	0.1
Gelidium spp.	0	0	0	0	0	0	0.4	0	0	0.9	0.2
Glycera americana	0.2	0.1	0	0	0	0.1	0	0	0	0	0
Glycinde picta	0.3	0.4	0	0	0	0	0	0	0.1	0.2	0
Gnorimosphaeroma oregonense	0	0	0	0	0	0.4	0	0	0	0	0
Gracilaria pacifica	0	0	0	0	0	0	0	0	0	0.2	0.5
Haminoea vesicula	0.1	0.7	0	0	0	0	0	0	0	0	0
Harmothoe imbricata	0	0.1	0	0	0	0.1	0.2	0	0	0	0
Hemigrapsus oregonensis	1.1	0	0.4	0	0	5.3	0.2	0	0	0.4	0
Hemipodus borealis	0.2	0	0.2	0.1	0.7	4.5	2.7	0	0	1.7	0.7
Hermissenda crassicornis	0	0	0	0	0	0.5	0.5	0	0	0	0
Idotea sp.	0	0	0	0	0	0.2	0	0	0	0	0
Lacuna spp.	0	0	0	0	0	0	0	0.1	0	1	0
Laminaria saccharina	0	0	0	0	0	0	0.2	0	0	0	0
Leptochelia dubia	0	0.2	0.2	0	0	0	0	0	0	0	0
Leptosynapta clarki	0	0	0	0	0	0.1	0	0.4	0	1	0.6
Littorina sp.	0	0	0	0	0	105.5	0	0	0	0	0
Live barnacles (Class Cirripedia)	2.6	0	1.4	0.9	1.4	67.5	57.5	0	0	1	0.4
Lophopanopeus bellus bellus	0.5	0	0	0	0	0	0	0	0	0	0
Lottid limpets	16.9	0	2.9	0	0	62.5	3.3	0	0	10	0.8
Lucina tenuisculpta	0.1	0.1	0	0	0	0	0	0	0	0	0
Lyonsia californica	0	0	0	0	0	0	0.1	0	0	0	0
Macoma inquinata	0.4	0	0	0	0	0	0	0	0	0	0

Appendix F (continued). Detailed List of Organisms Found at South Sound Beaches.

Site	Oro	Oro	Oro	Taylor	Taylor	Taylor	Taylor	Treble	Treble	Treble	Treble
Beach	Mid	North	South	North	North	South	South	North	North	South	South
Elevation (ft MLLW)	0	0	0	0	-2	0	-2	0	-2	0	-2
Macoma inquinata juveniles	1.3	0	0.1	0	0	0	0.3	0	0.2	0	0
Macoma nasuta	0	0.4	0.2	0	0	0	0	0	0	0	0
Macoma nasuta juv.	0.3	0.8	0	0	0	0	0	0.1	0.1	0	0
Majid (spider) crab	0	0	0	0	0	0	0	0	0	0.1	0.1
Malmgreniella nigralba	0	0	0	0	0	0	0	0	0	0.4	0.4
Mastocarpus jardinii	0	0	0.1	0	0	0	0	0	0	0	0
Mastocarpus papillatus	0.4	0	0.8	0	0	7.2	3.8	0	0	0.8	0.6
Mazzaella splendens	0	0	0	0	0	0	0	0	0	0	0.1
Mediomastus californiensis	0.2	0.2	0.3	0	0	0	0	0	0	0	0.1
Megamoera subtener	0	0	0.1	0	0	0	0	0	0	0	0
Metridium sp.	0	0	0	0	0	0.1	0.1	0	0	0.6	0.6
Monocorophium spp.	0	0	0	0	0	0	0	0.1	0	0	0
Mopalia lignosa	0.2	0	0.3	0	0	0	0.7	0	0	0.4	0.7
Rochefortia tumida	0.1	0	0.2	0	0	0	0	0	0	0.2	0
Mytilus trossulus	0	0	0	0	0	1	0	0	0	0	0
Nassarius sp.	0.2	0.2	0	0	0	0	0	0	0	0	1.8
Nemertean	0.5	0.2	0.6	0	0	0.1	0.1	0.1	0	0.4	0.5
Nephtys caecoides	0	0.4	0	0	0	0	0	0.1	0	0	0
Nereis procera	0.3	0	0.1	0	0	0	0	0	0	0	0.1
Nicolea zostericola (?)	0.1	0.2	0	0	0	0	0	0	0	0	0
Notomastus lineatus	0	0	0	0	0.1	0.1	0	0	0	0	0.1
Notomastus tenuis	3.9	0.8	7	0	0.1	12.8	4.8	0	0.1	4.6	0.9
Nucella lamellosa	0	0	0	0	0	1.6	1.7	0	0	0	0
Odostomia sp.	0.7	0	0	0	0	0	0	0	0	0	0
Onchidoris bilamellata	0	0	0	0	0	0.8	0.6	0	0	0	0.1
Owenia fusiformis	0	0	0	0	0	0.2	0.2	0	0	0.4	0
Pagurus spp.	2.1	0.1	0.1	0	0.1	102.5	7.9	0	0.1	7.8	14.2
Petalonia fascia	0	0	0	0	0	0	0.3	0	0	0	0

Appendix F (continued). Detailed List of Organisms Found at South Sound Beaches.

