Impacts of the Construction of the Brightwater Marine Outfall on Intertidal Biotic Communities

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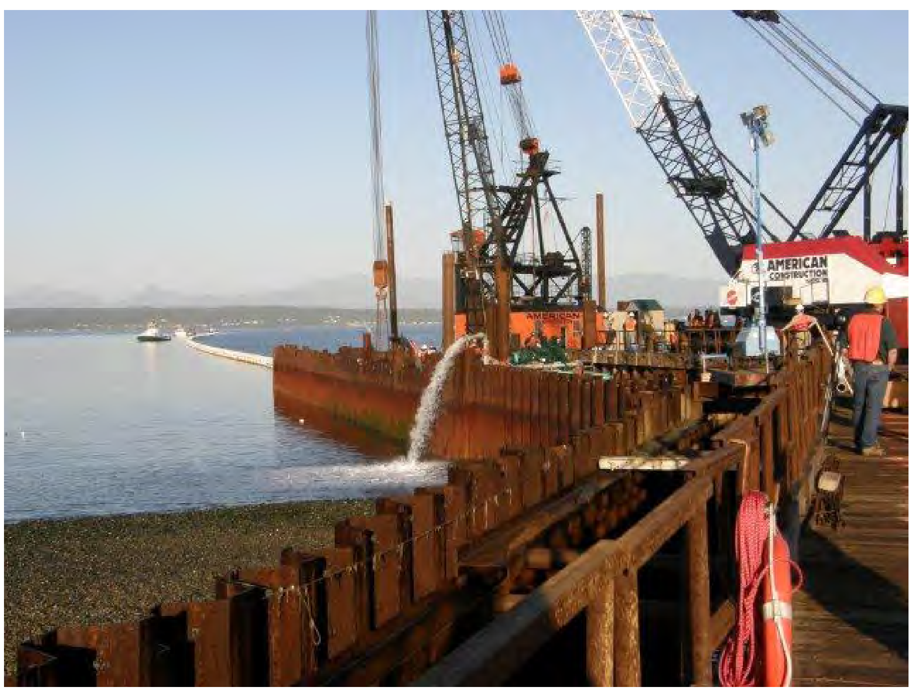

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WASHINGTON STATE DEPARTMENT OF
Natural Resources
Peter Goldmark - Commissioner of Public Lands

Contents

Executive Summary

King County's new Brightwater Treatment System will discharge treated effluent to Puget Sound through a marine outfall located over a mile offshore near Point Wells. Construction of the marine outfall involved excavating a trench, installing a pipe, backfilling the trench, and restoring the trench surface. All intertidal biota were lost in the trenched area and there was disturbance alongside it. The purpose of this project was to monitor impacts and document recovery of intertidal biota following this disturbance. A team from the University of Washington and the Washington Department of Natural Resources assessed impact by first monitoring the intertidal biotic community prior to construction to establish a baseline, and then documenting recovery following construction. Four sites were surveyed: the marine outfall corridor and two reference sites immediately north and south of it at Point Wells, and a third reference site 2 km to the south at Richmond Beach Park. Pre-construction surveys were conducted in June 2006, 2007, and 2008 (just before the trench was dug), and post-construction surveys in June 2009 and 2010 to follow the process of intertidal community recovery.

At each beach we established a series of four permanent horizontal intertidal transects, at: -2 ft MLLW (Mean Lower Low Water), MLLW (0), Mean Low Water (+2.8 ft), and Mean Sea Level (+6.6 ft). This design concentrated sampling at the lower levels where the biota are much more diverse, but provided an overview of impacts to higher-shore organisms as well. For each transect we placed a 50 m tape parallel to the water's edge and sampled 10 randomly chosen locations for intertidal organisms. Surface biota were quantified in 0.25 m^2 quadrats, and infauna (primarily polychaete worms and bivalves) in a 10 cm diameter x 15 cm deep core. Infaunal cores were sieved on 4 and 2 mm sieves. An exception to this sampling design allowed us to better quantify impacts in the relatively narrow (6 m) construction trench plus the immediately surrounding area that showed signs of surface impact. Following outfall construction, we sampled 5 random locations within the impacted section of the Outfall transects ("Trench" samples), and 5 locations outside of this section ("Edge" samples). In addition, at the lowest sampled level (-2 ft), following construction there was a "Pit" in the middle of the outfall transect line where the substrate was sunken and had atypical sediment. Five samples were taken in this Pit in 2009 and 2010.

Substrate (sediment) grain sizes were quantified in three samples per transect following standard Puget Sound Estuary Program (PSEP) protocols. In addition, visual estimates of percent cover of cobbles (>10 cm diam) and sand (<2 mm diam) were made in the surface quadrats. Temperatures and salinities of beach porewater and nearshore conditions were recorded each June.

As with much of the shoreline of Puget Sound that is open to wave energy, all four sites have sediments composed of a mix of cobble, pebble, and sand. Puget Sound's beaches are geomorphically complex and dynamic; the beach substrates at the sites differed to some extent among tidal heights, but even when comparing within a zone, the greatest source of variation in physical conditions was interannual. The High zones (+6.6 ft) at all sites were characterized by small, relatively unstable pebbles, with very little of the larger cobble that helps to stabilize the substrate at lower levels, and by highly variable amounts of sand among years. This zone is also submerged for relatively short periods per day, making it subject to large swings of temperature

and moisture. These characteristics, along with the temporal instability, make it a very stressful environment for marine organisms. The Mid zones (+2.8 ft) at all sites were characterized by a mix of sand, pebbles, and cobbles, while the Low (0 ft = MLLW) and Very Low (-2 ft) zones had patches of cobble and sand and generally a less steep slope. All sites had some eelgrass inhabiting patches of sand in the Very Low zone. Beach porewater temperatures in June of each year were higher (and much more variable) and salinities were lower (and much more variable) than conditions just offshore. Temperatures are heavily influenced by sun hitting the beach surface and warming the porewater, while the porewater salinities reflect groundwater draining down from the land.

The biota at all intertidal elevations in the beaches at the Pt Wells Outfall site and in the unimpacted Control sites are characterized by high interannual variation, making it more difficult to quantify impacts of construction than if types and abundances of beach organisms were stable from year to year. This high variation is typical of Puget Sound beaches, however, and probably relates to natural variation in both physical and biological parameters that ultimately affect the plants and animals on and in the sediment. Correlational data from our monitoring work suggest that high temperatures in the early summer may prove lethal for small invertebrates living near the surface of the sediment. In addition, there is large interannual variation in recruitment of organisms onto cobbles and into the sediment. An especially dramatic pattern was seen in barnacle coverage; recruitment of barnacles regularly alternates from high to low between years at all sites and elevations studied, although we know of no physical or biological reason for this pattern. Abundance of barnacles, in turn, potentially affects many other species, including the small snail *Lacuna*, limpets, the barnacle predators *Onchidoris* and *Nucella*, and mussels. Because of these regular patterns and other biotic changes that are regionally consistent within a year (e.g., large recruitment of a given worm species in some years), the biota at the different sites tended to shift among years in the same manner as each other. Analyses showed that the surface biota are particularly important in driving these year-to-year differences.

Statistical tests of which physical parameters best matched the patterns of biological communities among sites and years did not pinpoint one parameter as being of driving importance. For the Low zone, the physical variables that most closely matched variation in the biotic community were a complex combination of cover of cobble and sand plus nearshore salinity and temperature; no one variable correlated well. For the Very Low zone, the best single variable was cover of sand. In other analyses of Puget Sound biota, the cover of sand has frequently been shown to be correlated with low species richness.

Post-construction sampling at the Outfall site showed that in the High zone transects, biota were so depauperate that we could not analyze for construction impacts. Species richness was always low (0-10 species per transect in contrast with 20-50 species in the Mid zone) and highly variable with time. On three occasions we found no living organisms in any of the 10 samples per transect. Communities in the three lower zones were much richer, making analyses more straightforward. Overall impacts on the entire community were analyzed with a BACI (Before-After-Control-Impact) design in PERMANOVA+. If there was a construction impact on the whole community (at a given tidal level), we would expect the degree or direction of change in the biotic community from “before” (2006-8) to “after” (2009-10) to be different for the impact site than it is for the control sites. Statistically, this would manifest as an interaction term between the Control-Impact effect and the Before-After effect. Such an interaction was not seen in the BACI analyses for any of the tidal elevations.

The lack of an apparent construction effect in the multivariate BACI analyses could be due to two issues. The BACI test compares the variation among samples within a group (e.g., all the Control samples, or all the Before samples) to the variation among all samples; thus when the variation within a group is high (such as the high year to year variation seen in all control transects), it is hard to detect any significant effects. Second, the tests were somewhat confounded by calling both 2009 and 2010 data “After”, because if there was recovery towards the control state in 2010, this would ‘dilute’ the clarity of the construction effect. We thus ran two additional sets of analyses: an additional BACI test for each level (except the High zone) on species richness – the univariate parameter that ‘summarizes’ (and simplifies) the multivariate whole-community responses to the disturbance; and a multivariate PERMANOVA analysis on within-year contrasts just between Outfall samples and Pt Wells South samples, which were physically and biologically closest to the Outfall in the pre-construction data.

These additional tests showed clearly that the construction had an initial impact on the biota in all zones, but that most communities were showing signs of recovery after 2 years. In the Mid zone, species richness in the Outfall transect clearly dropped from Before to After construction, whereas the Controls stayed relatively stable. The biggest differences among communities were seen in 2009; by 2010, although species and abundances varied to some extent among transects, the Trench samples had regained many species that had been present before construction, including both surface-dwellers (anemones, mussels, hermits, whelks) and infaunal polychaetes (nereids, spionids, and capitellids).

Similar patterns of substantial change in community structure and loss of species richness were also seen following construction in the Low (0 ft) and Very Low (-2 ft) zones in 2009. In 2009 the Low zone at the Pt Wells South control area contained many species found in neither the Outfall Edge nor the Trench, including both surface biota (several algae, mussels, chitons) and infauna (a variety of clams, tube-building phoronids and oweniid polychaetes, and mobile polychaetes). By 2010 a variety of species had recolonized both the Edge and Trench samples, including anemones, algae, several species of clams, whelks, and others. Between 2009 and 2010 species richness increased in both impacted areas but especially in the Trench, while it declined in the control at Pt Wells South (presumably as a result of normal interannual variation). In the Very Low zone in 2009, the Edge samples were biologically similar to the control sites, suggesting either no construction impact or that changes that were small enough to have already disappeared within a year. In 2009 the Trench samples were different from both the Edge and from Pt Wells South. A year later the Trench had greatly increased species richness and was no longer significantly different from the Edge although it was still slightly different from the control samples. Because the natural mix of cobble and sand substrate was present in the Trench (because it was replaced post-construction), the community trajectory appeared to be rapidly approaching “normal” – recognizing that “normal” is a somewhat unpredictable state.

The anomalous “Pit” area, located where the construction trench bisected the Very Low transect line, was the most impacted of the studied locations and will take the longest to recover. This area, which should have had 20-40% surface cover of cobbles (and a subsurface mix of cobbles and sand), instead was an area about 15 m wide of pure sand. In 2009 the Pit samples were extremely different from all nearby samples; the total biota consisted of 2 individual polychaetes. Two years post-construction there was still only one worm and 6 small clams in the Pit samples, and traces of surface organisms on the few small rocks that had rolled into the area. Until larger rocks are washed into this area, which had not happened after 2 winter periods, the community will not recover to its pre-construction state.

Other than this Pit area, the impact done by the summer 2008 construction was limited in spatial scale to the 6 m of the trenched area and to a lesser extent to about 10-15 m on either side of that trench. Given the way the community has recovered at the Mid, Low, and Very Low Outfall transect sites in two years, it is our estimate that in another 1-3 years it will not be possible to distinguish the trenched beach from the reference areas either physically or biologically.

Introduction

King County's new wastewater treatment plant, the Brightwater Treatment System, will discharge treated effluent to Puget Sound through a marine outfall located over a mile offshore near Point Wells (Figure 1). Outfall construction began in spring 2008 and was completed by December 2008, with the outfall traversing both nearshore and offshore marine environments. To lay a pipe traversing the intertidal zone, an open trench had to be constructed, requiring excavation, pipeline installation, trench backfilling, and restoration of the trench surface. The trenched area comprised a 20 foot (ft) wide corridor centered along the outfall pipeline alignment that included a 12 ft wide sheeted trench area and an additional 4 ft wide area on either side of the sheeted trench to account for potential localized construction effects.

The purpose of this project was to monitor impacts and document recovery of intertidal biota following construction of the Brightwater marine outfall. During construction, all intertidal biota were lost in the trenched area and there was disturbance alongside it. A team from the University of Washington and the Washington Department of Natural Resources assessed impacts by first monitoring the intertidal biotic community for three years prior to construction in 2006, 2007, and 2008 to establish a baseline, and then documenting recovery following construction. Previous intertidal biotic surveys conducted in Puget Sound have shown there is substantial interannual variability in community structure (Dethier 2005, 2007; Dethier and Berry 2009), therefore it was necessary to conduct several annual surveys prior to construction to establish the normal range of variability at this site. Conditions at the site were then documented for two years post-construction in 2009 and 2010. In addition, three reference sites at a range of distances from the impact site were monitored each year for comparison to the impacted site. Obtaining data from multiple years both prior to and following outfall construction at both the impact and control sites strengthened the analyses of change.

Site Descriptions

The site for the Brightwater Treatment System marine outfall is located in the southwest corner of unincorporated Snohomish County at Point Wells. Point Wells is composed of a natural point of land that was reinforced with a rubble seawall by the railroad more than 100 years ago. The site borders are Puget Sound to the west, the terminal dock for the Paramount Asphalt and Petroleum Storage Facility to the north, and the Burlington Northern Santa Fe railroad to the east. Other land uses within a 0.25-mile of radius of the outer perimeter of the site include single-family residences to the southeast, and a forested terrace and ravine to the east and northeast.

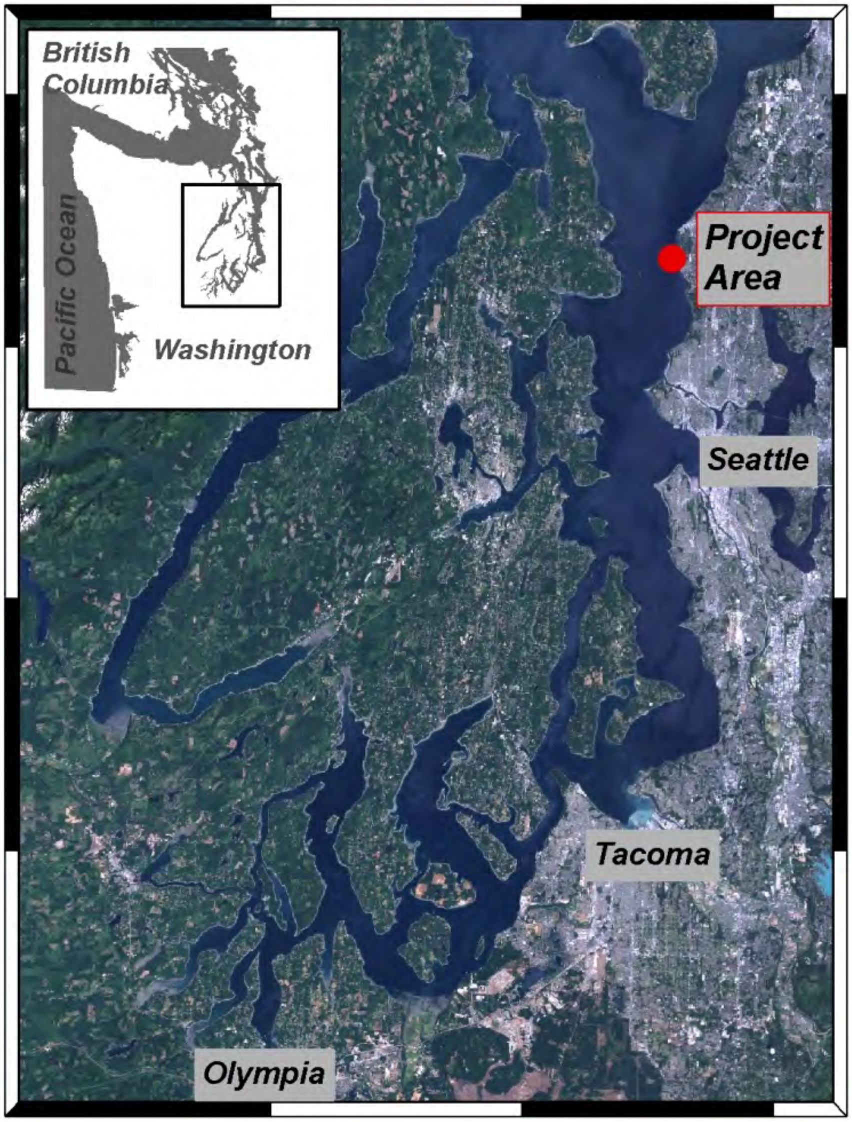

Figure 1. Project Area located at Point Wells, Puget Sound.

Four sites were surveyed for this project: the marine outfall corridor and two reference sites immediately north and south of the outfall corridor at Point Wells, and a third reference site at a greater distance from the outfall, at Richmond Beach Park 2 km to the south (Figure 2). The initial sampling design had not included a reference site immediately south of the Outfall but time allowed sampling of this additional transect in the Very Low (-2 ft) zone (only) in 2006, and in subsequent years we also sampled in the Low (0 ft) and Mid (+2.8 ft) zones at this site (Pt Wells South). No High (+6.6 ft) zone sampling was done at this site.