Site	Oro	Oro	Oro	Taylor	Taylor	Taylor	Taylor	Treble	Treble	Treble	Treble
Beach	**Mid**	**North**	**South**	**North**	**North**	**South**	**South**	**North**	**North**	**South**	**South**
Elevation (ft MLLW)	**0**	**0**	**0**	**0**	**-2**	**0**	**-2**	**0**	**-2**	**0**	**-2**
Photis spp.	0.1	0	0	0	0	0	0	0	0	0	0
Pinnixia schmitti/occidentalis	0.1	0	0	0	0	0	0.1	0	0	0	0
Pisaster ochraceus	0	0	0	0	0	0	0.2	0	0	0.1	0
Platynereis bicanaliculata	0	0.2	0.1	0	0	0	0	0	0	0	0
Podarke pugettensis	0.3	0.1	1	0	0	0	0	0	0	0	0
Pododesmus cepio	0	0	0	0	0	0	0.2	0	0	0.1	0
Polycirrus n. sp. (L. Harris)	0	0	0	0	0	0.2	0	0	0	0	0
Polydora cardalia	0.1	0.1	0	0	0	0	0	0.2	0.4	0	0.1
Polydora proboscidea	0	0	0	0	0	0	0	0	0.1	0	0
Polydora socialis	0	0	0	0	0	0	0	0	0	0.2	0
Polynoid	0.5	0	0.1	0	0	0	0.7	0	0	0.2	0.2
Polysiphonia sp.	0.2	0	0	0	0	0.1	3.9	0	0	0.6	3.4
Porphyra sp.	0	0	0.1	0	0	0.3	1.7	0	0	1.7	3.8
Prionitis sp.	0	0	0	0	0	0	0.6	0	0	0	0
Leukoma staminea	0	0	0.1	0	0	0	0	0	0	0	0
Leukoma staminea juv.	0	0	0.3	0	0	0	0	0	0	0	0
Pseudopolydora kempi japonica	0	0.1	0	0	0	0	0	0	0	0	0
Pycnopodia helianthoides	0	0	0	0	0	0	0.1	0	0	0	0
Sabellid	0	0	0.3	0	0	0	0	0	0	0.3	0
Sand percentage	34	97.8	13.1	4.2	8	9	18.5	99	99	26.5	73
Sarcodiotheca sp.	0	0	0	0	0	0	0.2	0	0	0	0.1
Sargassum muticum	0	0	0	0	0	0	0	0	0	0	0.5
Saxidomus giganteus juv.	0.4	0	0.1	0	0	0.1	0.1	0	0	0	0
Scytosiphon simplicissimus	0	0	0.1	0	0	0	0.4	0	0	0.1	0
Sphaeromid isopods	0	0	0	0	0	14.5	0	0	0	0	0
Spio filicornis	0.1	0	0	0	0	0	0.3	0	0	0	0
Spiochaetopterus costarum	0	0.2	0.7	0	0	0	0.7	0.5	0	1.5	3.7
Spiophanes bombyx	0	0.1	0	0	0	0	0	0	0	0	0

Appendix F (continued). Detailed List of Organisms Found at South Sound Beaches.

Site	Oro	Oro	Oro	Taylor	Taylor	Taylor	Taylor	Treble	Treble	Treble	Treble
Beach	Mid	North	South	North	North	South	South	North	North	South	South
Elevation (ft MLLW)	0	0	0	0	-2	0	-2	0	-2	0	-2
Stichaeidae (gunnels and pricklebacks)	0	0	0	0	0	0	0.5	0	0	0	0
Tellina modesta	0	0.1	0	0	0	0	0	0.4	0.7	0	0.4
Tharyx parvus	0	0	0	0	0	0.1	0	0	0	0.9	0.2
Tresus capax	0	0	0	0	0	0.2	0.1	0	0	0.1	0.2
Tresus capax juveniles	0	0	0	0	0	0	0.1	0	0	0	0
Ulvoids	76.4	44.7	69.5	3	10.6	68.1	74.4	14	4.8	89	81

Appendix G. Detailed List of Organisms Found at Central Sound Beaches

Organisms and their average abundances (counts for mobile organisms, percent cover for sessile organisms) in 0.25 m^2 quadrats and 10 cm x 15 cm deep cores (sieved with 2 mm mesh). 10 random samples collected along a 50 meter transect.

Site	**Maury Mine**	**Maury Mine**	**Maury Mine**	**Piner**	**Piner**	**Piner**
Beach	**Mid**	**North**	**South**	**Mid**	**North**	**South**
Elevation (ft MLLW)	**0**	**0**	**0**	**0**	**0**	**0**
Taxa Name						
Acrosiphonia spp.	0	0	0	0.3	0	4.5
Alia spp.	0	0	0	0	0	0.2
Anthopleura spp.	0	0	0	0.1	0.1	0
Armandia brevis	0	0	0	0	0	0.1
Axiothella rubrocincta	0	0	0	0.2	0	0
Calliopius spp.	0	0	0	0.2	0	0.1
Chaetozone acuta	0	0	0	0	0	0.1
Clinocardium nuttallii	0	0	0	0	0	0.1
Dead barnacles (Class Cirripedia)	0	0.2	0	2.5	0.2	0.4
Dendraster juv.	0.2	0	0.6	0.2	0	6.5
Diatoms, chain-forming	0	0	0	0.9	0	2.3
Eogammarus oclairi	0	0	0	0	0.1	0
Family Hippolytidae	0	0	0	0	0	0.05
Fleshy crust	0	0	0	0.6	0.1	0.2
Gammarid amphipods	0	0	0	0.2	1	0.5
Hemipodus borealis	0.1	0	0.1	1.8	0.4	0.3
Lacuna spp.	0	0	0	0.2	0.3	0.4
Live barnacles (Class Cirripedia)	0	0	0	4.1	1	2.2
Lottid limpets	0	0	0	2	0	0.6
Lucina tenuisculpta	0	0	0	0.2	0	0
Metridium sp.	0	0	0	0.1	0	0
Mopalia lignosa	0	0	0	0.2	0	0
Mytilus trossulus	0	0	0	0.2	0	0.3

Appendix G (continued). Detailed List of Organisms Found at Central Sound Beaches

Site	Maury Mine	Maury Mine	Maury Mine	Piner	Piner	Piner
Beach	**Mid**	**North**	**South**	**Mid**	**North**	**South**
Elevation (ft MLLW)	**0**	**0**	**0**	**0**	**0**	**0**
Nemertean	0	0	0.2	0.1	0.1	0
Nephtys caecoides	0	0	0	0.1	0	0
Nereis procera	0	0.1	0	0	0	0
Notomastus lineatus	0	0	0	0.2	0	0
Notomastus tenuis	0.1	0	0	1.1	0.2	0.1
Nuttallia obscurata juvenile	0	0	0.4	0	0	0
Owenia fusiformis	0	0	0	0.1	0	0
Pagurus spp.	0	0	0	0.2	0	0.8
Petalonia fascia	0	0	0	0.1	0	0.1
Polysiphonia sp.	0	0	0	0.1	0	0
Porphyra sp.	0	0	0	0.1	0	3
Pseudopolydora kempi japonica	0	0	0.1	0	0	0
Sabellid	0	0	0.1	0	0	0
Saxidomus giganteus juv.	0	0	0	0.2	0	0
Sphaeromid isopods	0	0	0	0.3	0.5	0
Spio filicornis	0	0	0	0.1	0	0.1
Spiochaetopterus costarum	0	0	2	0.3	0	4.7
Tellina modesta	0	0	0.3	0	0	1.1
Tellina nuculoides	0	0	0	0	0	0.2
Tharyx parvus	0	0	0	0.1	0	0
Tresus capax juveniles	0	0	0	0.1	0	0
Ulvoids	1.4	1.3	4.1	32.5	11.5	22.7
Zostera marina	0	0	0	0	0	1.6

Appendix H. Large Clams Found at South Sound and Central Sound Beaches

Mean density (and standard deviation) per box core at various tidal heights (ft, MLLW). Mean calculated based on 4 0.1 m^3 random samples collected along a 50 meter transect and sieved with 1 cm mesh. Sites where no clams were found are not included in the table (PinerN, PinerM, PinerS and TaylorN.)

Site	Beach	Tidal Height (ft MLLW)	*Clinocardium nuttallii*	*Leukoma staminea*	*Macoma bathica*	*Macoma inquinata*	*Macoma nasuta*	*Macoma secta*	*Nuttallia obscurata*	*Saxidomus gigantea*	*Tellina modesta*	*Tellina nuculoides*	*Tresus capax*
Maury Mine	M	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	M	1.5	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	N	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.25 (0.5)	0 (0)	0 (0)	0 (0)	0 (0)
	N	1.5	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	S	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.25 (0.5)	0 (0)	0 (0)	0 (0)
	S	1.5	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.75 (1.5)	0 (0)	0 (0)	0 (0)	0 (0)
Oro	M	0	0 (0)	0 (0)	0 (0)	5 (1.83)	0.75 (1.5)	0 (0)	0 (0)	0.5 (0.58)	0 (0)	0 (0)	0 (0)
	M	1.5	0 (0)	1 (1.41)	0 (0)	5.75 (1.26)	0 (0)	0 (0)	0 (0)	0.5 (0.58)	0 (0)	0 (0)	0 (0)
	N	0	0 (0)	0 (0)	0 (0)	1.5 (3)	8.25 (6.8)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	N	1.5	0.25 (0.5)	0.5 (0.58)	0 (0)	3.5 (4.12)	11 (8.37)	0 (0)	0 (0)	0.75 (0.96)	0 (0)	0 (0)	0.25 (0.5)
	N	3	0 (0)	0.25 (0.5)	0 (0)	4 (4.55)	4.5 (2.89)	0 (0)	0 (0)	0.25 (0.5)	0 (0)	0 (0)	0 (0)
	S	0	0 (0)	2.25 (1.71)	0 (0)	9.75 (6.02)	0.25 (0.5)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	S	1.5	0 (0)	4 (0.82)	0 (0)	6.25 (5.12)	0 (0)	0 (0)	0 (0)	1 (1.41)	0 (0)	0 (0)	0 (0)
Taylor	S	-2	0 (0)	0.75 (0.96)	0 (0)	0.5 (1)	0 (0)	0 (0)	0 (0)	0.25 (0.5)	0 (0)	0 (0)	0 (0)
	S	0	0 (0)	0.5 (0.58)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.5 (0.58)	0 (0)	0 (0)	0 (0)
	S	1.5	0 (0)	0.25 (0.5)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1.5 (0.58)	0 (0)	0 (0)	0 (0)
Treble	N	-3.3	0 (0)	0 (0)	0 (0)	0 (0)	0.5 (1)	0.25 (0.5)	0 (0)	0 (0)	0.75 (1.5)	0 (0)	0 (0)
	N	-2	0 (0)	0 (0)	0 (0)	0 (0)	1.25 (1.5)	0.5 (1)	0 (0)	0 (0)	2.5 (5)	0 (0)	0.25 (0.5)
	N	0	0 (0)	0 (0)	0 (0)	0.5 (0.58)	1.25 (0.96)	0.75 (0.5)	0 (0)	0 (0)	1.25 (1.26)	0 (0)	0 (0)
	N	1.5	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	N	3	0 (0)	0 (0)	0.25 (0.5)	0 (0)	0.25 (0.5)	3 (2.45)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	S	-3.3	0.25 (0.5)	0 (0)	0 (0)	0 (0)	0.5 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	S	-2	0.75 (0.5)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.25 (0.5)	0.25 (0.5)	0.5 (1)
	S	0	0.25 (0.5)	0.5 (0.58)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Appendix I. Summary of Organisms Retained At Taylor Beaches On 1 mm and 2 mm Sieve Mesh Sizes

Species listed in bold were retained only on 1 mm sieve within the transect.