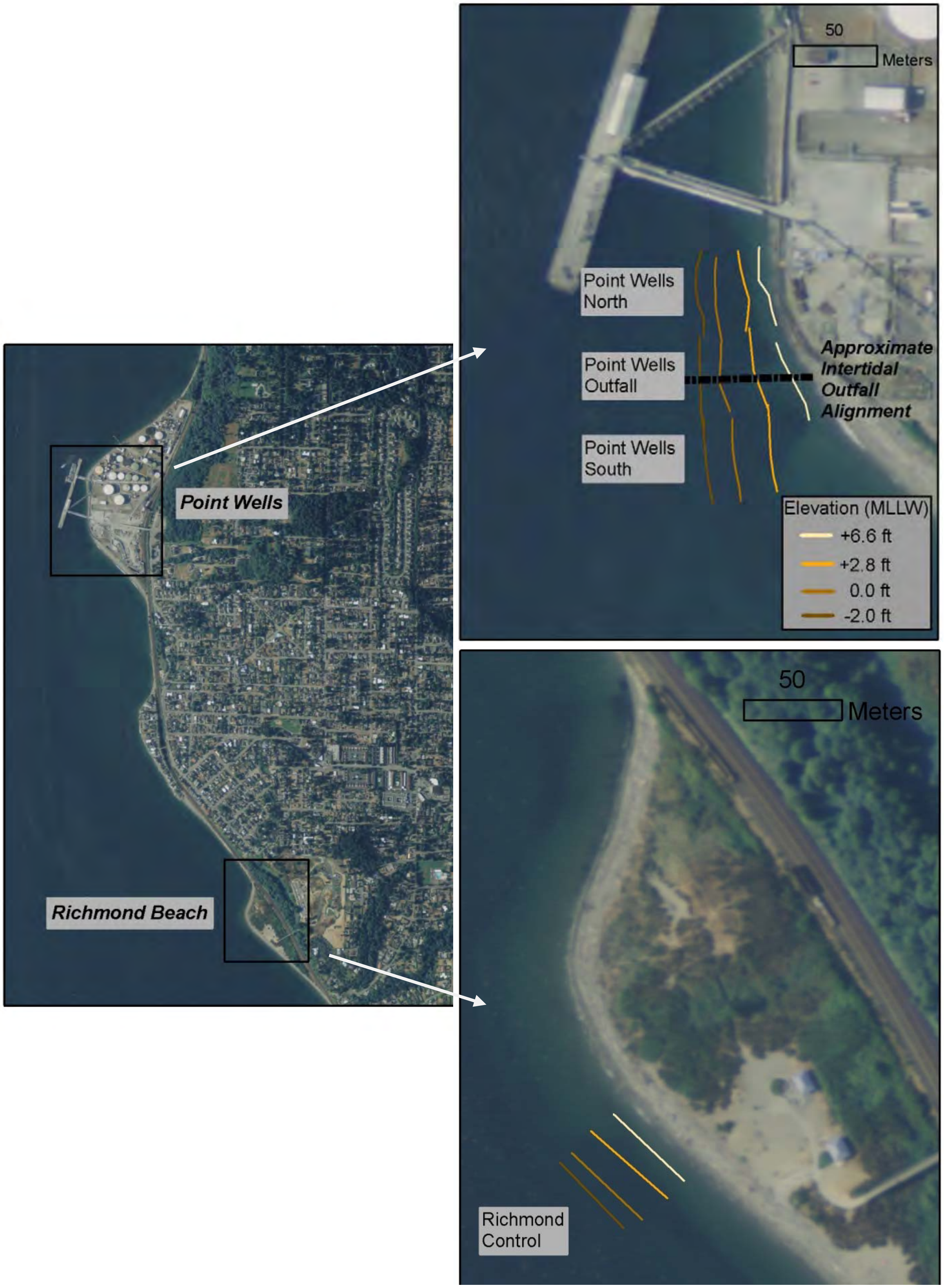

Figure 2. Relative locations of the surveyed areas at Point Wells and Richmond Beach, and approximate transect locations at each site.

As with much of the shoreline of Puget Sound that is open to wave energy, all four sites have a mix of cobble, pebble, and sand at Mean Lower Low Water (MLLW) (e.g., Figure 3a). The sites were most physically similar at that height, but differed to some extent at the other tidal heights sampled. The outfall corridor had some cobble extending below MLLW, whereas all three reference sites had a transition in sediment type from cobble to sand immediately below MLLW, as is common in Puget Sound. Thus the lowest level sampled (-2 ft below MLLW) was sandier at the reference sites than the outfall site.

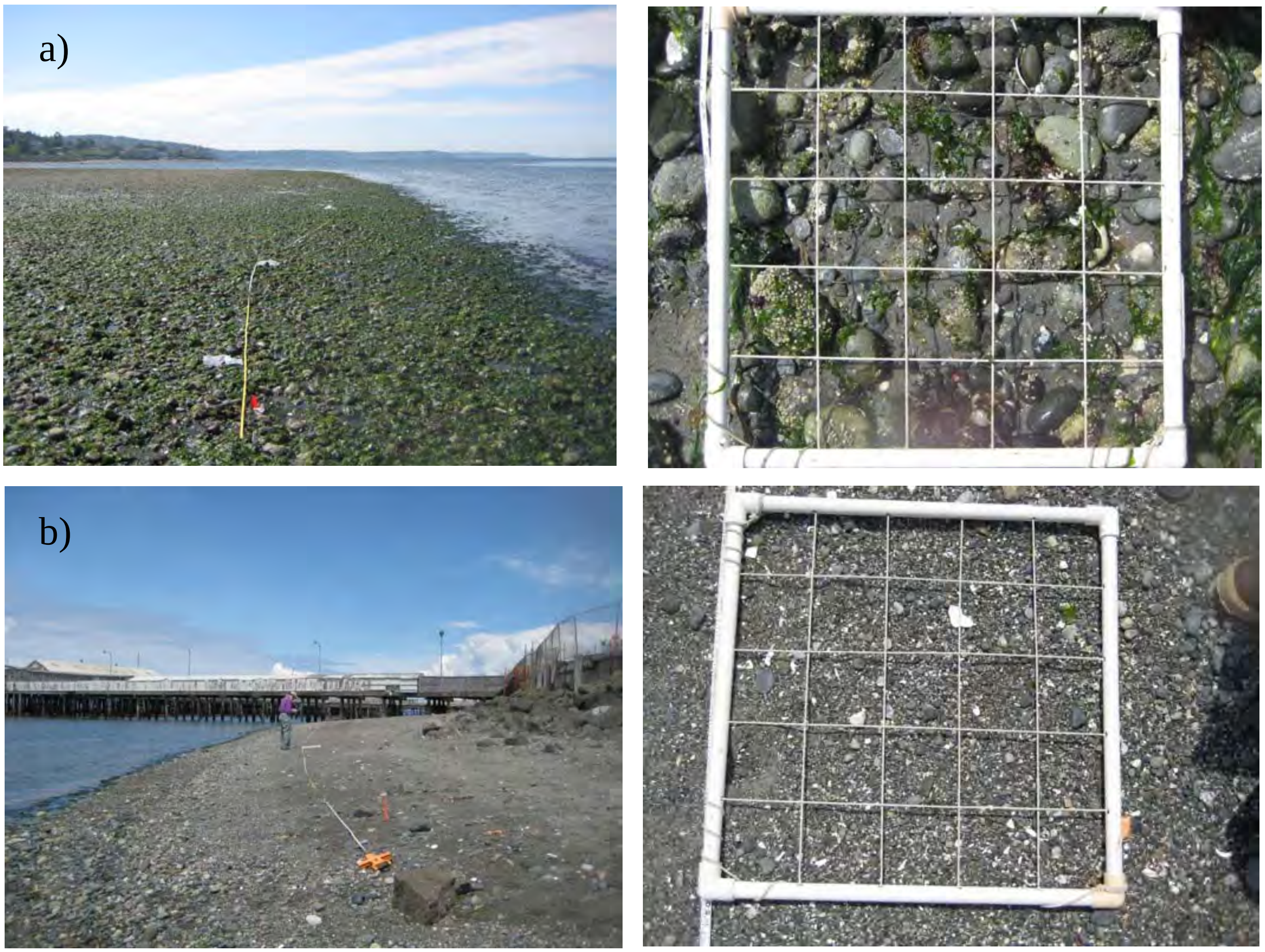

Figure 3. Whole-transect and individual quadrat in the outfall corridor pre-construction, showing a) typical substrate at MLLW, a mix of cobbles and sand, and b) typical substrate along the high shore (+6.6 ft), a mix of sand and pebbles.

The higher shore levels at all sites were a mix of pebbles and sand (e.g., Figure 3b), with the reference area just south of the outfall site having more cobbles (and a lower slope) than the other sites. At Richmond Beach, the reference site used in the first year of sampling (June 2006) had most of the shore covered with large cobbles, intermixed with pebbles and sand. Analyses of similarity of the biota of this beach versus the sites at Point Wells indicated that because of this physical difference, the Richmond Beach site was a poor ‘control’; thus beginning in 2007, we shifted to a different site at Richmond Beach (about 100m south of the old site) that was physically (and biologically) more similar to the Point Wells reference and outfall sites.

Sampling Design and Field Methods

A series of permanent horizontal intertidal transects were established at each of the four beaches (Figure 2). To make data as consistent as possible with other WDNR Nearshore Habitat Program monitoring data, we followed the SCALE sampling protocol for intertidal organisms, described below. To more fully characterize the intertidal biota than is done in most of the SCALE surveys, transects were established at four intertidal levels rather than just at MLLW. At each site we sampled biota at: -2 ft MLLW, MLLW (0), Mean Low Water (+2.8 ft), and Mean Sea Level (+6.6 ft), except that we did not sample at the highest level at the Pt Wells South reference area. This design concentrated sampling at the lower levels where the biota are much more diverse but provided a sufficient overview of impacts to higher–shore communities as well. Tidal elevations were determined relative to predicted water levels for the first field sampling day, and were marked at all sites 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 pole. Stakes were used to mark transect ends although these did not always remain in place from year to year. GPS points were taken along each transect, and tidal elevations were re-surveyed each year so that the proper elevations could be consistently sampled even if stakes were missing.

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, and Results below). 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 and sand) 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 four and two millimeter (mm) sieves; smaller meshes completely clog with this pebble-sand sediment type. Previous work showed that some small individuals but very few species are ‘missed’ with this sieve size relative to 1 mm sieves. 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.

An exception to this sampling design was made to better quantify impacts in the relatively narrow trench (Figure 4). The trench was only 6.1 m (20 ft) wide out of the 50 m Outfall transect, although the area showing visible impact was larger at about 15 m. Following outfall construction, we sampled 5 random locations within the 15-20 m wide impacted (trenched) section of each transect ("Trench" samples), and the remaining 5 locations were divided between the two sides of this section ("Edge" samples). In addition, at the lowest sampled level (-2 ft), following construction there was a "Pit" in the middle of the outfall transect line where the substrate was sunken and completely lacking in the cobble that was otherwise present along this transect line both before and after construction (Figure 5). The Very Low transect ran around the upper edge of this depression such that we always sampled that zone at the -2 ft elevation. To examine biota in the anomalous "pit", we sampled 5 locations, at a tidal elevation of approx. -2.5 ft, on a line that had been part of the Very Low transect before the sediment sank in the depression (Figures 4 and 5).

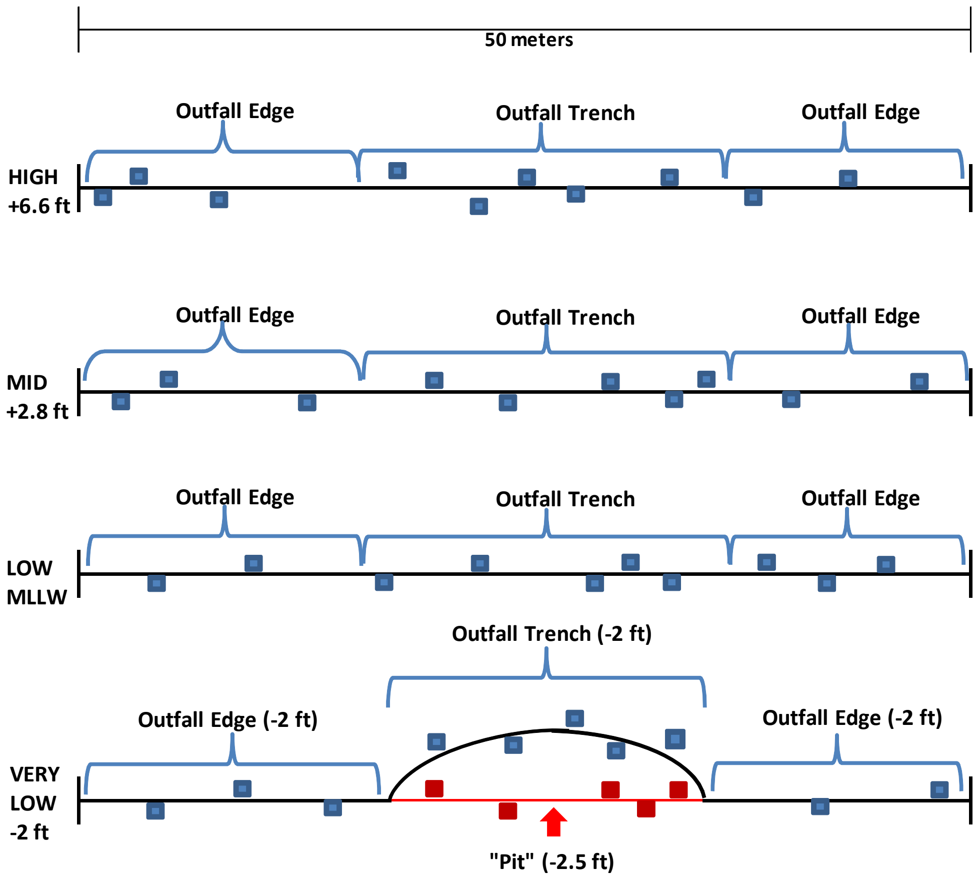

Figure 4. Diagram showing the sub-division of the Pt Wells Outfall site into Edge and Trench sampling sub-areas following construction. The 50 m transects at 4 tidal heights are shown in black, and randomly placed quadrat and core samples are depicted as blue squares. Half of the 10 samples per level were collected in the trench and half were collected on the edges. In the Very Low Zone, the -2 ft line curved up in the trenched area to maintain the same tidal elevation. Samples were added in the newly formed "Pit" area in the center of the transect at a lower elevation, shown in red. Sample locations are approximate, exact sample locations were randomly selected each year.

Figure 5. The “pit” at the lowest intertidal portion of the Outfall corridor, June 2010. The transect line running though the sandy area was where we collected “pit” samples; a second transect line skirts the upper edge of the sand at the fixed -2 ft (Very Low) tidal elevation.

Substrate (sediment) types were quantified in two ways. First, at each of the four tidal levels at each sampling site except Pt Wells South, three sediment samples were taken for analyses of grain sizes following standard Puget Sound Estuary Program (PSEP) grain size protocols . Samples were collected from the surface down to 10 cm depth at 5.2, 23.0, and 40.7 m along each transect line, placed in plastic storage bags, and transported to the King County Environmental Laboratory for analysis. Second, visual estimates of two classes of sediment were made in each surface quadrat along each transect: cobbles (defined as >10 cm diam) and sand (<2 mm diam). Because these were purely surface estimates, and in addition we did not quantify intermediate grain sizes, the two methods are not directly comparable.

Temperatures and salinities were measured during each sampling day both within 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. Frequently the high transects were dry, so no data were gathered for these parameters. Nearshore data were taken in ca. 1 m water depth just offshore of the transects.

Laboratory Methods

All organisms not identifiable to the species level in the field, including all infaunal organisms, were identified in the lab using microscopes. Taxonomic references included Kozloff (1996) and Blake et al. (1997) for invertebrates, and Gabrielson et al. (2000) for macroalgae. All surface flora and fauna as well as infauna were entered into an Access database maintained by WDNR personnel.

Grain size data were processed following ASTM D422 methodology, which is a combination of sieve and hydrometer analyses. Individual phi sizes and percent sand, gravel, silt, and clay were enumerated by the King County Environmental Laboratory and entered into the lab's LIMS database following quality control procedures. Grain size results are presented in units of percent on a dry-weight basis. The method detection limit is 0.1% and the reporting limit is 1.0%. Quality control consisted of triplicate analysis with the relative percent difference being ≤20%.

Data Analyses

Two years of prior data, 1999 and 2001, existed for one intertidal level (MLLW) at the impact site, and are used in some analyses to contribute to the pre-impact baseline dataset. Multivariate statistical analyses of the entire community (species present and abundances) at each elevation were conducted in PRIMER6 to test how the communities shifted over time both naturally (pre-construction at the impact and reference sites) and post-construction. These analyses used square-root transformed abundances to downweight the importance of abundant species, and used Bray-Curtis resemblance measures. In addition, spatial and temporal patterns of species richness were evaluated among the four sites. Observed changes in the biotic community over time relative to changes in physical characteristics were compared.

Grain size data (maintained in the King County Environmental Laboratory LIMS database) were analyzed for proportion of the dry weight of each sample in 4 categories: clay, silt, sand, and "gravel+", which included all sediments over 2 mm diameter. The three samples per transect were averaged.

Overall construction impacts were analysed with a BACI (Before-After-Control-Impact) design in PERMANOVA+ (Anderson et al. 2008). We ran a full 4-factor PERMANOVA (permutational ANOVA) test following a BACI (Before-After, Control-Impact) design to test for impacts of the construction on the biota in each of the three lower zones. The four factors were Control-vs-Impact (fixed factor, 2 levels), Before-vs-After (fixed factor, 2 levels), Year (random factor nested in Before-After, since 3 years were Before and 2 years were After), and Site (random factor nested in Control-Impact, with 3 control sites and 1 impact site). For these analyses we used the 'raw' sample data (N =10 replicates per treatment/site/year), pooling the Edge and Trench samples for the Impact-After years. The analyses were run on a "modified Gower resemblance matrix" (Anderson et al. 2006), which works better than some other similarity measures (such as Bray-Curtis, which we used in tests involving mean values among samples) when species are sparse in samples. The Gower measure uses absolute abundances rather than proportional ones, and specifically 'weights' a change in presence vs. absence of one species the same as an order-of-magnitude change in abundance of another; thus it accounts for both absolute presence/absence and relative abundance. In the BACI tests for each elevation, we first ran the PERMANOVA routine with all factors, then pooled interaction terms that were non-significant to increase the power of the test. For all zones, we ended up pooling both the non-significant terms Control-Impact x Years(Before-After) and Before-After x Sites(Control-Impact) into a "pooled" factor. Additional BACI tests were run comparing just the Outfall with one adjacent control area, and comparing species richness values across the entire dataset.

Results

Sampling Effectiveness

Analyses of the number of species found in samples suggest that our methodology of sampling 10 points (quadrats and cores) per transect is quite effective at capturing most of the species present at that site and zone. The rate of accumulation of new species with additional samples was calculated in PRIMER6 for each Point Wells transect and year, generating curves such as in Figure 6; these are based on random permutations of the numbers of species found in increasing numbers of samples.