TaylorN -2 ft MLLW	TaylorN 0 ft MLLW	TaylorS -2 ft MLLW	TaylorS 0 ft MLLW
Notomastus lineatus	*Hemipodus borealis*	*Armandia brevis*	***Allorchestes angusta***
Notomastus tenuis	***Tharyx parvus***	*Asabellides sibirica*	*Asabellides sibirica*
Hemipodus borealis		*Axiothella rubrocincta*	*Axiothella rubrocincta*
		Dendraster juv.	***Calliopius spp.***
		Eulalia sanguinea	*Dendraster* juv.
		Harmothoe imbricata	*Glycera americana*
		Hemipodus borealis	*Gnorimosphaeroma oregonense*
		Lyonsia californica	*Harmothoe imbricata*
		Macoma inquinata juveniles	*Hemipodus borealis*
		Rochefortia tumida	*Leptosynapta clarki*
		Nemertean	***Rochefortia tumida***
		Notomastus tenuis	Nemertean
		Owenia fusiformis	*Notomastus lineatus*
		Pinnixia schmitti/occidentalis	*Notomastus tenuis*
		Podarkeopsis glabrus	*Owenia fusiformis*
		Saxidomus giganteus juv.	*Polycirrus* n. sp. (L. Harris)
		Spio filicornis	*Saxidomus giganteus* juv.
		Tresus capax juveniles	*Tharyx parvus*

Appendix J. Summary of Organisms Retained At Treble Beaches On 1 mm and 2 mm Sieve Mesh Sizes

Species listed in bold were retained only on 1 mm sieve.

TrebleN -2 ft MLLW	TrebleN 0 ft MLLW	TrebleS -2 ft MLLW	TrebleS 0 ft MLLW
Anisogammarus pugettensis	***Ampelisca agassizi***	*Asabellides sibirica*	***Armandia brevis***
Asabellides sibirica	*Dendraster* juv.	*Axiothella rubrocincta*	*Cirratulus multioculatus*
Barantolla americana	*Edwardsia sipunculoides*	*Clinocardium nuttallii* juveniles	*Clinocardium nuttallii* juveniles
Dendraster juv.	*Leito/Scoloplos*	*Dendraster* juv.	*Dendraster* juv.
Edwardsia sipunculoides	*Leptosynapta clarki*	*Edwardsia sipunculoides*	*Edwardsia sipunculoides*
Euclymene spp.	*Macoma nasuta* juv.	*Euclymene spp.*	*Euclymene* spp.
Fabia subquadrata	***Magelona hobsonae***	*Hemipodus borealis*	*Glycinde picta*
Glycinde picta	***Malacoceros glutaeus***	*Leito/Scoloplos*	*Hemipodus borealis*
Leito/Scoloplos	***Malmgreniella nigralba***	*Leptosynapta clarki*	*Leito/Scoloplos*
Macoma inquinata juveniles	*Monocorophium* spp.	*Malmgreniella nigralba*	*Leptosynapta clarki*
Macoma nasuta juv.	***Rochefortia tumida***	*Mediomastus californiensis*	*Malmgreniella nigralba*
Magelona hobsonae	Nemertean	***Rochefortia tumida***	*Rochefortia tumida*
Rochefortia tumida	*Nephtys caecoides*	Nemertean	Nemertean
Notomastus tenuis	*Polydora cardalia*	*Nereis procera*	*Notomastus tenuis*
***Photis* spp.**	*Tellina modesta*	*Notomastus lineatus*	*Owenia fusiformis*
Polydora cardalia		*Notomastus tenuis*	***Polycirrus* n. sp. (L. Harris)**
Polydora proboscidea		***Podarke pugettensis***	*Polydora socialis*
Protomedeia articulata		*Polydora cardalia*	***Samytha californica***
Rhepoxynius pallidus		*Tellina modesta*	*Tharyx parvus*
Tellina modesta		***Tellina nuculoides***	
Transennella tantilla		*Tharyx parvus*	
		Transennella tantilla	

Appendix K. Detailed List of Organisms Retained at Treble and Taylor Sites with 1 mm and 2 mm Sieve Mesh Sizes

Organisms and their average abundances (counts for mobile organisms, percent cover for sessile organisms) in 0.25 m^2 quadrats and 10 cm x 15 cm deep cores. 10 random samples collected along a 50 meter transect.

	Site	**TaylorN**		**TaylorN**		**TaylorS**		**TaylorS**		**TrebleN**		**TrebleN**		**TrebleS**		**TrebleS**		**Summary**			
	Elevation (ft MLLW)	**-2**		**0**		**-2**		**0**		**-2**		**0**		**-2**		**0**		**#individuals**			
	Sieve mesh (mm)	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**All**	**1 mm**	**2 mm**	**Sieve Mesh Size**
Group	**Species**																				
amphipod	*Allorchestes angusta*							1										**1**	**1**	**0**	1 mm only
amphipod	*Ampelisca agassizi*											1						**1**	**1**	**0**	1 mm only
amphipod	*Anisogammarus pugettensis*									2	1							**3**	**2**	**1**	Both
amphipod	*Calliopius* spp.							1										**1**	**1**	**0**	1 mm only
amphipod	*Monocorophium spp.*												1					**1**	**0**	**1**	2 mm only
amphipod	*Photis spp.*									1								**1**	**1**	**0**	1 mm only
amphipod	*Protomedeia articulata*									1								**1**	**1**	**0**	1 mm only
amphipod	*Rhepoxynius pallidus*									1								**1**	**1**	**0**	1 mm only
anemone	*Edwardsia sipunculoides*									8	20	2	16	1	15	1	5	**68**	**12**	**56**	Both
bivalve	*Clinocardium nuttallii juveniles*													1	2		1	**4**	**1**	**3**	Both
bivalve	*Lyonsia californica*						1											**1**	**0**	**1**	2 mm only
bivalve	*Macoma inquinata juveniles*					7	3				2							**12**	**7**	**5**	Both
bivalve	*Macoma nasuta juv.*									1	1		1					**3**	**1**	**2**	Both
bivalve	*Rochefortia tumida*					35		2		16		3		54		43	2	**155**	**153**	**2**	Both
bivalve	*Saxidomus giganteus juv.*						1		1									**2**	**0**	**2**	2 mm only
bivalve	*Tellina modesta*										7		4		4			**15**	**0**	**15**	2 mm only
bivalve	*Tellina nuculoides*													1				**1**	**1**	**0**	1 mm only
bivalve	*Transennella tantilla*									3				4				**7**	**7**	**0**	1 mm only
bivalve	*Tresus capax juveniles*						1											**1**	**0**	**1**	2 mm only
crab	*Fabia subquadrata*										1							**1**	**0**	**1**	2 mm only

Appendix L (continued). Taxonomic Information About Intertidal Organisms Collected During 2011

	Site	TaylorN		TaylorN		TaylorS		TaylorS		TrebleN		TrebleN		TrebleS		TrebleS		Summary			
	Elevation (ft MLLW)	-2		0		-2		0		-2		0		-2		0		#individuals			
	Sieve mesh (mm)	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	All	1 mm	2 mm	Sieve Mesh Size
Group	**Species**																				
crab	*Pinnixia schmitti/occidentalis*						1											**1**	**0**	**1**	2 mm only
isopod	*Gnorimosphaeroma oregonense*								4									**4**	**0**	**4**	2 mm only
nemertean worm	*Nemertean*						1		1				1		5		4	**12**	**0**	**12**	2 mm only
polychaete worm	*Armandia brevis*					1	2									1		**4**	**2**	**2**	Both
polychaete worm	*Asabellides sibirica*					1	34		5		3			1	3			**47**	**2**	**45**	Both
polychaete worm	*Axiothella rubrocincta*						1		1						2			**4**	**0**	**4**	2 mm only
polychaete worm	*Barantolla americana*									3								**3**	**3**	**0**	1 mm only
polychaete worm	*Cirratulus multioculatus*																2	**2**	**0**	**2**	2 mm only
polychaete worm	*Euclymene spp.*										1				5		12	**18**	**0**	**18**	2 mm only
polychaete worm	*Eulalia sanguinea*						1											**1**	**0**	**1**	2 mm only
polychaete worm	*Glycera americana*								1									**1**	**0**	**1**	2 mm only
polychaete worm	*Glycinde picta*									5	1						2	**8**	**5**	**3**	Both
polychaete worm	*Harmothoe imbricata*					1	2		1									**4**	**1**	**3**	Both
polychaete worm	*Hemipodus borealis*		7		1	6	27	14	45					11	7	2	17	**137**	**33**	**104**	Both
polychaete worm	*Leito/Scoloplos*									20	8	17	9	4	4		1	**63**	**41**	**22**	Both
polychaete worm	*Magelona hobsonae*									2		1						**3**	**3**	**0**	1 mm only
polychaete worm	*Malacoceros glutaeus*											2						**2**	**2**	**0**	1 mm only
polychaete worm	*Malmgreniella nigralba*											1			4		4	**9**	**1**	**8**	Both
polychaete worm	*Mediomastus californiensis*														1			**1**	**0**	**1**	2 mm only

Appendix K (continued). Detailed List of Organisms Retained at Treble and Taylor Sites with 1 mm and 2 mm Sieves

	Site	TaylorN		TaylorN		TaylorS		TaylorS		Treble N		TrebleN		TrebleS		TrebleS		Summary			
	Elevation (ft MLLW)	-2		0		-2		0		-2		0		-2		0		#individuals			
	Sieve mesh (mm)	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	All	1 mm	2 mm	Sieve Mesh Size
Group	**Species**																				
polychaete worm	*Nephtys caecoides*												1					**1**	**0**	**1**	2 mm only
polychaete worm	*Nereis procera*														1			**1**	**0**	**1**	2 mm only
polychaete worm	*Notomastus lineatus*		1						1						1			**3**	**0**	**3**	2 mm only
polychaete worm	*Notomastus tenuis*		1				48	2	128		1			1	9		46	**236**	**3**	**233**	Both
polychaete worm	*Owenia fusiformis*						2		2								4	**8**	**0**	**8**	2 mm only
polychaete worm	*Podarke pugettensis*													2				**2**	**2**	**0**	1 mm only
polychaete worm	*Podarkeopsis glabrus*					1												**1**	**1**	**0**	1 mm only
polychaete worm	*Polycirrus* n. sp. (L. Harris)								2							1		**3**	**1**	**2**	Both
polychaete worm	*Polydora cardalia*										4	1	2		1			**8**	**1**	**7**	Both
polychaete worm	*Polydora proboscidea*										1							**1**	**0**	**1**	2 mm only
polychaete worm	*Polydora socialis*																2	**2**	**0**	**2**	2 mm only
polychaete worm	*Samytha californica*															1		**1**	**1**	**0**	1 mm only
polychaete worm	*Spio filicornis*						3											**3**	**0**	**3**	2 mm only
polychaete worm	*Tharyx parvus*			1					1						2		9	**13**	**1**	**12**	Both
sand dollar	*Dendraster* juv.						3		1	1	4		11		12		8	**40**	**1**	**39**	Both
sea cucumber	*Leptosynapta clarki*								1				4		6		10	**21**	**0**	**21**	2 mm only
	TOTAL INDIVIDUALS		**9**	**1**	**1**	**52**	**131**	**20**	**195**	**64**	**55**	**28**	**50**	**80**	**84**	**49**	**129**	**948**	**294**	**654**	
	TOTAL SPECIES		**3**	**1**	**1**	**7**	**16**	**5**	**15**	**13**	**14**	**8**	**10**	**10**	**18**	**6**	**16**				