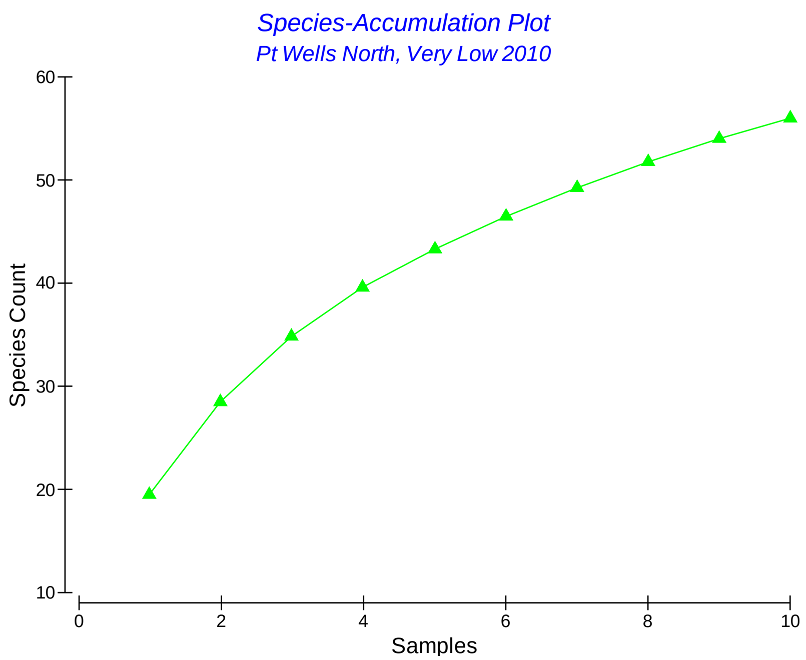

Figure 6. Sample plot of a species-accumulation curve for one transect; the asymptotic value for this curve was estimated at 60 species.

The number of species found in 5 and 10 samples and the asymptotic values for number of species per transect were estimated from these curves, and the means of these values are shown for each tidal level in Figure 7 (for non-impacted transects and years). Species richness is very similar for Very Low and Low zones, but clearly reduced in the Mid zone; the High zone samples were so species-depauperate (and variable) that curves could not be calculated. Five samples captured an overall average of 72% (range 55-79%) of the asymptotic number of species, and ten samples an average of 93% (range 83-97%).

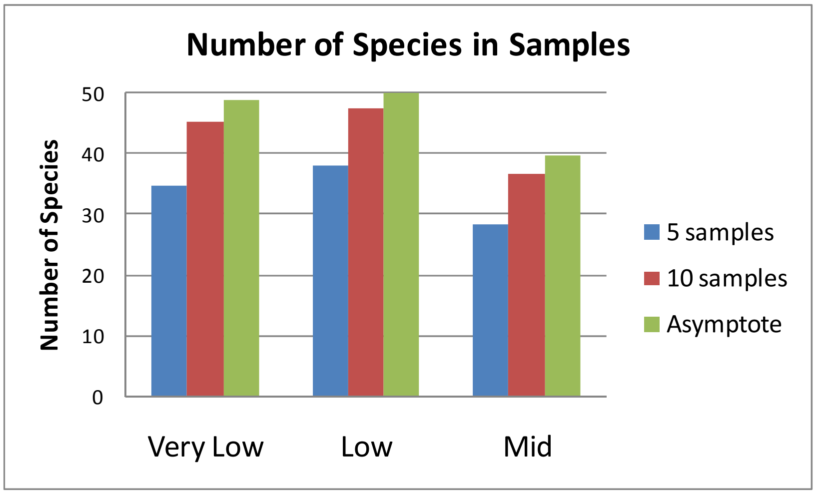

Figure 7. Numbers of species found in all Point Wells samples in non-impacted areas.

These percents did not depend on the overall richness of the transect; Figure 8 shows that there is virtually no relationship between the asymptotic richness value and the proportion of species captured in 10 samples.

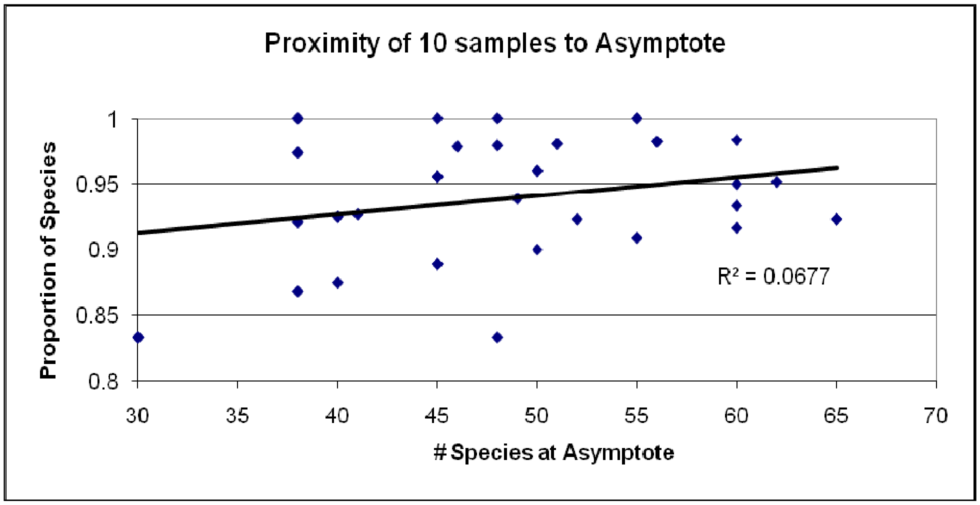

Figure 8. Correlation between the asymptotic number of species and the proportion of species found in 10 samples for each calculated species-accumulation curve (non-impacted transects only).

Pre-construction Variation in Communities

The data from the 3 sampling periods preceding construction (2 years at the Richmond Beach reference site) showed that year to year variation in biotic communities is high at all intertidal levels. This is illustrated in Figure 9, which shows a multidimensional scaling (MDS) plot of the communities in the Low and Very Low transects at all the sites in the years prior to construction. Each point (in this and subsequent MDS plots) represents in two dimensions all the biota in a transect for a given year; points closer together in the plot have communities more similar in both species and their abundances. The plot illustrates several important issues. First, the points group together closely by year (colors), but the points for a given site (e.g. Pt Wells S) are scattered among years, showing that the biota at each beach changes from year to year, but that the biota at all the sites tended to shift among years in the same manner as each other. For example (as discussed later), between 2007 and 2008 there was a very large decline in abundances of barnacles at all sites, and a corresponding change in barnacle predators and other surface-dwelling organisms; these changes (and others) led the community composition at all the sites to shift from the lower left to the upper right of the plot. The dramatic nature of these interannual changes illustrates why it is so important to have both controls (reference sites) and "before" data when attempting to quantify the impacts of a particular event such as trench construction. Second, the plot shows how poorly the old 'Rich Beach' transects matched the other 2006 sampled sites, which caused us to drop it as a reference area and switch to the 'Richmond' sites, which were biological more similar (although still visibly different) to the Point Wells areas (in 2007 and 2008). Third, the "Pt Wells Old" data from 1999 differed considerably from the other sites and years, and are not considered further in the analyses.

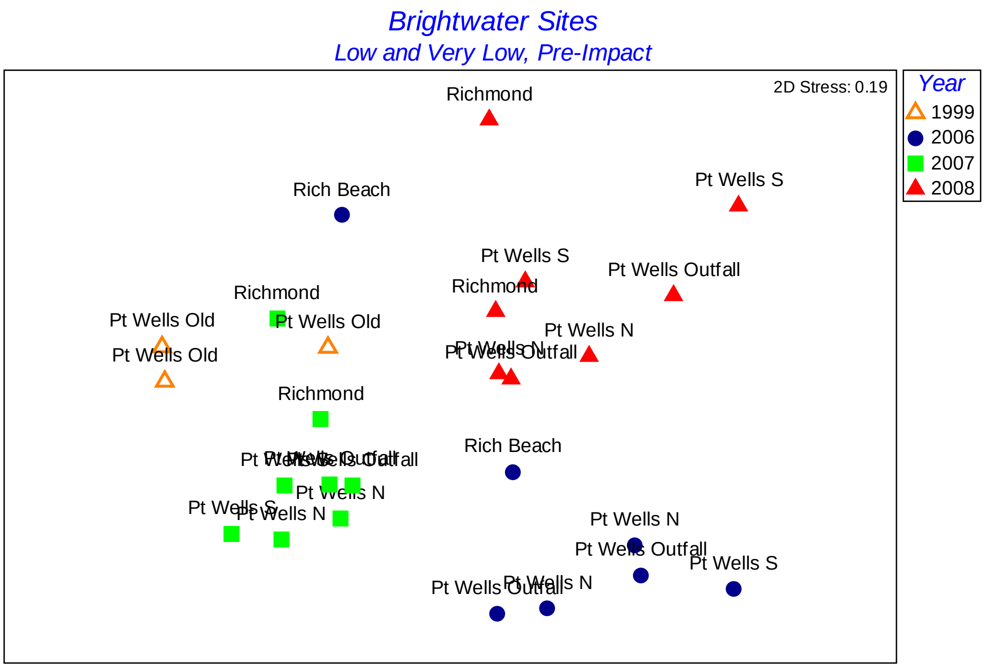

Figure 9. MDS plot of the biota at the Low and Very Low transects prior to construction, illustrating data from 2 areas (Rich Beach and Pt Wells Old) not used in subsequent analyses because they were poor reference areas for the main sites. Each point represents mean biota from a transect in a given year, with abundances squareroot transformed.

Figures 10 and 11 further explore the sources of the substantial year to year variation at all sites by dividing the biota into surface-dwelling algae and invertebrates (Figure 10) versus infauna (mostly polychaete worms and clams, Figure 11). Site-labels for the points have been omitted for clarity. Each year's data include all the points from the Low zone at each of the 4 sites (Pt Wells Outfall, South, and North, and Richmond Beach) except we have no Richmond data from 2006.

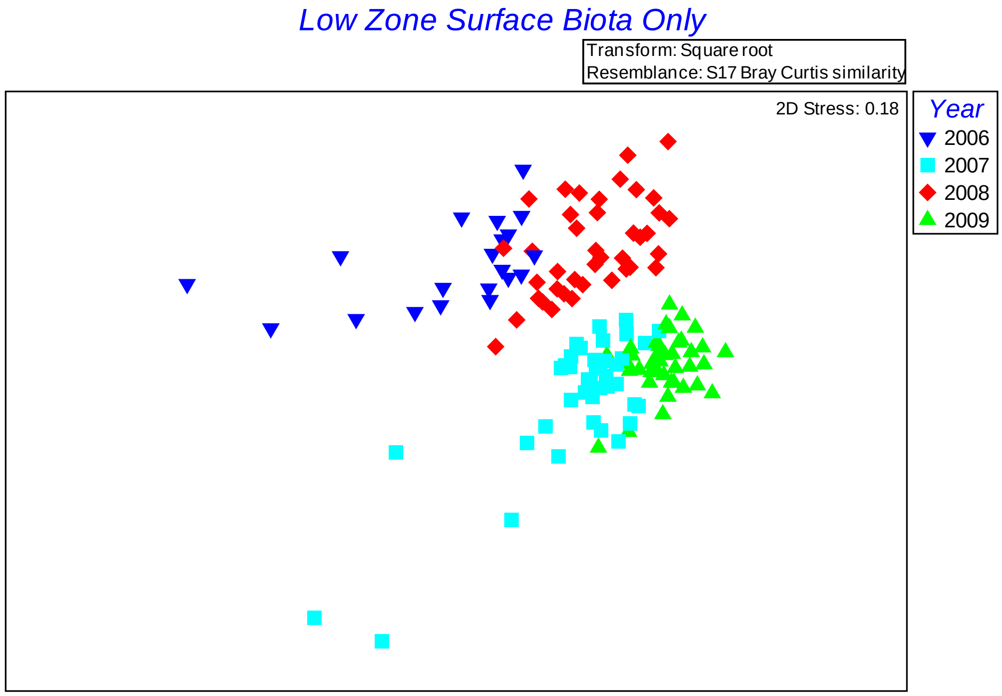

Figure 10. MDS plot of the surface biota (only) of all Low zone samples 2006-2009; each point represents the biota in one quadrat rather than a mean among all 10 samples per transect.

Figure 10 shows that the surface biota are very important in driving year-to-year differences in overall communities. There are large differences among years; an ANOSIM (analysis of similarity) test among years for these Low zone data gave a Global R[1] = 0.605, p = 0.001, and all pairwise tests between years are significant. Species that drove these differences (as seen in SIMPER [similarity percentage] analyses) were barnacles (see below), the small snail *Lacuna*, limpets, the barnacle predators *Onchidoris* and *Nucella*, and mussels. To test to what extent these communities varied simply in the abundances of these taxa, we transformed the data to presence/absence and reran the ANOSIM test; it still gave a significant result although with a lower R value (R = 0.369, p = 0.001), showing that the types of species present as well as their abundances are changing among years.

When the infauna are analyzed by themselves, they show much less clear differences among years than do the surface biota (Fig. 11). An ANOSIM analysis among years for infauna gave a much lower R value (0.185) than for the surface biota; some year to year comparisons were still significantly different, but 2006 and 2008 were not different, nor were 2006 and 2007. When the data were transformed to presence/absence, the R value was almost the same (0.172). Infaunal

[1] Global R is a test statistic that reflects the observed differences between groups (here, years) contrasted with differences within groups. It usually falls between 0 and 1. R = 1 if all the points within a group are more similar to each other than any of the points from a different group; thus a high R value indicates a clear separation among groups (here, years). R = 0 if the similarities between and within groups are not different. Visually, a high R value is represented by how tightly a group is clustered, and how easily one could draw a circle around the points without including points from some other group.

taxa that varied among years were the polychaetes *Spio filicornis* (abundant in 2009, entirely absent in 2008*), Hemipodus*, *Mediomastus*, *Notomastus*, *Owenia*, and *Nereis vexillosa*, and juvenile *Tresus* clams. At least some of this variation is likely to result from interannual differences in recruitment, e.g. in small clams and in short-lived polychaetes such as *Spio*.

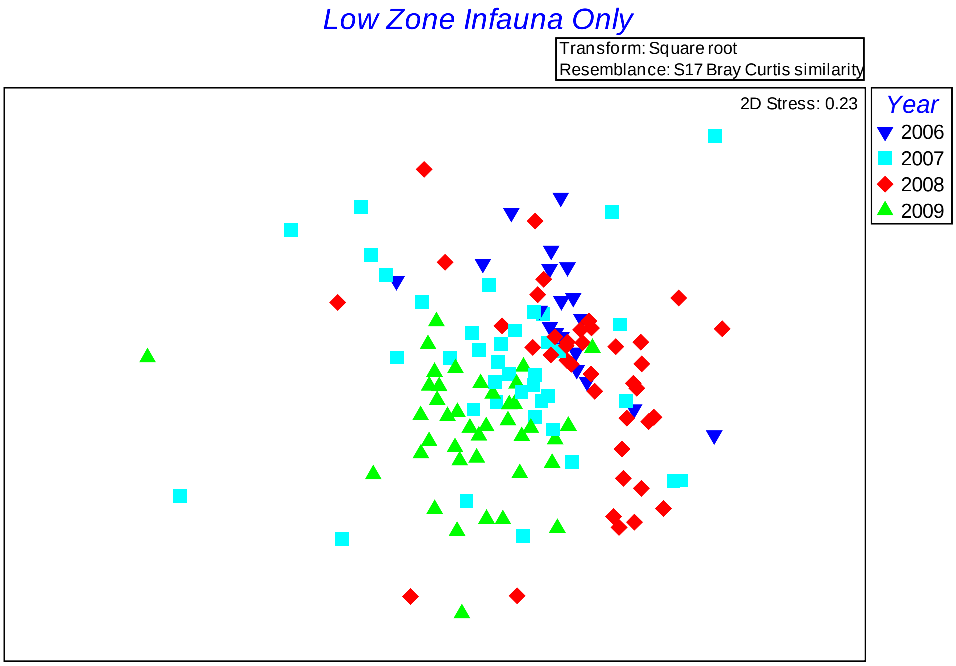

Figure 11. MDS plot of the infauna (only) of all Low zone samples 2006-2009; each point represents the biota in one core, rather than a mean among all 10 samples per transect.

Some of the year to year variation in biota (surface and perhaps also infauna) at these sites is caused by the enormous variation in barnacle coverage on the cobbles in each quadrat. This variation is consistent within years not only among tidal levels but among sites, as shown in Figure 12. Barnacle cover is very sparse in the High zone and is not plotted, but in the Mid, Low, and Very Low zones there is a large and consistent alteration among years between ‘good years’ and ‘bad years’ for barnacles. This variation has also been seen at other sites in the Sound, e.g. Possession Point at the south end of Whidbey Island (Dethier and Berry 2009), which has shown this pattern since monitoring began in 1999. The barnacle cover each year is a clear function of recent recruits (probably over the previous 9 months), although sometimes cobbles are dominated by tiny barnacles and sometimes by larger ones. Most of these cobbles probably roll over in winter storms or large boat wakes, thus killing the crop of barnacles that had been on the top. The data imply that recruitment of barnacles regularly alternates from high to low between years, although we know of no physical or biological reason for this pattern. Abundance of barnacles on the cobbles, in turn, potentially affects many other species; algae recruit well in the rough spaces on and between barnacles, a variety of mobile invertebrates take advantage of the microhabitats created, and abundances of barnacle predators such as whelks and *Onchidoris* nudibranchs clearly increase. Dying barnacles may also create shell hash and organic matter that affect infaunal composition and abundance, but this would be harder to demonstrate.