Appendix L. Taxonomic Information About Intertidal Organisms Collected During 2011

Taxa	General Type	Taxonomic Information	Trophic Group	Measure	Sample Type
Acrosiphonia spp.	green alga	Phylum: Chlorophyta; Class: Ulvophyceae; Family: Acrosiphoniaceae	Prim	percent	quad
Alia spp.	gastropod	Phylum: Mollusca; Class: Gastropoda; Family: Columbellidae	Carn	count	quad
Allorchestes angusta	amphipod	Phylum: Arthropoda; Class: Malacostraca; Family: Hyalidae	Scav	count	core
Ampelisca agassizi	amphipod	Phylum: Arthropoda; Class: Malacostraca; Family: Ampeliscidae	Scav	count	core
Ampharete labrops	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Ampharetidae	Dep	count	core
Anisogammarus pugettensis	amphipod	Phylum: Arthropoda; Class: Malacostraca; Family: Anisogammaridae	Scav	count	core
Anthopleura artemisia	anemone	Phylum: Cnidaria; Class: Anthozoa; Family: Actiniidae	Carn	percent	quad
Anthopleura elegantissima	anemone	Phylum: Cnidaria; Class: Anthozoa; Family: Actiniidae	Carn	percent	quad
Aphelochaeta multifilis	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Cirratulidae	Dep	count	core
Armandia brevis	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Opheliidae	Dep	count	core
Asabellides sibirica	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Ampharetidae	Dep	count	core
Axiothella rubrocincta	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Maldanidae	Dep	count	core
Barantolla americana	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Capitellidae	Dep	count	core
Bryozoa (miscellaneous)	bryozoan	Phylum: Bryozoa; Class: ; Family:	Susp.	percent	quad
Calliopius spp.	amphipod	Phylum: Arthropoda; Class: Malacostraca; Family: Calliopiidae	Scav	count	core
Cancer productus	crab	Phylum: Arthropoda; Class: Malacostraca; Family: Cancridea	Carn	count	quad
Cancer sp.	crab	Phylum: Arthropoda; Class: Malacostraca; Family: Cancridea	Carn	count	quad
Capitella capitata	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Capitellidae	Dep	count	core
Caulleriella ?pacifica	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Cirratulidae	Dep	count	core

Appendix L (continued). Taxonomic Information About Intertidal Organisms Collected During 2011

Taxa	General Type	Taxonomic Information	Trophic Group	Measure	Sample Type
Chaetozone acuta	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Cirratulidae	Dep	count	core
Cirratulus multioculatus	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Cirratulidae	Dep	count	core
Clinocardium nuttallii	bivalve	Phylum: Mollusca; Class: Bivalvia; Family: Cardiidae	Susp	count	core
Clinocardium nuttallii juveniles	bivalve	Phylum: Mollusca; Class: Bivalvia; Family: Cardiidae	Susp	count	core
Crepidula dorsata	gastropod	Phylum: Mollusca; Class: Gastropoda; Family: Calyptraeidae	Susp	count	quad
Cryptosiphonia woodii	red alga	Phylum: Rhodophyta; Class: Rhodophyceae; Family: Dumontiaceae	Prim	percent	quad
Dead barnacles (Class Cirripedia)	barnacle	Phylum: Arthropoda; Class: Cirripedia; Family:	Susp	percent	quad
Dendraster excentricus	sand dollar	Phylum: Echinodermata; Class: Echinoidea; Family: Dendrasteridae	Susp	count	quad
Dendraster juv.	sand dollar	Phylum: Echinodermata; Class: Echinoidea; Family: Dendrasteridae	Susp	count	core
Diatoms, chain-forming	diatom	Phylum: Bacillariophyta; Class: Bacillariophyta; Family:	Prim	percent	quad
Edwardsia sipunculoides	anemone	Phylum: Cnidaria; Class: Anthozoa; Family: Edwardsiidae	Susp	count	core
Eogammarus oclairi	amphipod	Phylum: Arthropoda; Class: Malacostraca; Family: Anisogammaridae	Scav	count	core
Euclymene spp.	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Maldanidae	Dep	count	core
Eulalia sanguinea	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Phyllodocidae	Carn	count	core
Eupentacta quinquesemita	sea cucumber	Phylum: Echinodermata; Class: Holothuroidea; Family: Sclerodactylidae	susp	count	quad
Evasterias troschelii	seastar	Phylum: Echinodermata; Class: Asteroidea; Family: Asteriidae	Carn	count	quad
Fabia subquadrata	crab	Phylum: Arthropoda; Class: Malacostraca; Family: Pinnotheridae	Comm	count	core

Appendix L (continued). Taxonomic Information About Intertidal Organisms Collected During 2011