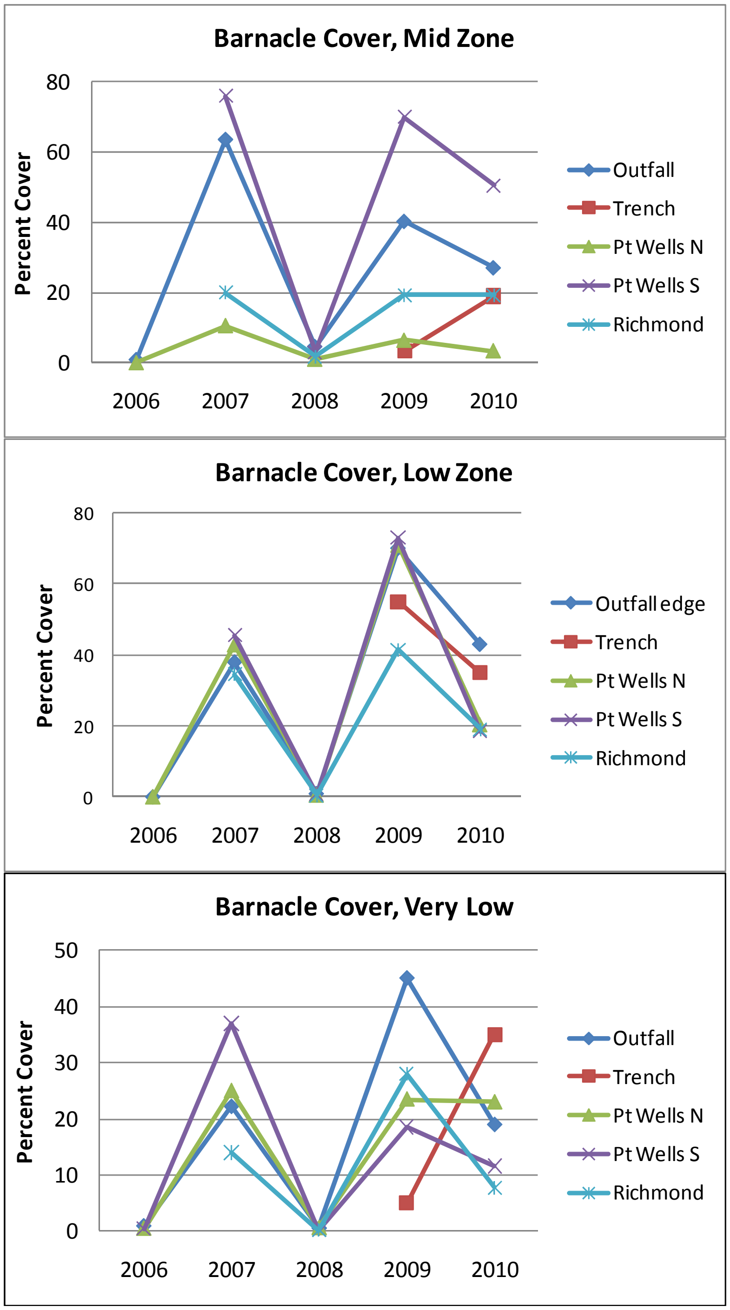

Figure 12. Mean barnacle cover values for each year among the 10 samples per transect (5 in 2009 and 2010 at Outfall and Trench).

Abundances of other organisms often showed similar interannual variation. Eelgrass, *Zostera marina*, was present in small amounts in the Very Low zones of all 4 sites, but was most abundant at Pt Wells South. Figure 13 shows its abundance in quadrats over the 5 years of sampling. It appears to undergo dramatic changes in cover, but there is a more likely explanation; this species grows in discrete patches (Fig. 14), and quadrats thus usually had either a lot or no eelgrass. It is likely that in 2006 and 2010 the randomly placed quadrats just did not 'hit' any of the patches, whereas they did in the other 3 years.

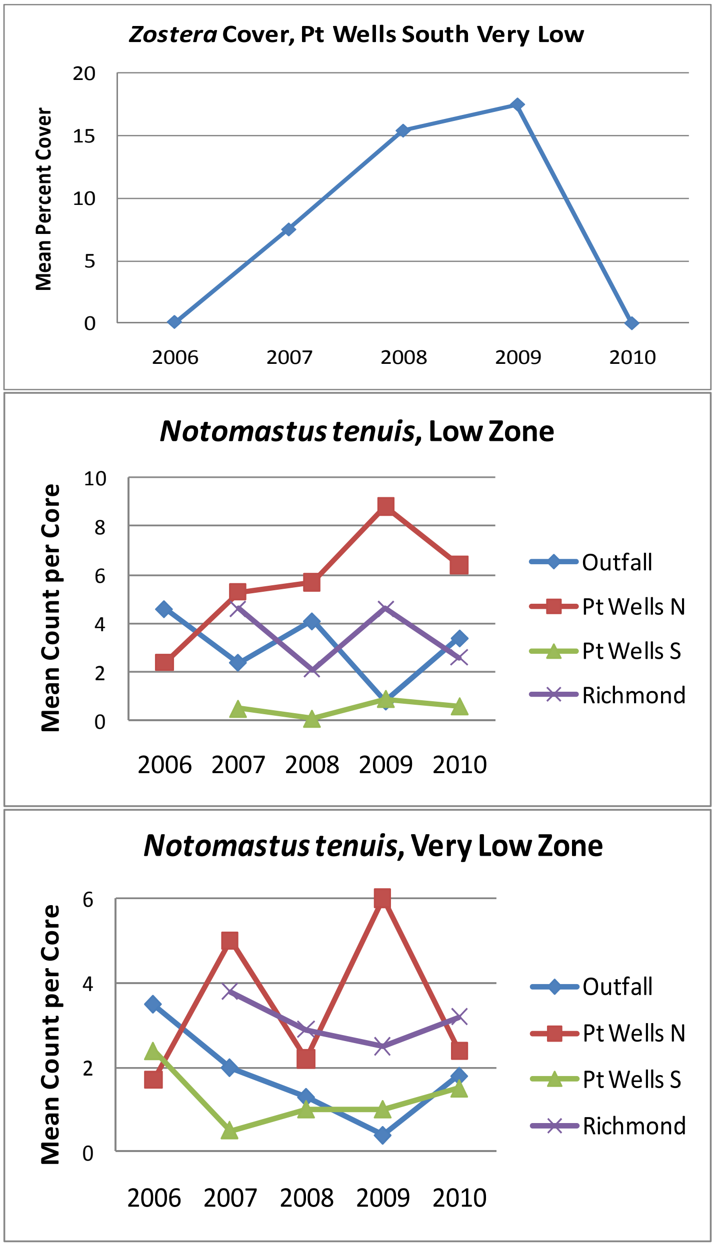

Figure 13. Abundances of a surface organism (eelgrass, top panel) and a common infaunal polychaete (a capitellid, middle and lower panel) showing normal interannual variation.

Figure 14. Transect at Point Wells (June 2008) showing patches of *Zostera* and sand.

The abundances of infaunal organisms could also be patchy, although generally not to the degree of *Zostera*. One of the most common polychaetes found in these sites was the capitellid *Notomastus tenuis*. Its abundances, even in unimpacted transects, routinely varied among years by a factor of 2-3 (Figure 13).

Different tidal levels varied in the amount of change their communities underwent from year to year. In Figure 15, each point represents the biotic community for one transect. A PERMDISP analysis shows that the dispersion among communities, or the spread of points in multivariate space in the different years, varies highly ($p = 0.001$) among tidal levels. Dispersion was highest for the High and Mid zones, less for the Very Low zone, and lowest for the Low zone; that is, the biota in the Low zone transects were more similar to each other from year to year than were the biota in the transects at other levels. Much of this variation probably relates to site-to-site and year-to-year differences in sediments (see next section); Very Low substrates, for example, ranged from 60-90% sand among sites, and High transects had waves of sand moving onto them in some years.

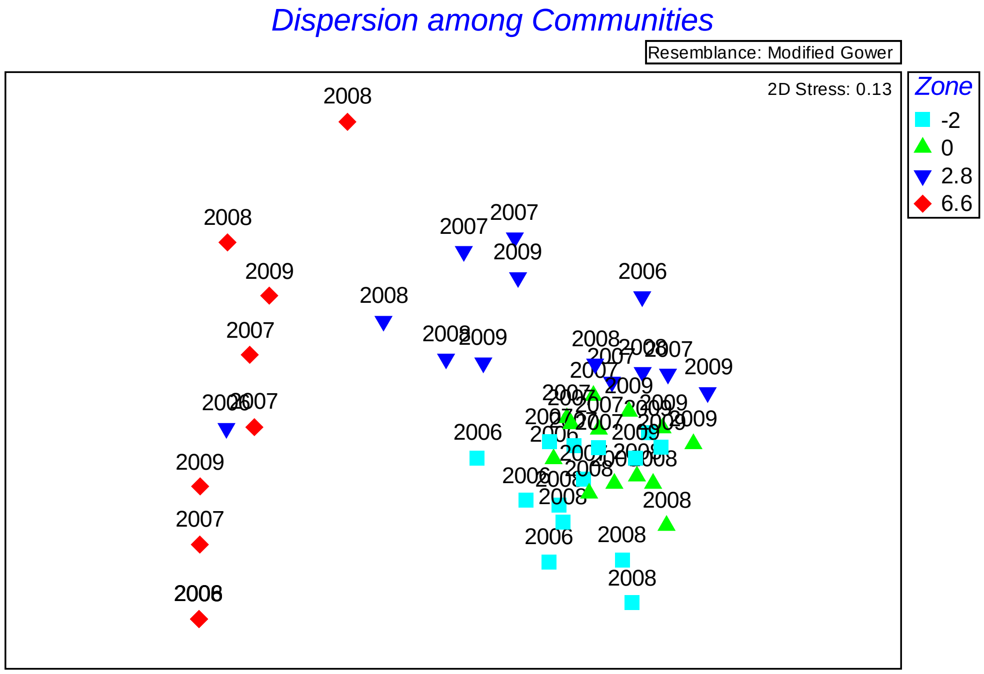

Figure 15. MDS analysis illustrating the results of a PERMDISP analysis of the differences in biota among transect-years in 2006-2009 (non-impact transects only), color-coded by tidal zone. Each point represents the centroid (the point lying in the center of the multivariate data cloud) for the 10 samples from one transect's biota in one year.

Physical Conditions at the Transects

Substrate (sediment) types were quantified both as surface estimates of cobble and sand in quadrats, and in samples collected for laboratory analyses of grain sizes (see Methods); data through time from both methods are illustrated in Figures 16 and 17. The grain size data (Fig. 16) lumped all larger grain sizes (less than phi -1: granules, pebbles, and cobbles) into "gravel+", making that category not comparable to the surface "cobble" category in Figure 17. Both methods used approximately the same "sand" grain size, however, of ca. 2-4 mm (phi -1 to 4). Overall, there was a rough positive correlation between per-transect averages of sand abundance calculated as percent cover on the surface vs. dry weight in the sediment, with $r^2 = 0.24$.

Sediment types differed distinctly among tidal levels, and to a lesser extent among sites and years. The High zones at all sites were characterized by small, relatively unstable pebbles (see Fig. 3b), with very little of the larger cobble that helps to stabilize the substrate at all the lower levels, and by highly variable amounts of sand among years (green bars in Fig. 16, right column in Fig. 17). Our attempts to permanently mark High transects with stakes failed at all sites, probably due to the sediment shifting from year to year (and among seasons). The coarse sediment at this level means that it holds little water, and the zone is submerged for relatively short periods per day, making it subject to large swings of temperature and moisture. These characteristics, along with the temporal instability, make it a very stressful environment for marine organisms. The Mid zones at all sites were characterized by a mix of sand, pebbles, and cobbles. The grain size data suggest relative stability among years except at the Pt Wells North site, but the surface data again show high year to year variability. The surface data suggest that the sites were relatively good ‘replicates’ of each other at this level; sites were chosen to be substrate-matched in the Mid and Low zones in particular. Although not clear in any of our quantified parameters, the Mid zone at Pt Wells South differed from other Mid zones in being less steeply sloping; this transect ran along the broad shallow spit that formed the south portion of the Pt Wells area (south of the Outfall area in Figure 2). This gentler slope may have made the substrate here more stable than the Mid zone in other areas.

The Low zone at all sites was characterized by patches of cobble and sand; the Low transect at Richmond Beach had more surface sand than the other areas (Fig 16). Another clear pattern in the surface data was that in 2009 there was more cobble than in other years; the fact that this happened at Richmond as well as at the three Pt Wells transects suggests that this was not a construction-related change but a natural one, e.g. from storms the previous winter pulling more sand offshore at all sites.

The Very Low zone, like the Low zone, had patches of cobble and sand, but as with many beaches in Puget Sound, sand becomes more prevalent at this level. All transects had some eelgrass inhabiting the patches of sand. The grain size data show a much greater dominance of sand at Richmond than at the other sites, but the surface data show that there were still cobbles in this transect; the large sand proportion in the grain size data suggest that the subsurface sediment was probably purely sand rather than a mix of many grain sizes as in other sites and zones.

Figure 16. Summary for all gathered samples of the grain size analyses conducted by the King County Environmental Laboratory. Very little clay or silt was found at any sites or dates.

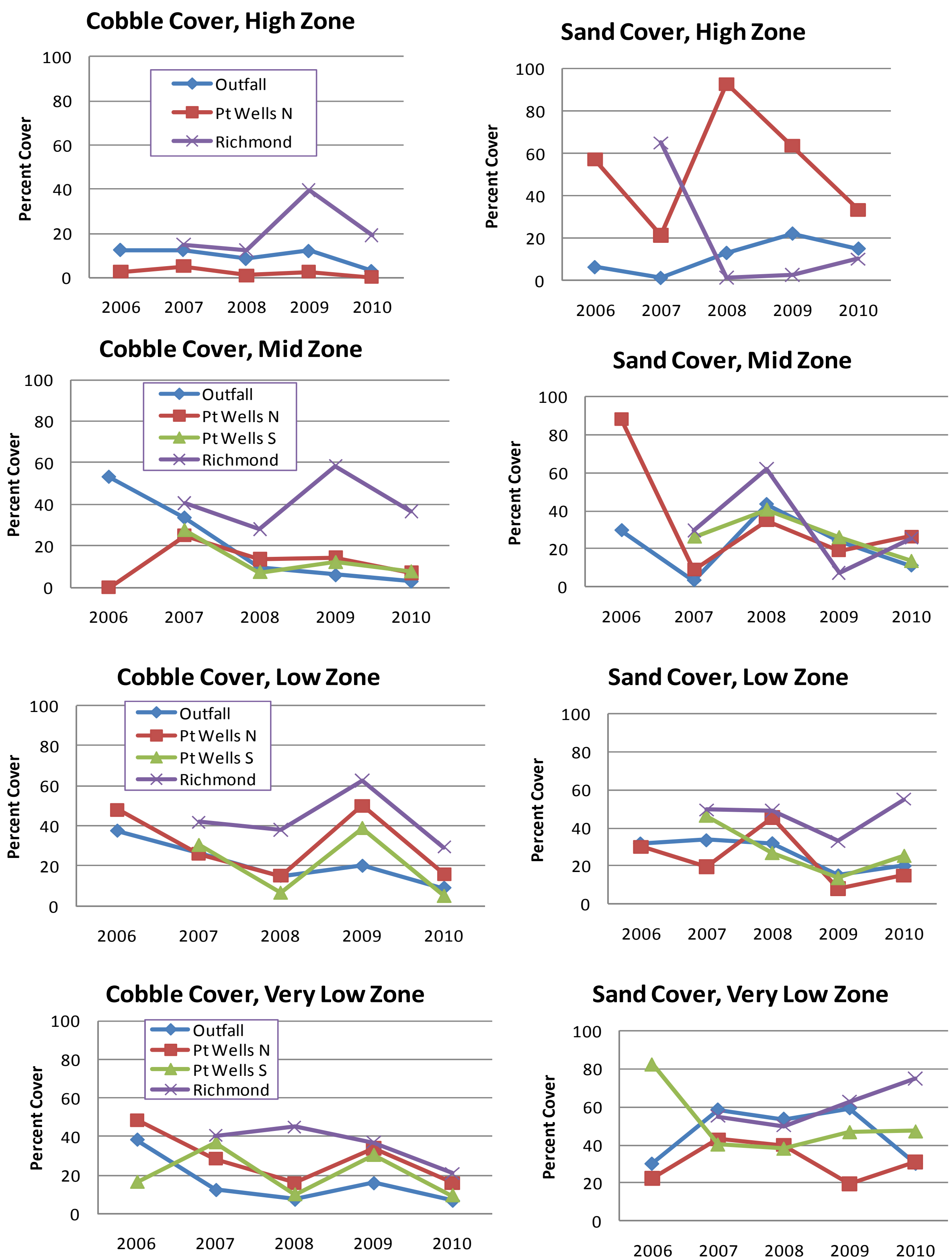

Figure 17. Abundances of surface cobble and sand measured in quadrats on all sampling dates.

Temperatures and salinities were measured on each sample date both in the shallow water near each site and in the porewater of 3 holes dug in each transect. Mean values for each are illustrated in Figure 18; most holes in the High zone were dry on most occasions, so no data are shown. Not surprisingly, both porewater temperatures and salinities are more variable year to year than the nearshore conditions, which are probably close to the Sound as a whole. Temperatures nearshore had an overall average of 12.9°C, with a range of 10.2-17.1, while porewater averaged 14.9°C, with a range of 11.1 to 24.4. Nearshore salinity averaged 28.4 psu, with a range of 26.8-29.4, while porewater salinity averaged 24.2 psu, with a range of 16.0-29.1. Thus for these June data, porewater temperatures were higher (and much more variable) and salinities were lower (and much more variable) than conditions just offshore. Temperatures are heavily influenced by sun hitting the beach surface and warming the porewater, while the porewater salinities reflect groundwater draining down from the land (Dethier et al. 2010). The salinity effect is especially readily seen, perhaps paradoxically, in the Very Low and Low zones, which generally had lower salinities than the Mid zone; a common pattern observed at many sites around the Sound is that the groundwater lens comes to the sediment surface (during low tide) near the low water mark. Both porewater temperature and salinity measurements are also influenced by when in the tidal cycle they were measured on sampling dates; temperatures in the Very Low zone are consistently close to nearshore temperatures because that zone is only exposed briefly, and conditions were measured right after exposure to the air. The high variability in the porewater conditions is presumably stressful for infauna in the beach sediments and probably affects the suite of species found at the different tidal elevations (Dethier et al. 2010).