Taxa	General Type	Taxonomic Information	Trophic Group	Measure	Sample Type
Family Hippolytidae	shrimp	Phylum: Arthropoda; Class: Malacostraca; Family: Hippolytidae	Scav	count	quad
Flatworm	flatworm	Phylum: Platyhelminthes; Class: ; Family:	Carn	count	quad
Fleshy crust	alga	Phylum: ; Class: ; Family:	Prim	percent	quad
Gammarid amphipods	amphipod	Phylum: Arthropoda; Class: Malacostraca; Family:	Scav	count	quad
Gelidium spp.	red alga	Phylum: Rhodophyta; Class: Rhodophyceae; Family:	Prim	percent	quad
Glycera americana	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Glyceridae	Carn	count	core
Glycinde picta	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Goniadidae	Carn	count	core
Gnorimosphaeroma oregonense	isopod	Phylum: Arthropoda; Class: Malacostraca; Family: Sphaeromatidae	Scav	count	core
Gracilaria pacifica	red alga	Phylum: Rhodophyta; Class: Rhodophyceae; Family: Gracilariaceae	Prim	percent	quad
Haminoea vesicula	gastropod	Phylum: Mollusca; Class: Gastropoda; Family: Atyidae	Herb	count	quad
Harmothoe imbricata	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Polynoidae	Carn	count	core
Hemigrapsus oregonensis	crab	Phylum: Arthropoda; Class: Malacostraca; Family: Grapsidae	Scav	count	quad
Hemipodus borealis	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Glyceridae	Carn	count	core
Hermissenda crassicornis	gastropod	Phylum: Mollusca; Class: Gastropoda; Family: Facelinidae	Carn	count	quad
Idotea sp.	isopod	Phylum: Arthropoda; Class: Malacostraca; Family: Idoteidae	Herb	count	quad
Lacuna spp.	gastropod	Phylum: Mollusca; Class: Gastropoda; Family: Lacunidae	Herb	count	quad
Laminaria saccharina	brown alga	Phylum: Phaeophyta; Class: Phaeophyceae; Family: Laminariaceae	Prim	percent	quad
Leito/Scoloplos	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Orbiniidae	Dep	count	core
Leptochelia dubia	tanaid (crustacean)	Phylum: Arthropoda; Class: Malacostraca; Family: Tanaidacea	Scav	count	core

Appendix L (continued). Taxonomic Information About Intertidal Organisms Collected During 2011

Taxa	General Type	Taxonomic Information	Trophic Group	Measure	Sample Type
Leptosynapta clarki	sea cucumber	Phylum: Echinodermata; Class: Holothuroidea; Family: Synaptidae	Dep	count	core
Leukoma staminea	bivalve	Phylum: Mollusca; Class: Bivalvia; Family: Veneridae	Susp	count	core
Leukoma staminea juv.	bivalve	Phylum: Mollusca; Class: Bivalvia; Family: Veneridae	Susp	count	core
Littorina sp.	gastropod	Phylum: Mollusca; Class: Gastropoda; Family: Littorinidae	Herb	count	quad
Live barnacles (Class Cirripedia)	barnacle	Phylum: Arthropoda; Class: Cirripedia; Family:	Susp	percent	quad
Lophopanopeus bellus bellus	crab	Phylum: Arthropoda; Class: Malacostraca; Family: Xanthidae	Carn	count	quad
Lottid limpets	gastropod	Phylum: Mollusca; Class: Gastropoda; Family: Lottiidae	Herb	count	quad
Lucina tenuisculpta	bivalve	Phylum: Mollusca; Class: Bivalvia; Family: Lucinidae	Susp	count	core
Lyonsia californica	bivalve	Phylum: Mollusca; Class: Bivalvia; Family: Lyonsiidae	Susp	count	core
Macoma inquinata	bivalve	Phylum: Mollusca; Class: Bivalvia; Family: Tellinidae	Dep	count	core
Macoma inquinata juv.	bivalve	Phylum: Mollusca; Class: Bivalvia; Family: Tellinidae	Dep	count	core
Macoma nasuta	bivalve	Phylum: Mollusca; Class: Bivalvia; Family: Tellinidae	Dep	count	core
Macoma nasuta juv.	bivalve	Phylum: Mollusca; Class: Bivalvia; Family: Tellinidae	Dep	count	core
Magelona hobsonae	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Magelonidae	Dep	count	core
Majid (spider) crab	crab	Phylum: Arthropoda; Class: Malacostraca; Family: Majidae	Scav	count	quad
Malacoceros glutaeus	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Spionidae	Dep/Susp	count	core
Malmgreniella nigralba	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Polynoidae	Comm	count	core

Appendix L (continued). Taxonomic Information About Intertidal Organisms Collected During 2011

Taxa	General Type	Taxonomic Information	Trophic Group	Measure	Sample Type
Mastocarpus jardinii	red alga	Phylum: Rhodophyta; Class: Rhodophyceae; Family: Petrocelidaceae	Prim	percent	quad
Mastocarpus papillatus	red alga	Phylum: Rhodophyta; Class: Rhodophyceae; Family: Petrocelidaceae	Prim	percent	quad
Mazzaella splendens	red alga	Phylum: Rhodophyta; Class: Rhodophyceae; Family: Gigartinaceae	Prim	percent	quad
Mediomastus californiensis	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Capitellidae	Dep	count	core
Megamoera subtener	amphipod	Phylum: Arthropoda; Class: Malacostraca; Family: Melitidae	Scav	count	core
Metridium sp.	anemone	Phylum: Cnidaria; Class: Anthozoa; Family: Metridiidae	Susp	percent	quad
Monocorophium spp.	amphipod	Phylum: Arthropoda; Class: Malacostraca; Family: Corophiidae	Scav	count	core
Mopalia lignosa	chiton	Phylum: Mollusca; Class: Polyplacophora; Family: Mopaliidae	Herb	count	quad
Mytilus trossulus	bivalve	Phylum: Mollusca; Class: Bivalvia; Family: Mytilidae	Susp	percent	quad
Nassarius sp.	gastropod	Phylum: Mollusca; Class: Gastropoda; Family: Nassariidae	Scav	count	quad
Nemertean	nemertean worm	Phylum: Nemertea; Class: ; Family:	Carn	count	core
Nephtys caecoides	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Nephtyidae	Carn	count	core
Nereis procera	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Nereidae	Omni	count	core
Nicolea zostericola (?)	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Terebellidae	Dep	count	core
Notomastus lineatus	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Capitellidae	Dep	count	core
Notomastus tenuis	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Capitellidae	Dep	count	core
Nucella lamellosa	gastropod	Phylum: Mollusca; Class: Gastropoda; Family: Nucellidae	Carn	count	quad
Nuttallia obscurata juvenile	bivalve	Phylum: Mollusca; Class: Bivalvia; Family: Psammobiidae	Susp	count	core
Odostomia sp.	gastropod	Phylum: Mollusca; Class: Gastropoda; Family: Pyramidellidae	Carn	count	quad