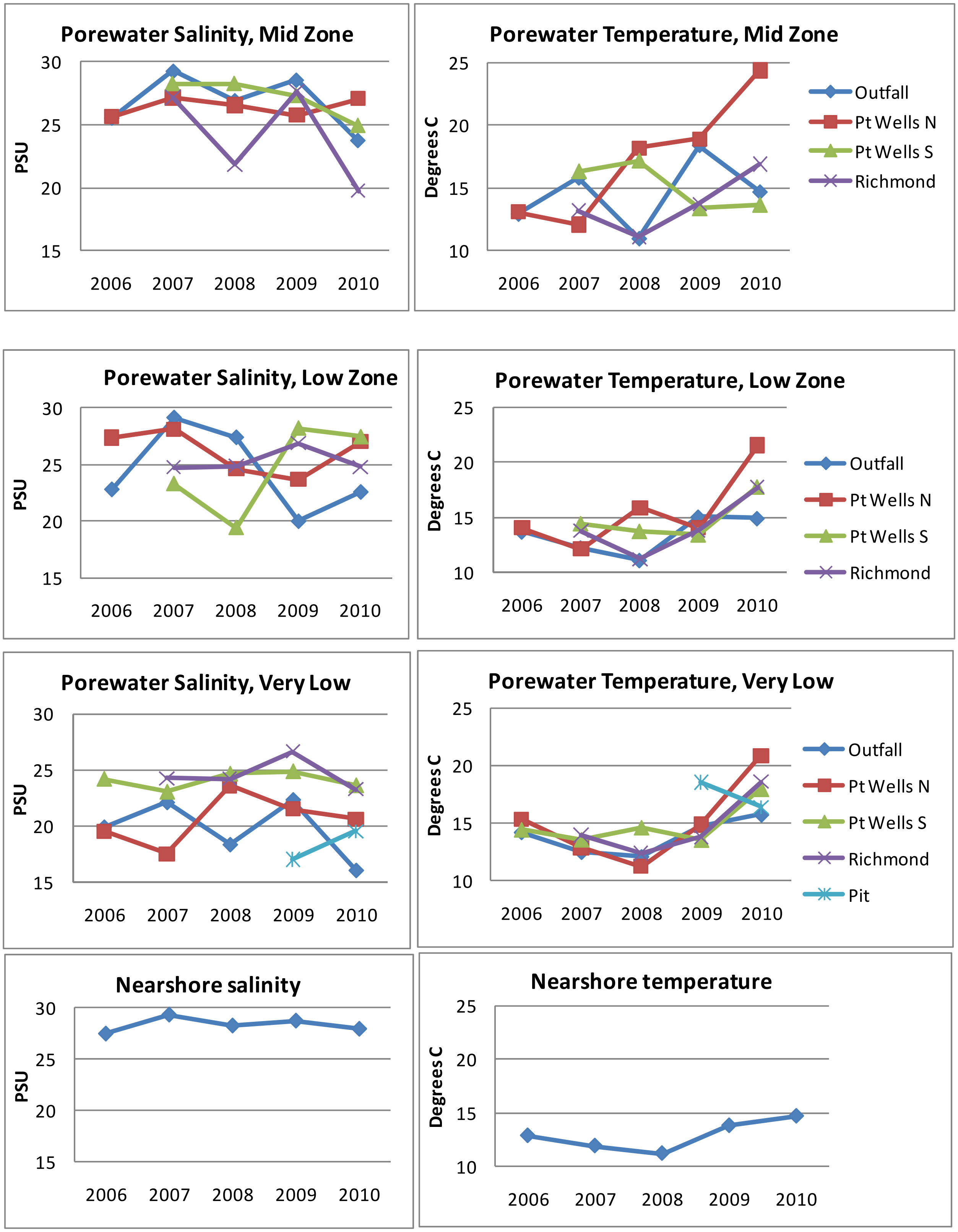

Figure 18. Mean salinities and temperatures in porewater on each transect and in nearshore waters on each sampling date.

When the 6 independently measured physical variables (Cobble and Sand cover, porewater temperature and salinity, nearshore temperature and salinity) are treated as ‘species’ in an ordination analysis, and all tidal levels are examined together, a dominant pattern of year-to-year variation over site-to-site variation is visible, as is the case for most of the biotic data. Sites overall showed poor separation in terms of physical variables (R = 0.063), Zones somewhat better (R = 0.207), and Years the best (R = 0.452), with the latter pattern visible in Figure 19. Examining the physical data by zone shows this even more clearly – ANOSIM tests for each zone were highly significant for differences among Years (R values = 0.34 to 0.49) but weakly or not significant for Sites (R values = 0 to 0.17). Thus while sites did differ physically, even when comparing within a zone, the greatest source of variation in physical conditions was again interannual.

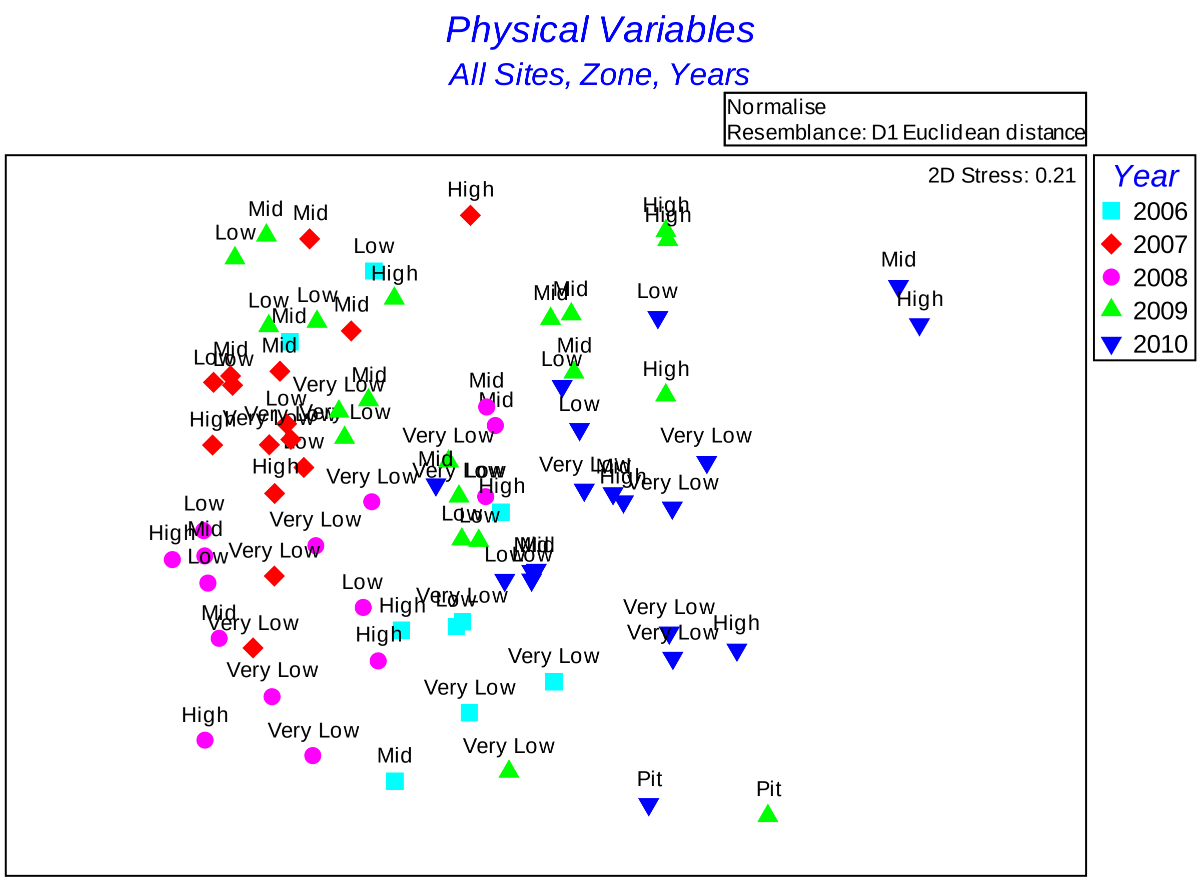

Figure 19. MDS plot of similarities among transects in the physical variables measured.

The correlation of physical factors with biotic communities can be examined statistically by using RELATE analyses to compare the patterns of resemblance among physical samples (e.g. as in Figure 19) with patterns of resemblance among biotic samples (as in Figure 9). If these resemblances (e.g. the relative positioning of points) were identical, then the RELATE test would give a value of rho = 1.0, indicating perfect correlation between these patterns and suggesting (but not proving) a causative relationship. These analyses could not be done with the High zone biota because samples were often devoid of biota. For the Mid zone, there was not a significant relationship between the physical variables and the biota (rho = 0.15, p = 0.11). There was, however, for the Low zone (rho = 0.17, p =0.034). A BEST analysis allows us to examine which physical variables best explain this correlation. For the Low zone, the physical variables that most closely matched variation in the biotic community were a complex combination of percents of cobble and sand plus nearshore salinity and temperature; no one variable correlated well. For the Very Low zone (rho = 0.427, p = 0.02), the best variables were a combination of cobble, sand, and nearshore salinity. The best single variable was cover of sand (rho = 0.34). In other analyses of Puget Sound biota, the cover of sand has frequently been shown to be correlated with low species richness (Dethier 2005, Dethier and Berry 2009, 2010).

Evidence of Impacts and Community Recovery at Outfall Site

Sampling for biotic impacts caused by cutting the trench through the beach at the Pt Wells Outfall site was done almost exactly one year and two years post-trenching. Data collection followed standard pre-impact protocols except that transects at the Outfall site were subdivided into 5 samples taken just outside the (narrow) trenched corridor (“Edge” samples) and 5 inside the trenched corridor (“Trench”). In addition, in the Very Low zone an additional 5 samples were taken in the “Pit” bisecting the Very Low transect (see Methods and Figures 4 and 5). Figures illustrating post-impact sampling thus distinguish Edge and Trench samples for most levels. Figures 20, 22, 26, and 29 illustrate overall patterns of similarity in biotic communities at all sites and years for each tidal level. As in the pre-impact data, all zones show major shifts in community structure from year to year, with most sites shifting in similar ways; the challenge is thus differentiating impacts caused by the construction from natural interannual change.

High Zone

In the High zone (Mean Sea Level, +6.6’), we did not distinguish Edge and Trench samples, as a clear trace of this impact could not be seen on the surface after a year (unlike at the other levels); samples from the Outfall High transects in 2009 and 2010 are labeled as “Post Construction”. The MDS plot (Fig. 20) of these High data show year to year variation (colors) but also a fair amount of site to site variation, for example at the Outfall site in 2008 (pre-construction) which was very different biologically from the other transects that year. Three transects had to be omitted from this analysis because no organisms were found in any samples, and thus similarities with other transects could not be calculated for the MDS analyses: these were Pt Wells North 2006 and 2008, and Pt Wells Outfall 2006. The 2009 ‘Post construction’ biota were clearly different from the other 2009 samples, although this is actually because that transect had more organisms than the closely adjacent Pt Wells North or the more distant Richmond site (8 species total at the Outfall site, including very sparse barnacles and two algal species and snails on cobbles, and one polychaete species in the sediment). The 2010 biota grouped more closely with the other 2010 transects. However, the biota in all these transects are so depauperate and so variable that these results are not very meaningful.

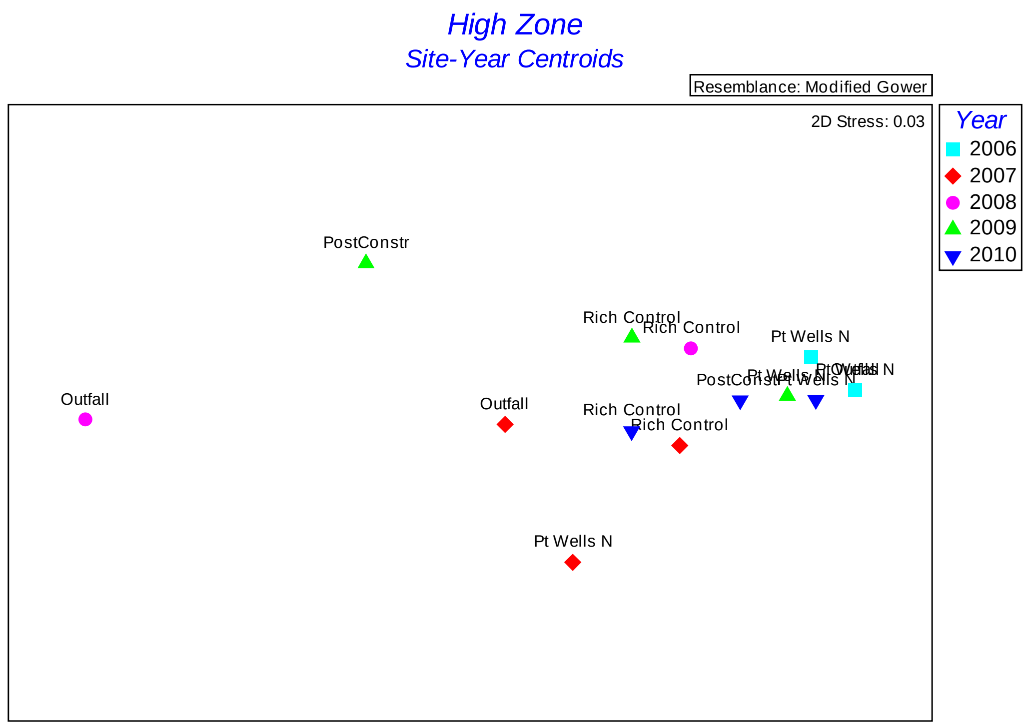

Figure 20. MDS analysis illustrating similarities in biota among transects in all years in the High zone. Each point represents the centroid (the point lying in the center of the multivariate data cloud) for the 10 samples from one transect's biota in one year.

Figure 21 illustrates species richness in the High zone at all 3 sampled sites. Richness was always low (contrast the 0-10 species with 20-50 species in the Mid zone) and highly variable with time. As mentioned above, on three occasions we found no living organisms in any of the 10 samples per transect. When species were found, the "community" often consisted of only 1-2 individuals, or very low percent cover on one cobble in one quadrat. Thus we did not attempt further statistical analyses of data from this zone.

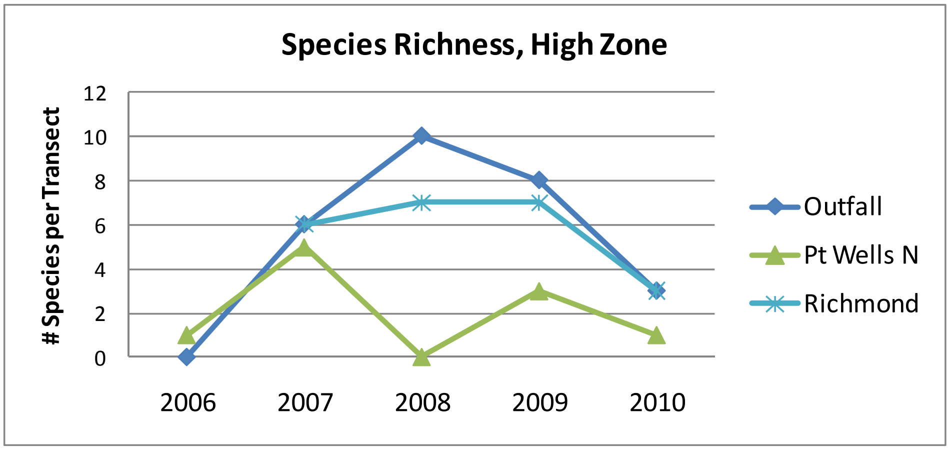

Figure 21. Species richness in transects in each year. In the High zone, no transects were run at Pt Wells S, and 'edge' vs 'trench' areas were not distinguished post-impact.

Mid Zone

Mid zone samples were much richer in biota than High zone, making analyses more straightforward. Figure 22 illustrates patterns of community similarity for all sites and years. Unlike in many other analyses, the biota in transects do not group together clearly by years; each year's points (colors) are rather widely scattered. An ANOSIM test of pre-impact data (2006-2008, to avoid confounding impact effects) showed that years were not significantly different ($R = 0.21$, $p = 0.14$), but sites were ($R = 0.43$, $p = 0.02$); these clear differences among sites can be seen when the points in the MDS plot are re-coded to illustrate sites, as shown in Figure 23. Note that Pt Wells South was not sampled until 2007 (see Study Sites). In general, the Pt Wells South transect (whose data points cluster at one edge of the plot) was characterized by high abundances of many species, such as barnacles, limpets, hermit crabs, mussels, and polychaetes such as *Mediomastus*; it was consistently the richest of the Mid-zone transects (see below). The Outfall site, directly to its north, had many of the same species but usually in lower abundances (Outfall points cluster separately but near South points in Figure 22). The Pt Wells North site, immediately to the north of the Outfall, had both fewer species and lower abundances than the Outfall site. The Richmond site differed in both species and abundances from the Pt Wells sites.

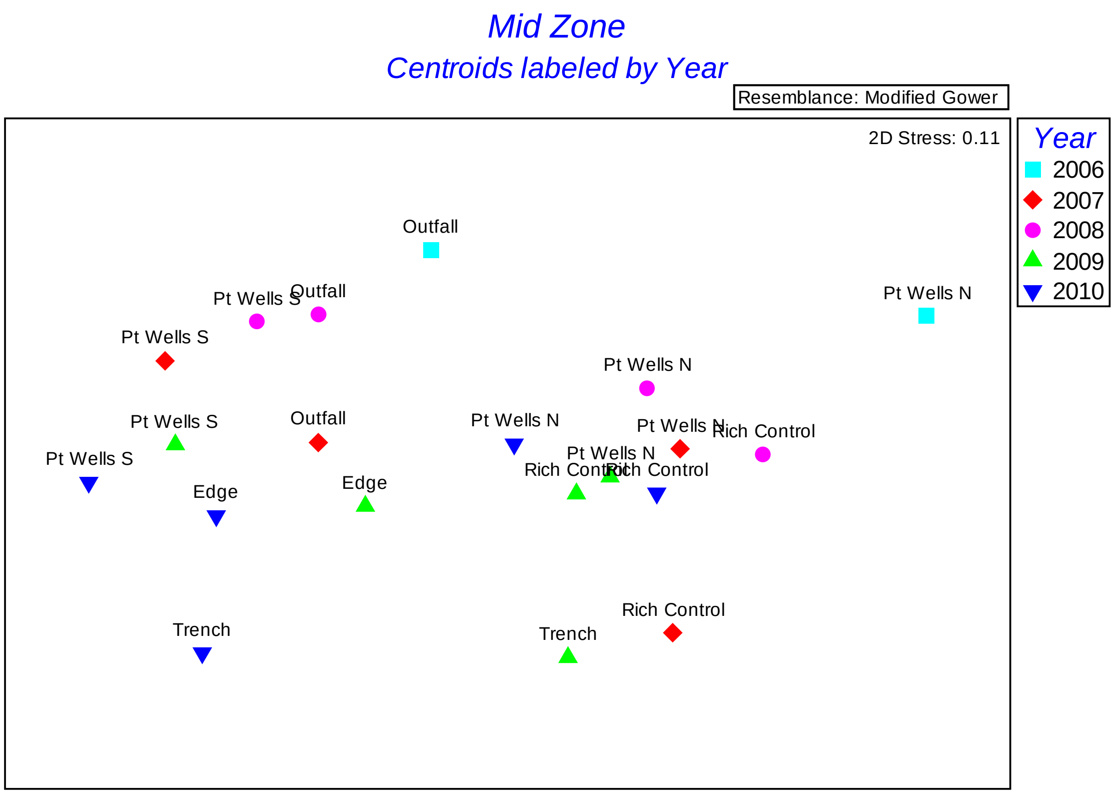

Figure 22. MDS analysis illustrating similarities in biota among transects in all years in the Mid zone. Each point represents the centroid (the point lying in the center of the multivariate data cloud) for the 10 samples from one transect's biota in one year, except for Edge and Trench points which represent centroids of 5 samples.

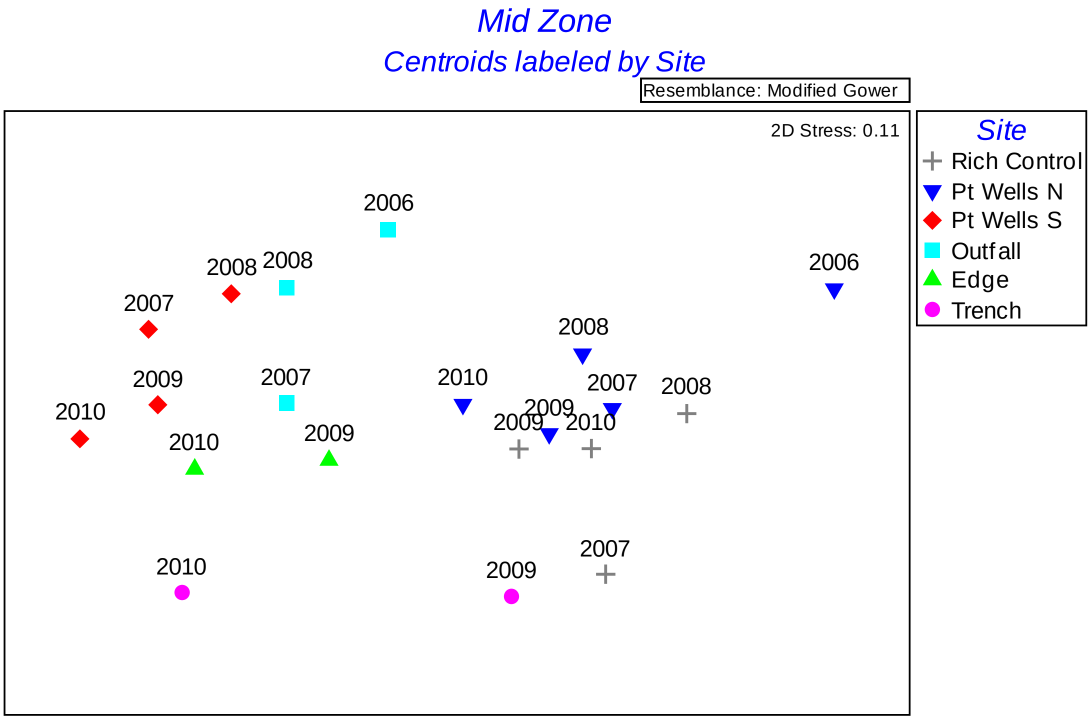

Figure 23. MDS analysis illustrating similarities in biota among transects in all years in the Mid zone. Each point represents the centroid (the point lying in the center of the multivariate data cloud) for the 10 samples from one transect's biota in one year, except for Edge and Trench points which represent centroids of 5 samples.

A BACI (Before-After, Control-Impact) test was run on the community-level dataset from the Mid zone for all 4 sites and all 5 years. For this test to demonstrate that there was a meaningful impact of an event (in our case, an effect of trench construction on the biotic community at a given tidal elevation), it needs to show a statistically significant *interaction* between the Before-After differences and the Control-Impact differences. That is, *if there is an impact, we expect the degree or direction of change in the biotic community from "before" (2006-8) to "after" (2009-10) to be different for the impact site than it is for the control sites*. The BACI test for the Mid zone communities showed (as suggested by Fig. 22 and 23) that there is a significant effect of site and a significant effect of year on the composition and abundance of species (i.e., high site-to-site and year-to-year variation), but no significant interaction term (Table 1); that is, the post-construction Outfall communities, while somewhat different from the other sites and other years, are not clearly different from the pre-construction communities, or at least not in ways that are distinguishable from changes in the reference sites.

Table 1. Results of PERMANOVA BACI analyses.

Tidal Elevation	**Factor**	**F statistic**	**df**	**p**
Mid	Control-Impact (C-I)	0.480	1	0.87
	Before-After (B-A)	1.191	1	0.34
	Site(C-I)	7.203	2	0.0003
	Year(B-A)	2.181	3	0.0015
	C-I x B-A	1.091	1	0.36
	Pooled	2.922	9	0.0001
	Residual		162	
Low	Control-Impact	0.432	1	0.95
	Before-After	1.973	1	0.14
	Site(C-I)	3.270	2	0.0002
	Year(B-A)	4.022	3	0.0001
	C-I x B-A	0.976	1	0.48
	Pooled	2.588	9	0.0001
	Residual		162	
Very Low	Control-Impact	0.435	1	0.95
	Before-After	1.359	1	0.24
	Site(C-I)	2.512	2	0.002
	Year(B-A)	3.835	3	0.0001
	C-I x B-A	0.729	1	0.73
	Pooled	2.537	10	0.0001
	Residual		171	

The lack of an apparent construction effect in the BACI analysis could be due to two issues. As with standard parametric ANOVAs, the PERMANOVA BACI test compares the variation among samples within a group to the variation among all samples; thus when the variation within a group is high (as in communities within the control transects among all years), it is hard to detect any significant effects. Second, the test is somewhat confounded by calling both 2009 and 2010 data “After”, because if there was recovery towards the reference state in 2010, this would ‘dilute’ the clarity of the construction effect. Thus we next ran one-factor (within year) PERMANOVA tests just between Outfall samples and the reference site that was most similar to the Outfall site pre-impact, which was Pt Wells South. We tested for differences between those two transects in 2008 (pre-construction), 2009, and 2010 (Table 2). In the Mid zone, the biota in the Outfall transect (all 10 samples pooled) were different from those in the Pt Wells South transect in all 3 years. When the post-construction Outfall data are divided into Edge samples versus those in the Trench, however, a different pattern emerges. In 2009, one year post-construction, the Edge communities were different from those in the Trench and both were different from those in the adjacent control area. By 2010, however, the Edge was no longer significantly different from either of those other areas, although the Trench was still different from the control. These results suggest that the construction had an initial impact on the biota, but the communities were showing clear signs of recovery after 2 years.

Table 2. P values from pairwise (site-site) comparisons from one-way PERMANOVA tests of biotic communities just before (2008) vs. 2 years after construction. PWS = Pt Wells South.

Level	Year	Outfall v PWS	PWS v Edge	PWS v Trench	Edge v Trench
Mid	2008	0.003	--	--	--
	2009	0.001	0.012	0.001	0.031
	2010	0.003	0.132	0.002	0.109
Low	2008	0.001	--	--	--
	2009	0.001	0.027	0.002	0.54
	2010	0.044	0.072	0.044	0.02
Very Low	2008	0.236	--	--	--
	2009	0.020	0.068	0.004	0.008
	2010	0.027	0.062	0.017	0.137

Examination of the biotic data from these sites and years show the sorts of community changes that occurred both post-construction and during recovery. In 2009, the Edge samples contained a subset of the species found in the Pt Wells South samples, but some organisms were lacking, such as chitons, littorinid snails, and sphaeromid isopods. Barnacles were present, but in reduced abundance. The Trench biota in 2009 was quite depauperate (Fig. 24), with very few algae except for the disturbance-adapted green *Acrosiphonia*, few surface-dwelling invertebrates such as limpets, anemones, isopods, and hermit crabs, and few infauna such as clams or the common polychaete *Spio*. By 2010, although species and abundances varied to some extent among transects, the Trench samples had regained many species including both surface-dwellers (anemones, mussels, hermits, whelks) and infaunal polychaetes (nereids, spionids, and capitellids).

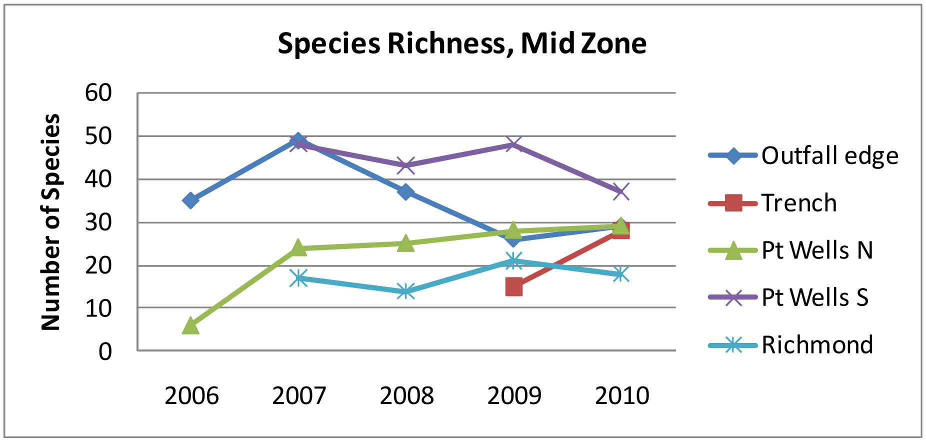

Figure 24. Species richness in transects in each year. Richness values from ‘Edge’ and ‘Trench’ are from N=5 samples in each case. Note: richness values for N=5 samples are expected to be ca. ¾ of full 10 samples.

Because species richness appeared to be a variable showing demonstrable effects of the construction, we did one further set of analyses on this parameter. For each tidal level (Mid to Very Low) we ran an additional BACI analysis on species richness – the univariate parameter that 'summarizes' (and simplifies) the multivariate whole-community responses to the disturbance. Table 3 summarizes these analyses, and Figure 25 summarizes the Mid-zone species richness data into changes through time in all the reference sites versus in the Outfall site. In contrast with the multivariate BACI analyses, the analysis for species richness shows a highly significant interaction term for the Control-Impact versus Before-After test. Sites and Years are still significantly different, but despite this variation, the trenching impact is visible. Figure 25 shows the source of this effect; in the Outfall, richness clearly dropped from Before to After, whereas the Controls stayed relatively stable (after starting at a low value in 2006).

Table 3. BACI analyses run with PERMANOVA using the univariate variable species richness rather than multivariate community data.

Tidal Elevation	**Factor**	**F statistic**	**df**	**p**
Mid	Control-Impact	0.289	1	0.73
	Before-After	0.190	1	0.69
	Site(C-I)	119.7	2	0.001
	Year(B-A)	4.687	3	0.02
	C-I x B-A	41.86	1	0.001
	Pooled	0.850	9	0.55
	Residual		162	
Low	Control-Impact	0.007	1	0.915
	Before-After	31.11	1	0.01
	Site(C-I)	3.847	2	0.073
	Year(B-A)	0.520	3	0.71
	C-I x B-A	17.367	1	0.003
	Pooled	1.473	9	0.154
	Residual		162	
Very Low	Control-Impact	2.641	1	0.17
	Before-After	3.426	1	0.103
	Site(C-I)	4.747	2	0.086
	Year(B-A)	5.700	3	0.044
	C-I x B-A	0.104	1	0.986
	B-A x Site(C-I)	7.756	2	0.046
	C-I x Year(B-A)	11.872	3	0.011
	Site(C-I) x Year (B-A)	0.479	5	0.778
	Residual		171	

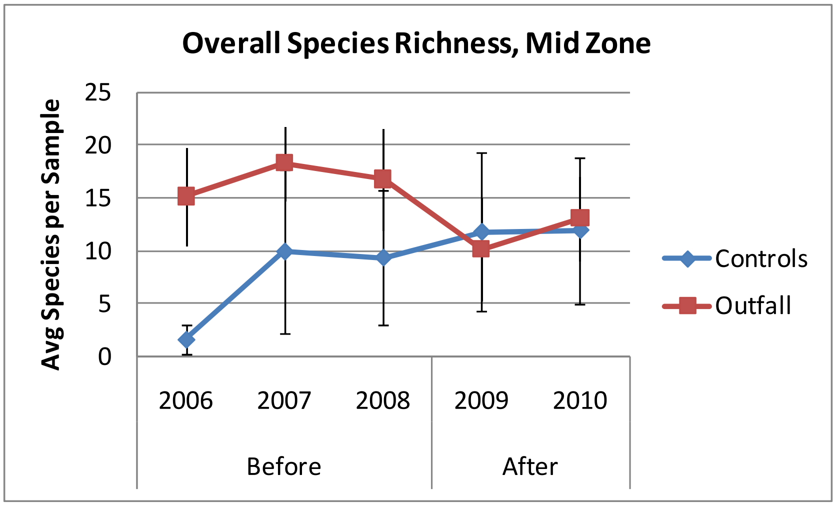

Figure 25. Richness through time in the Mid zone, simplified to the mean values among all the Control samples versus the Outfall samples. Each point is the mean (and one s.d.) per-sample richness for all the samples in that year at that level.

Low Zone

Patterns of community similarity for the Low zone for all sites and years are shown in Figure 26. At this elevation (in contrast to the Mid zone), the biota in the transects group together very clearly by years, with communities shifting in similar ways from year to year. An ANOSIM test of pre-impact data (2006-2008) showed that years were highly different ($R = 0.96$, $p = 0.002$), and different years within each site show no tendency to be similar to each other ($R = 0$, $p = 0.53$). As described above, much of this interannual variation is driven by surface flora and fauna rather than by infauna. The figure also shows that even the Edge and Trench biota group fairly closely with the other sets of samples for both 2009 and 2010.

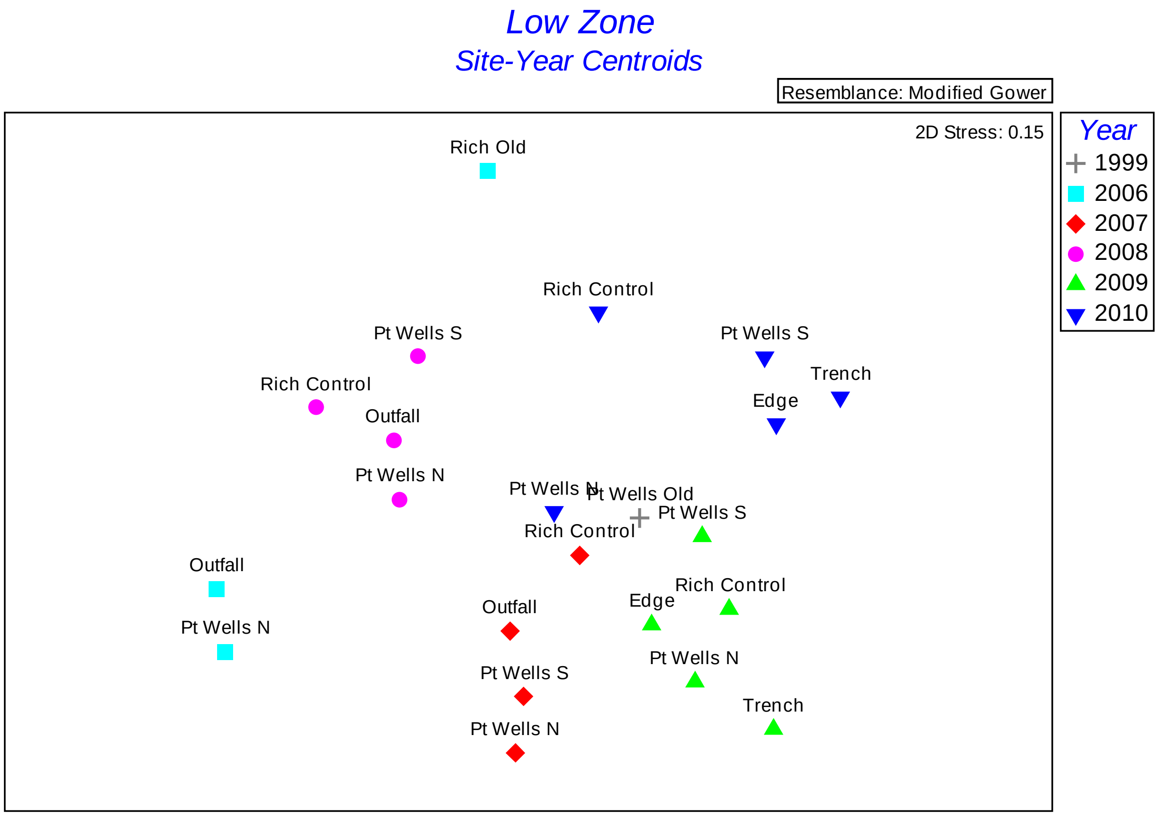

Figure 26. MDS analysis illustrating similarities in biota among transects in all years in the Low zone. Each point represents the centroid (the point lying in the center of the multivariate data cloud) for the 10 samples from one transect's biota in one year, except for Edge and Trench points which represent centroids of 5 samples.