Appendix L (continued). Taxonomic Information About Intertidal Organisms Collected During 2011

Taxa	General Type	Taxonomic Information	Trophic Group	Measure	Sample Type
Onchidoris bilamellata	gastropod	Phylum: Mollusca; Class: Gastropoda; Family: Onchidorididae	Carn	count	quad
Owenia fusiformis	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Oweniidae	Dep	count	core
Pagurus spp.	hermit crab	Phylum: Arthropoda; Class: Malacostraca; Family: Paguridae	Scav	count	quad
Petalonia fascia	red alga	Phylum: Phaeophyta; Class: Scytosiphonaceae; Family: Scytosiphonaceae	Prim	percent	quad
Photis spp.	amphipod	Phylum: Arthropoda; Class: Malacostraca; Family: Isaeidae	Scav	count	core
Phyllodoce spp.	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Phyllodocidae	Carn	count	core
Pinnixia schmitti/occidentalis	crab	Phylum: Arthropoda; Class: Malacostraca; Family: Pinnotheridae	Comm	count	core
Pisaster ochraceus	seastar	Phylum: Echinodermata; Class: Asteroidea; Family: Asteriidae	Carn	count	quad
Platynereis bicanaliculata	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Nereidae	Omni	count	core
Podarke pugettensis	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Hesionidae	Omni	count	core
Podarkeopsis glabrus	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Hesionidae	Omni	count	core
Pododesmus cepio	bivalve	Phylum: Mollusca; Class: Bivalvia; Family: Anomiidae	Susp	count	quad
Polycirrus n. sp. (L. Harris)	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Terebellidae	Dep	count	core
Polydora cardalia	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Spionidae	Dep/Susp	count	core
Polydora proboscidea	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Spionidae	Dep/Susp	count	core
Polydora socialis	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Spionidae	Dep/Susp	count	core
Polynoid	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Polynoidae	Carn	count	quad
Polysiphonia sp.	red alga	Phylum: Rhodophyta; Class: Rhodophyceae; Family: Rhodomelaceae	Prim	percent	quad
Porphyra sp.	red alga	Phylum: Rhodophyta; Class: Rhodophyceae; Family: Bangiaceae	Prim	percent	quad
Prionitis sp.	red alga	Phylum: Rhodophyta; Class: Rhodophyceae; Family: Halymeniaceae	Prim	percent	quad
Protomedeia articulata	amphipod	Phylum: Arthropoda; Class: Malacostraca; Family: Isaeidae	Scav	count	core

Appendix L (continued). Taxonomic Information About Intertidal Organisms Collected During 2011

Taxa	General Type	Taxonomic Information	Trophic Group	Measure	Sample Type
Pseudopolydora kempi japonica	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Spionidae	Dep/Susp	count	core
Pycnopodia helianthoides	seastar	Phylum: Echinodermata; Class: Asteroidea; Family: Asteriidae	Carn	count	quad
Rhepoxynius pallidus	amphipod	Phylum: Arthropoda; Class: Malacostraca; Family: Phoxocephalidae	Scav	count	core
Rochefortia tumida	bivalve	Phylum: Mollusca; Class: Bivalvia; Family: Montacutidae	Susp	count	core
Sabellid	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Sabellidae	Susp	count	quad
Samytha californica	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Ampharetidae	Dep	count	core
Sarcodiotheca sp.	red alga	Phylum: Rhodophyta; Class: Rhodophyceae; Family: Solieriaceae	Prim	percent	quad
Sargassum muticum	brown alga	Phylum: Phaeophyta; Class: Phaeophyceae; Family: Sargassaceae	Prim	percent	quad
Saxidomus giganteus juv.	bivalve	Phylum: Mollusca; Class: Bivalvia; Family: Veneridae	Susp	count	core
Scytosiphon simplicissimus	brown alga	Phylum: Phaeophyta; Class: Phaeophyceae; Family: Scytosiphonaceae	Prim	percent	quad
Sphaeromid isopods	isopod	Phylum: Arthropoda; Class: Malacostraca; Family: Sphaeromatidae	Scav	count	quad
Spio filicornis	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Spionidae	Dep/Susp	count	core
Spiochaetopterus costarum	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Chaeotopteridae	Susp	count	quad
Spiophanes bombyx	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Spionidae	Dep/Susp	count	core
Stichaeidae (gunnels and pricklebacks)	fish	Phylum: Chordata; Class: Actinopterygii; Family:	Omni	count	quad
Tellina modesta	bivalve	Phylum: Mollusca; Class: Bivalvia; Family: Tellinidae	Dep	count	core
Tellina nuculoides	bivalve	Phylum: Mollusca; Class: Bivalvia; Family: Tellinidae	Dep	count	core

Appendix L (continued). Taxonomic Information About Intertidal Organisms Collected During 2011

Taxa	General Type	Taxonomic Information	Trophic Group	Measure	Sample Type
Tharyx parvus	polychaete worm	Phylum: Annelida; Class: Polychaeta; Family: Cirratulidae	Dep	count	core
Transennella tantilla	bivalve	Phylum: Mollusca; Class: Bivalvia; Family: Veneridae	Susp	count	core
Tresus capax	bivalve	Phylum: Mollusca; Class: Bivalvia; Family: Mactridae	Susp	count	quad
Tresus capax juveniles	bivalve	Phylum: Mollusca; Class: Bivalvia; Family: Mactridae	Susp	count	core
Ulvoids	green alga	Phylum: Chlorophyta; Class: Chlorophyceae; Family:	Prim	percent	quad
Zostera marina	plant	Phylum: Anthophyta; Class: ; Family: Potamogetonaceae	Prim	percent	quad