The BACI test results for the Low zone communities were very similar to those from the Mid zone (Table 1). There were significant effects of site and of year but again no significant interaction term that would demonstrate an overall effect of construction that could be differentiated from the other sources of variation in the system. However, as with the Mid zone, when we ran one-factor (within year) PERMANOVA tests just between Outfall samples and the Pt Wells South samples, we found clear evidence both of a construction effect and of recovery from 2009 to 2010 (Table 2). In 2009, the Trench samples were similar to the Edge samples but very dissimilar to the adjacent control area. By 2010, Edge samples were no longer significantly different from the control and the Trench was much more similar to the control than in the previous year. In 2009 the Low zone at Pt Wells South contained many species found in neither the Edge nor the Trench (note the contrasts in richness in Figure 27), including both surface biota (several algae, mussels, chitons) and infauna (a variety of clams, tube-building phoronids and oweniid polychaetes, and mobile polychaetes). By 2010 a variety of species had colonized both the Edge and Trench samples, including anemones, algae, several species of clams, whelks, and others. Species richness (Fig. 27) increased in both impacted areas but especially in the Trench between 2009 and 2010, while it declined in Pt Wells South (presumably as a result of normal interannual variation).

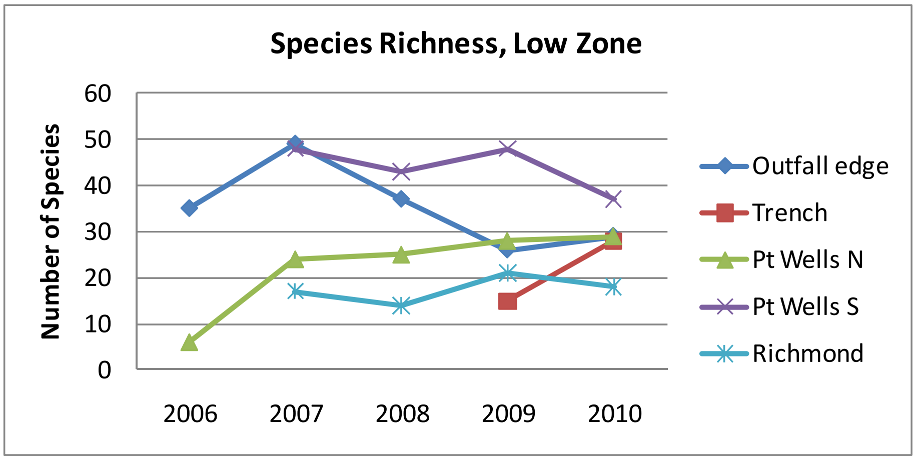

Figure 27. Species richness in transects in each year. Richness values from 'Edge' and 'Trench', are from N=5 samples in each case. Note: richness values for N=5 samples are expected to be ca. ¾ of full 10 samples.

As in the Mid zone, simplifying the data to look at just species richness and running a BACI analysis on this parameter demonstrated that there was a significant effect of the construction on richness (Table 3). Figure 28 illustrates that this significant effect arose from a different pattern than the Mid zone, where richness clearly dropped in the "After" period; for the Low zone, richness in the Outfall stayed very stable, but was significantly different than the Controls because richness there rose dramatically at that time. This increase is presumably not related to the construction but simply represents the normal year to year variation that is so evident in this zone (Fig. 10). 2009 was the year of highest barnacle abundance (Fig. 12) in the Controls, and richness often increased in those years.

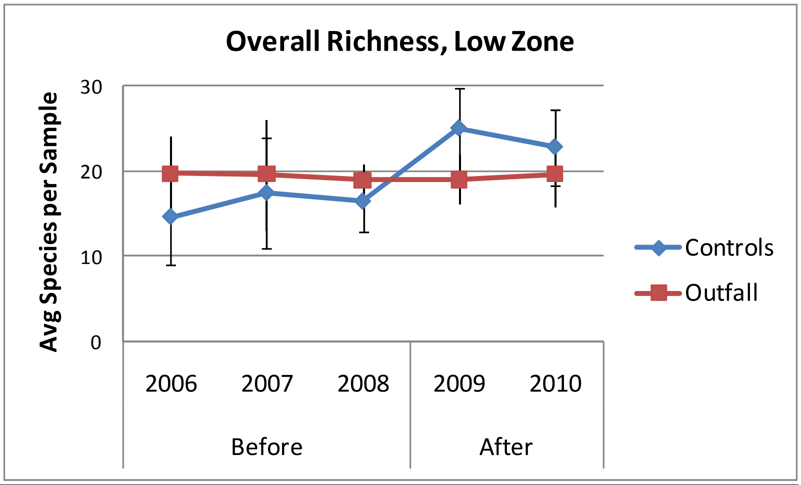

Figure 28. Richness through time in the Low zone, simplified to the mean values among all the Control samples versus the Outfall samples. Each point is the mean (and one s.d.) per-sample richness for all the samples in that year at that level.

Very Low Zone

Patterns of community similarity for the Very Low zone for all sites and years are shown in Figure 29. At this elevation (as in the Low zone), the biota in the transects group together clearly by years, with communities shifting in similar ways from year to year. An ANOSIM test of pre-impact data (2006-2008) showed that years were highly different ($R = 0.77$, $p = 0.001$), and different years within each site show no tendency to be similar to each other ($R = 0$, $p = 0.56$). The figure also includes three types of post-construction samples at the Outfall site; the Edge and Trench, as in the Mid and Low zones, but also the “Pit” samples (see Study Sites) which were about 0.5’ in elevation below the Trench samples. In 2009, the Edge samples clustered fairly closely with the control sites, the Trench was quite separate, and the Pit was extremely different from any other Very Low transects; the total biota found in 5 Pit samples consisted of 2 individual polychaetes (a Nereid and a Nephtyid, both mobile species). In 2010 the Edge and Trench were both similar to the other samples from that year and the Pit, while still dissimilar, was less of an outlier. By that time there were a few rocks at the edge of the Pit area (which was otherwise pure sand), bringing with them small amounts of ulvoid algae, barnacles, *Lacuna* snails, and *Laminaria* kelp; infauna consisted of some small *Tellina* clams and one nemertean worm.

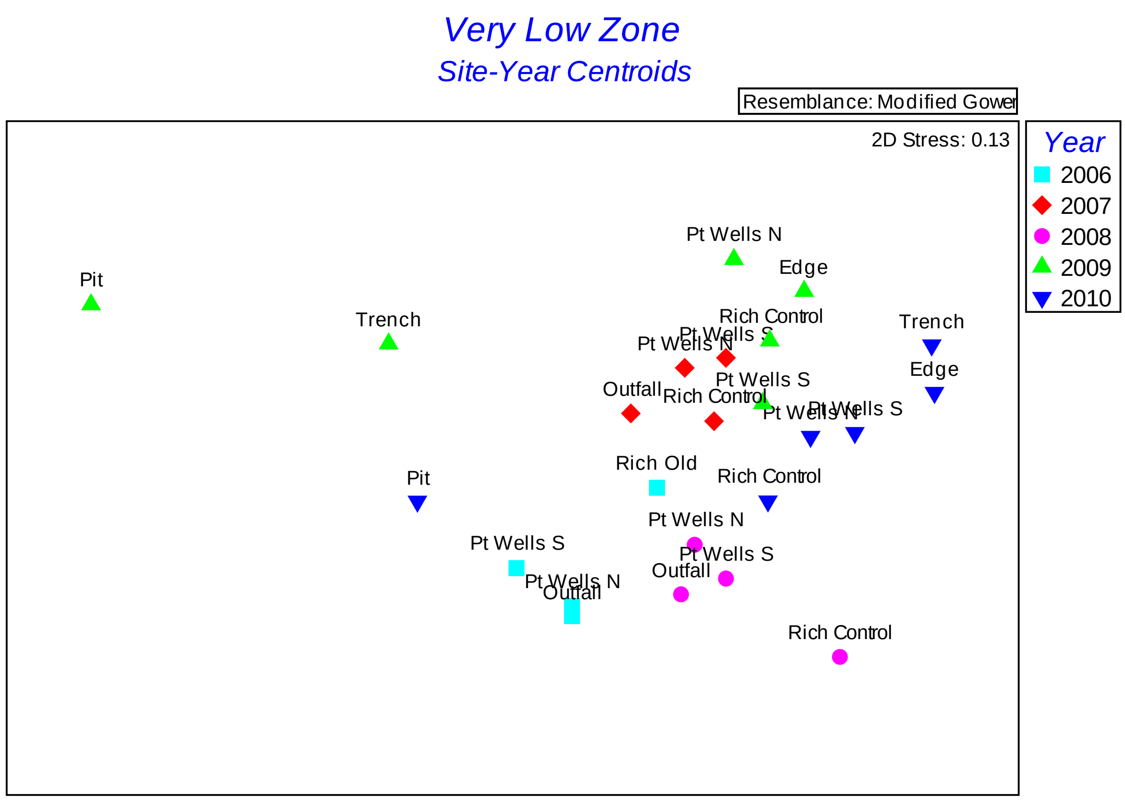

Figure 29. MDS analysis illustrating similarities in biota among transects in all years in the Very Low zone. Each point represents the centroid (the point lying in the center of the multivariate data cloud) for the 10 samples from one transect’s biota in one year, except for Edge, Trench, and Pit points which represent centroids of 5 samples.

BACI analyses were run without the Pit samples, since they were at a lower elevation and we have no controls for this zone. As in the Mid and Low zones, there was a significant effect of site and of year but no significant interaction term (Table 1). When we ran one-factor (within year) PERMANOVA tests just between Very Low samples in the Outfall and at Pt Wells South, we again found evidence of a construction effect and of subsequent recovery (Table 2). At this level, the Edge communities were not significantly different from those in the Pt Wells South samples in either year, suggesting either no construction impact or changes that were small enough to have largely disappeared within a year. In 2009 the Trench samples were different from both the Edge and from Pt Wells South. A year later the Trench was no longer significantly different from the Edge although it was still slightly different from the control samples.

As in the Low zone, the Trench was very depauperate one year after construction (see Fig. 30), containing small amounts of surface organisms including barnacles, ulvoid algae, hermit crabs, and *Lacuna* snails, and one polychaete species (a capitellid). The Edge samples and Pt Wells South were quite species-rich in both surface biota and infauna. By 2010 the Trench samples, as well as the Edge and Pt Wells South, had experienced a large recruitment of barnacles onto the cobbles, which also had populations of snails, isopods, algae, hermit crabs, and amphipods. Richness and abundance was still somewhat lower than the adjacent control, however (Fig. 30); most kinds of clams, larger tube-building worms, some red algae, and various other polychaete species were still absent.

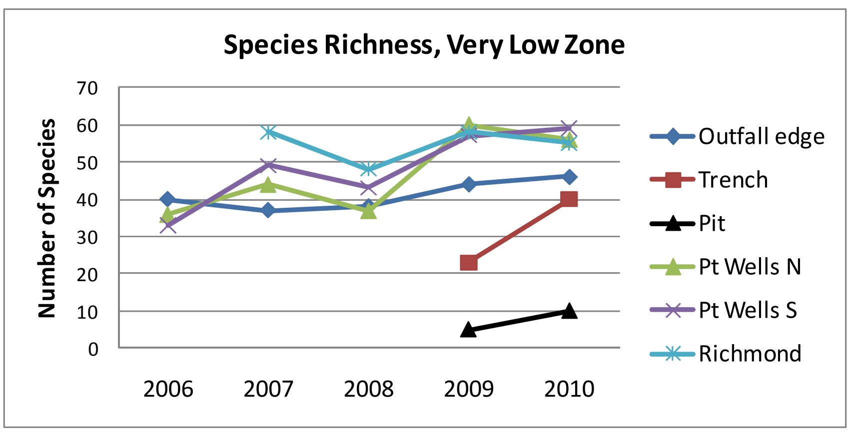

Figure 30. Species richness in transects in each year. Richness values from ‘Edge’, ‘Trench’, and ‘Pit’ are from N=5 samples in each case. Note: richness values for N=5 samples are expected to be ca. ¾ of full 10 samples.

Unlike for the Mid and Low zones, the BACI analysis on species richness did not demonstrate a significant construction impact (Table 3). Other interaction terms were significant, showing that richness changed substantially among sites and years, but not in a pattern that can be attributed to the effect of the construction. Figure 31 shows how variable richness was in the Controls among all years, and how it was often higher than in the Outfall corridor even before the impact year. Changes in the post-impact period (i.e. between 2009 and 2010) caused richness to converge in the two treatments (because of the large increase in richness in the Trench, Figure 30), making it statistically less likely to find a Before-After difference.

Figure 31. Richness through time in the Very Low zone, simplified to the mean values among all the Control samples versus the Outfall samples. Each point is the mean (and one s.d.) per-sample richness for all the samples in that year at that level.

Discussion

Interannual variation

The biota at all intertidal elevations in the beaches at the Brightwater Outfall site and in the unimpacted Control sites are characterized by high interannual variation, making it more difficult to quantify impacts of construction than if types and abundances of beach organisms were stable from year to year. This high variation is typical of Puget Sound beaches, however, and probably relates to natural variation in both physical and biological parameters that ultimately affect the plants and animals on and in the sediment.

One key variable that was demonstrated to change from year to year is the mix of sediment types, both visible on the surface in our sampling quadrats and subsurface in the grain size data collected by King County (Figs. 16 and 17). Puget Sound's beaches are geomorphically complex and dynamic (Finlayson 2006), with the sediments present at any one moment affected by type and rate of supply (from bluffs, streams, and other beaches "updrift"), and by seasonal and daily wave energy (e.g., winter storms tend to pull sand off beaches, leaving them steeper and coarser). We have found the amount of sand at MLLW at our long-term monitoring sites to vary highly from year to year, as sand moves vertically and alongshore. Cobble deposits (lag deposits: Finlayson 2006) appear to remain in relatively stable locations but may get temporarily covered with sand, killing much of the biota.

A second parameter showing high interannual variation is recruitment of organisms onto cobbles and into the sediment. Most algae and invertebrates inhabiting Puget Sound's beaches have a larval or reproductive stage that spends hours to weeks in the plankton in the Sound and then must return to the beach (actively or passively) to begin its adult life – and both time in the plankton and the transition to a benthic life depend on unpredictable factors (such as onshore winds) and result in high mortality. Recruitment variation is most dramatically visible in the huge change from year to year in abundance of barnacles on cobbles, but also occurs for some species in the sediment, e.g. juvenile clams and various species of polychaetes (Dethier 2010, Dethier and Berry 2010). Abundance of small horse clams (<1.5 cm *Tresus*), for example, varies widely among years (Dethier and Berry 2010). Because many polychaete worms probably live less than a year (although field data on longevities are lacking), their abundance in a given beach and year will be dependent on success of recruitment.

A third parameter that may be causing variation is physical stresses impacting organisms on the shore. Temperatures and salinities vary substantially even in porewater in the sediment, and surface temperatures on cobbles can reach very high temperatures on a low tide in the summer (Dethier et al., in prep.). We have no data on other parameters such as oxygen content of the sediment, but during periods of low wave energy or when cobbles "armor" the surface of the beach, oxygen may get very low. Correlational data from our monitoring work suggest that high temperatures in the early summer may prove lethal for small invertebrates living near the surface of the sediment, further reducing the unpredictability of successful recruitment each year.

Our pre-construction data showed that much of the interannual variation in beach biota was driven by surface flora and fauna, especially (but not entirely) by dramatic and regular changes in abundance of barnacles and of species that use the food or microhabitats they supply. The infauna was less variable from year to year but also had species coming and going; one of the most obvious was the tiny polychaete *Spio filicornis*, which some years was one of the most common infaunal organisms and other years was absent altogether. Tidal elevations were not all alike in their degree of interannual variation; High and Mid zones were most variable, and the Low zone the least. Tests of which physical parameters best matched the patterns of biological communities among sites and years indicated that while the cover of sand is often important (especially in the Very Low zone), all the variables measured (cobble, sand, and temperatures and salinities of the porewater and the nearshore) correlated to some extent with these community patterns.

Evidence of Impacts and Recovery

Cutting a trench through the beach to lay the Brightwater Outfall pipe clearly impacted the organisms in the intertidal zone, especially at the mid-shore and below, but this impact was constrained to the narrow corridor that was actually excavated. Evidence of impact and of recovery from these impacts can be seen in the multivariate analyses of the entire biotic community and in analyses of species richness.

Examination of the whole community of organisms found in samples from the Mid zone (Mean Low Water, +2.8 ft) showed that in the years prior to construction, the biota tended to be more 'faithful' to their site than to other sites within that year, i.e. site to site differences were greater than year to year differences. Within the Outfall site, large changes were seen from 2008 (immediately pre-impact) to 2009 (immediately post-impact). Species richness dropped substantially in the Edge samples and even further in the Trenched area. Barnacles were very abundant at the Edge (as they were in almost all 2009 samples) but almost absent in the Trenched area. The Trench was also lacking in clams. Other species in low abundance at the Edge as well as the Trench were littorinid snails, anemones, mussels, and capitellid polychaetes. In 2010 there was clear evidence of recovery in both the Edge and Trench samples. Both showed large increases in numbers of barnacles, amphipods, isopods, limpets, mussels, and hermit crabs, and the cobbles in the Trench were colonized by a variety of algae that had been lacking in 2009. Thus while construction-related impacts in this zone were clear one year after completion of the trench, recovery of the beach biota was clearly well on its way within 2 years.

Similar patterns of substantial change in community structure and loss of species richness were seen following construction in the Low (MLLW) and Very Low (-2') zones in 2009. These effects were clearly visible in the Trench, while the Edge samples had species and abundances reduced relative to control samples but not as drastically as in the Trench. By 2010, the Edge samples were no longer significantly different from those at the adjacent Pt Wells South transect, and the Trench samples were becoming more similar to the Edge, both in terms of community composition and species richness. Species that had not recovered in the Trench included both some surface biota (algae and invertebrates) and some infauna (polychates and clams). Because the natural mix of cobble and sand substrate was present (because it was replaced post-trenching), the community trajectory appeared to be rapidly approaching "normal" – recognizing that "normal" is a somewhat unpredictable state.

The anomalous "Pit" area, located where the construction trench bisected the Very Low transect line, was the most impacted of the studied locations and will take the longest to recover. This area, which should have had 20-40% surface cover of cobbles (and a subsurface mix of cobbles and sand), instead was an area about 15 m wide of pure sand (Fig. 5). Presumably because of the way this area was filled post-construction and the type of sediment used, the substrate in it sank during the first year after construction, so that after a year (and still after 2 years) it was about 0.5 ft below the elevation of the surrounding beach. One year post-construction there was no surface flora or fauna (as is usually the case in pure sand, unless there is eelgrass), and a total of only 2 worms in the 5 core samples (versus 13 worms in 7 species in the highly disturbed but appropriate-substrate Trench samples, adjacent to the Pit). Two years post-construction there was still only one worm and 6 small clams in the Pit samples, and traces of surface organisms on the few small rocks that had rolled into the area. Until larger rocks are washed into this area, which had not happened after 2 winter periods, the community will not recover to its pre-construction state.

Other than this Pit area, the impact done by the summer 2008 construction was limited in spatial scale to the 6 m width of the trenched area and to a lesser extent to about 10-15 m on either side of that trench. Given the way the community has recovered at the Mid, Low, and Very Low Outfall transect sites in two years, it is our estimate that in another 1-3 years it will not be possible to distinguish the trenched beach from the reference areas either physically or biologically.

Acknowledgements

Jennifer Ruesink was instrumental in designing the monitoring program and helping with the fieldwork. Many other helpers made the extensive field work possible, especially Kim Stark, Scott Mickelson, Amy Glaub Sprenger, Betty Bookheim, Tiffany Stephens, Christopher Barnes, and other King County, DNR and UW volunteers. Craig Staude identified the amphipods. Access to the sites was provided by Paramount (Point Wells) and King County Department of Natural Resources and Parks (Richmond Beach Park). Beach Naturalists helped run interference at Richmond Beach Park.

References

Anderson, M.J., K.E. Ellingsen, and B.H. McArdle. 2006. Multivariate dispersion as a measure of beta diversity. Ecology Letters 9:683-693.

Anderson, M.J., R.N. Gorley and K.R. Clarke. 2008. PERMANOVA+ for PRIMER: Guide to Software and Statistical Methods. PRIMER-E, Plymouth, U.K.

Blake, J.A., Hilbig, B. & Scott, P.H. 1997. Taxonomic Atlas of the Benthic Fauna of the Santa Maria Basin and Western Santa Barbara Channel. Santa Barbara Museum of Natural History, Santa Barbara, CA.

Dethier, M.N., J. Ruesink, H. Berry, A. G. Sprenger, B. Reeves. 2010. Restricted ranges in physical factors may constitute subtle stressors for estuarine biota. Marine Environmental Research 69:240-247.

Dethier, M.N. 2005. Spatial patterns and temporal trends in shoreline biota in Puget Sound: analyses of data collected through 2004. Report for the Washington State Dept. of Natural Resources, Nearshore Habitat Program, June 2005.

Dethier, M.N. 2007. Long-term and seasonal trends of shoreline biota in Puget Sound: analyses of data collected through 2006. Report to the Washington State Dept. of Natural Resources, Nearshore Habitat Program, June 2007.

Dethier, M.N. 2010. Variation in recruitment does not drive the cline in diversity along an estuarine gradient. Marine Ecology Progress Series 410:43-54.

Dethier, M.N. and H.D. Berry. 2009. Puget Sound intertidal biotic community monitoring: 2008 monitoring report. Washington State Dept. of Natural Resources, December 2009.

Dethier, M.N. and H.D. Berry. 2010. Shoreline Changes over 40 Years in the Seahurst Region, Central Puget Sound. Washington State Dept. of Natural Resources, October 2010.

Dethier, M.N. and G.C. Schoch. 2005. The consequences of scale: assessing the distribution of benthic populations in a complex estuarine fjord. Estuarine, Coastal and Shelf Science 62:253-270.

Finlayson, D. 2006. The geomorphology of Puget Sound beaches. Puget Sound Nearshore Partnership Report No. 2006-02. Published by Washington Sea Grant Program, University of Washington, Seattle, Washington. Available at http://pugetsoundnearshore.org

Gabrielson, P.W., Widdowson, T.B., Lindstrom, S.C., Hawkes, M.W. & Scagel, R.F. 2000. Keys to the benthic marine algae and seagrasses of British Columbia, southeast Alaska, Washington and Oregon. Phycological Contribution Number 5, University of British Columbia, Vancouver, B.C.

Kozloff, E.N. 1996. Marine Invertebrates of the Pacific Northwest. Univ. of Washington Press, Seattle, WA

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	**Pt Wells Outfall**							
Year	**2006**	**2006**	**2006**	**2006**	**2007**	**2007**	**2007**	**2007**
Intertidal Height (feet above MLLW)	**-2**	**0**	**2.8**	**6.6**	**-2**	**0**	**2.8**	**6.6**
Acrosiphonia spp.	0.3	7.1	0.3	0	2.2	5.1	3.8	0
Allorchestes angusta	0	0	0	0	0	0	0	0
Ampithoe dalli	0	0	0	0	0	0	0	0
Ampithoe lacertosa	0	0	0	0	0	0	0	0
Anisogammarus pugettensis	0	0	0	0	0	0	0	0
Anthopleura spp.	0.1	0.2	0.3	0	0.1	0.2	1.3	0
Armandia brevis	0	0	0	0	0	0.9	0.4	0.1
Axiothella rubrocincta	0	0	0	0	0	0	0	0
Bryozoa (miscellaneous)	0	0	0	0	0	0	0	0
Calliopius spp.	0	0	0	0	0	0	0	0
Cancer sp.	0	0	0	0	0.1	0	0	0
Cancer sp. Juvenile	5.4	1.9	0.1	0	0	0	0	0
Capitella capitata	0	0.2	0	0	0.1	0.8	0.1	0
Caulleriella ?pacifica	0	0	0	0	0	0	0	0
Ceramium sp.	0	0.2	0	0	0	0	0	0
Chondracanthus exasperata	0	0	0	0	0	0	0	0
Cirratulus multioculatus	0	0	0	0	0	0	0	0
Clinocardium nuttallii	0.1	0.1	0	0	0.1	0.1	0	0
Clinocardium nuttallii juveniles	0	0.1	0	0	0	0	0	0
Cobble percentage	38.5	37.6	53	12.5	12.5	26.5	33.5	12.5
Cottidae (sculpins)	0.3	0	0	0	0	0	0	0
Crangon franciscorum ssp. franciscorum	0	0	0	0	0	0	0	0
Crassostrea gigas	0	0	0	0	0	0	0	0
Crepidula dorsata	0	0	0	0	0	0	0	0
Cryptosiphonia woodii	0	0	0	0	0	0	0	0
Cumagloia andersonii	0.1	0	0	0	0	0	0	0
Dead barnacles (Class Cirripedia)	4.3	3.8	9.5	0	3.4	3	3	0.8
Delesseria sp.	0	0	0	0	0	0	0	0
Dendraster juv. in core	0	0	0	0	0	0	0	0
Desmarestia spp.	1.5	0	0	0	0	0	0	0
Diatoms, chain-forming	0.1	3.9	7.8	0	0.3	0.5	0.1	0
Diopatra ornata	0	0	0	0	0	0	0	0
Edwardsia sipunculoides	0	0	0.1	0	0	0	0	0
Epiactis prolifera	0	0	0	0	0	0	0	0
Eteone spp.	0.1	0.1	0	0	0	0.1	0.1	0
Euclymene spp.	0	0.1	0	0	0	0	0	0
Eulalia sanguinea	0	0	0	0	0	0	0	0
Evasterias troschelii	0	0	0	0	0	0	0	0
Exosphaeroma inornata	0	0	0	0	0	0	0	0
Family Hippolytidae	0.05	0	0	0	0	0	0	0
Flatworm (unident.)	0	0	0	0	0.2	0.4	0.3	0
Fleshy crust	2.2	1.3	0.4	0	1.5	1.7	0.5	0
Gammarid amphipods	0.5	0	0	0	0.3	0.6	0.4	0
Gelidium spp.	0.1	0	0	0	0	0	0	0
Glycera americana	0.1	0	0	0	0	0.1	0	0
Glycinde picta	0.1	0	0	0	0.1	0.1	0.1	0
Glycinde polygnatha	0	0	0	0	0	0	0	0
Gnorimosphaeroma oregonense	0	0	0	0	0	0	0	0
Gracilaria pacifica	0	0	0	0	0	0	0	0
Grateloupia sp.	0	0	0	0	0	0	0	0
Green filaments	0	0	0	0	0	0	0	0

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	**Pt Wells Outfall**							
Year	**2006**	**2006**	**2006**	**2006**	**2007**	**2007**	**2007**	**2007**
Intertidal Height (feet above MLLW)	**-2**	**0**	**2.8**	**6.6**	**-2**	**0**	**2.8**	**6.6**
Haminoea vesicula	0	0	0.1	0	0	0	0	0
Harmothoe imbricata	0	0	0	0	0	0	0	0
Hemigrapsus nudus	0	0	0	0	0	0	0.1	0
Hemigrapsus oregonensis	0	0.1	0.4	0	0	0	0.6	0
Hemipodus borealis	0	1.1	4.2	0	0.2	2.3	5.4	1.6
Hermissenda crassicornis	0.1	0	0.1	0	0.2	0	0.3	0
Hiatella arctica	0	0	0	0	0	0	0	0
Protohyale (= Hyale) spp.	0	0	0	0	0	0	0	0
Idotea sp.	0	0	0	0	0	0	0.4	0
Ischyrocerus anguipes	0	0	0	0	0	0	0	0
Lacuna spp.	0.7	0.6	0	0	13.7	13.9	1.3	0
Saccharina latissima (=Laminaria saccharina)	3.5	0	0	0	0	0	0	0
Lepidochitona dentiens	0	0	0	0	0	0	0	0
Leptochelia dubia	0	0	0	0	0	0	0	0
Leptosynapta clarki	0	0.2	0	0	0	0	0	0
Littorina scutulata	0	0	6.7	0	0	0	0.2	1.5
Littorina sp.	0	0	0	0	0	0	0	0
Live barnacles (Class Cirripedia)	1	0.1	0.9	0	22.2	38	63.5	0.7
Lophopanopeus bellus bellus	0	0.3	0	0	0	0	0	0
Lottiid limpets	0.8	6.5	7	0	0.9	1.9	10.3	0
Lucina tenuisculpta	0	0	0.1	0	0	0	0	0
Lumbrineris zonata	0.1	0.5	0	0	0.1	0.5	0	0
Macoma inquinata	0	1.9	0.1	0	0	1.1	0	0
Macoma inquinata juveniles	0.1	0.7	0.8	0	0	0.1	0.3	0
Magelona hobsonae	0	0.1	0	0	0	0	0	0
Majid (spider) crab	0	0	0	0	0	0	0	0
Majid juvenile crab	0	0	0	0	0	0	0	0
Malacoceros glutaeus	0	0	0	0	0	0	0	0
Malmgreniella nigralba	0	0	0	0	0	0	0	0
Margarites sp.	0	0	0	0	0	0	0	0
Mastocarpus jardinii	0	0.1	0	0	0	0	0	0
Mastocarpus papillatus	0.5	1.3	0.3	0	0.9	0.5	0.7	0
Mazzaella heterocarpa/oregona	0	0.1	0	0	0	0	0	0
Mazzaella sp.	0.6	0.1	0	0	0	0	0	0
Mazzaella splendens	0	0	0	0	0	0	0.5	0
Mediomastus californiensis	0	8.3	6.4	0	1.5	20.4	15.1	0
Megalorchestia pugettensis	0	0	0	0	0	0	0	0
Melanochlamys diomedea	0	0	0	0	0	0	0	0
Metridium sp.	0	0	0	0	0.3	0	0	0
Microcladia borealis	0	0	0	0	0	0	0	0
Micropodarke dubia	0	0	0	0	0	0	0	0
Mopalia lignosa	0.5	0.7	0.2	0	0.7	0.7	0.2	0
Mopalia muscosa	0	0.3	0.2	0	0	0.2	0	0
Rochefortia tumida (=Mysella tumida)	0	0	0	0	0	0.1	0.1	0
Mytilus trossulus	0	0	0.8	0	0.4	0.8	1.6	0.1
Naineris dendritica	0	0	0	0	0	0	0	0
Nassarius sp.	0.4	0	0	0	0	0	0	0
Nemertean (unident.)	0.2	0.8	0.1	0	0.3	0.6	0.1	0
Neotrypaea californiensis	0	0	0	0	0	0	0	0

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	**Pt Wells Outfall**							
Year	**2006**	**2006**	**2006**	**2006**	**2007**	**2007**	**2007**	**2007**
Intertidal Height (feet above MLLW)	**-2**	**0**	**2.8**	**6.6**	**-2**	**0**	**2.8**	**6.6**
Nephtys caeca	0	0	0	0	0	0	0	0
Nephtys caecoides	0	0	0	0	0	0	0	0
Nephtys ferruginea	0	0	0	0	0	0	0	0
Nereis procera	0.2	0	0	0	0.3	0	0.1	0
Nereis vexillosa	0	0	0	0	0	0.1	0	0
Notomastus lineatus	0	0	0	0	0	0	0	0
Notomastus tenuis	3.5	4.6	0.2	0	2	2.4	0.4	0.1
Nucella lamellosa	1.4	4	6	0	0	0.9	0.8	0
Ocenebra lurida	0	0	0	0	0	0	0	0
Odonthalia floccosa	0	0	0	0	0	0	0	0
Odostomia sp. (unident.)	0	0	0	0	0	0	0	0
Oenopota sp.	0	0	0	0	0	0	0	0
Onchidoris bilamellata	0	0	0	0	2.1	0.7	0.7	0
Onuphis elegans	0	0	0	0	0	0	0	0
Onuphis iridescens	0	0	0	0	0	0	0	0
Owenia fusiformis	0.2	2.2	0.7	0	0.1	0	0.2	0
Pagurus spp.	2.8	4.8	5.8	0	1.4	0.7	4.6	0
Paracalliopiella pratti	0	0	0	0	0	0	0	0
Petalonia fascia	0.3	0.1	0	0	1.1	1.3	1.2	0
Pholoe minuta	0	0	0	0	0	0	0	0
Phoronopsis harmeri	0.1	0.5	2.4	0	0	0.8	2.1	0
Photis spp.	0	0	0	0	0	0	0	0
Phyllaplysia taylori	0	0	0	0	0	0	0	0
Pinnixia faba	0	0	0	0	0	0	0	0
Pinnixia schmitti/occidentalis	0	0	0	0	0	0	0	0
Pinnotherid sp. (unident.)	0	0	0	0	0	0	0	0
Pisaster ochraceus	0	0	0	0	0	0	0	0
Platynereis bicanaliculata	0	0.1	0	0	0	0	0	0
Podarke pugettensis	0	0	0	0	0	0	0	0
Podarkeopsis glabrus	0	0	0	0	0	0	0	0
Pododesmus cepio	0	0	0	0	0	0	0	0
Euspira (=Polinices) lewisii	0	0	0	0	0	0.1	0	0
Polydora brachycephala	0	0	0	0	0	0	0.3	0
Polydora cardalia	0	0	0	0	0	0	0	0
Polydora columbiana	0	0	0	0	0	0.3	0.1	0
Polydora quadrilobata	0	0	0	0	0	0	0	0
Polyneura sp.	0	0	0	0	0	0	0	0
Polynoid (unident., in quadrat)	0	0.2	0	0	0	0.3	0.1	0
Polysiphonia sp.	0	0.7	0.2	0	0.7	1	0.3	0
Pontogeneia ivanovi	0	0	0	0	0	0	0	0
Porphyra sp.	5.1	6.6	6.2	0	1.3	0.4	1.2	0
Prionitis sp. (unident.)	0	0	0	0	0	0	0	0
Prionospio steenstrupi	0	0	0	0	0	0	0	0
Leukoma (=Protothaca) staminea	0.1	0.1	0.7	0	0	0.2	0.6	0
Leukoma staminea juv.	0	0.2	0.2	0	0	0	0.1	0
Pseudopolydora kempi japonica	0	0	0	0	0	0	0	0
Ptilohyale plumulosa	0	0	0	0	0	0	0	0
Pugettia gracilis	0	0	0	0	0	0	0	0
Sabellid (unident.)	0	0	0	0	0	0	0	0
Sand percentage	30	31.9	29.7	6.4	58.3	33.6	3.2	1.4

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	**Pt Wells Outfall**							
Year	**2006**	**2006**	**2006**	**2006**	**2007**	**2007**	**2007**	**2007**
Intertidal Height (feet above MLLW)	**-2**	**0**	**2.8**	**6.6**	**-2**	**0**	**2.8**	**6.6**
Sarcodiotheca sp. (unid.)	0.4	0.1	0	0	0.6	0	0	0
Sargassum muticum	0	0	0	0	0	0	0	0
Saxidomus giganteus	0	0.4	0.1	0	0	0.1	0.5	0
Saxidomus giganteus juv.	0.1	0.2	1.3	0	0	0.2	0.1	0
Scleroplax granulata	0	0	0	0	0	0	0	0
Scolelepis squamata	0	0	0	0	0	0	0	0
Scytosiphon simplicissimus	0.6	1	0.1	0	0.1	0.4	0.1	0
Smithora naiadum	0	0	0	0	0.5	0	0	0
Sphaeromid isopods	0	0.4	0	0	0	0	0	0
Spio filicornis	0	0	0	0	0.1	0.2	0.7	0
Spiochaetopterus tube	0	0	0	0	0	0	0	0
Spiophanes bombyx	0	0	0	0	0	0	0	0
Stichaeidae (gunnels and pricklebacks)	0	0	0	0	0	0	0	0
Strongylocentrotus sp.	0	0	0	0	0	0	0	0
Tellina modesta	0	0	0	0	0	0.1	0	0
Tonicella lineata	0	0	0	0	0	0	0	0
Nutricola (= Transenella) tantilla	0	0	0	0	0	0	0	0
Tresus capax	0	1	0	0	0	0.1	0.2	0
Tresus capax juveniles	0	0	0	0	0.2	0.2	0.4	0
Ulvoids (unident.)	91.6	62	64	0	38.1	78.5	79.4	0
Urticina sp.	0	0	0	0	0	0	0	0
Zostera marina	0	0	0	0	0.5	0	0	0

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	**Pt Wells Outfall**				**Outfall Pit**	
Year	**2008**	**2008**	**2008**	**2008**	**2009**	**2010**
Intertidal Height (feet above MLLW)	**-2**	**0**	**2.8**	**6.6**	**-2.5**	**-2.5**
Acrosiphonia spp.	0.3	2.2	0	0	0	0
Allorchestes angusta	0.2	0	0.2	0	0	0
Ampithoe dalli	0.1	0	0	0	0	0
Ampithoe lacertosa	0	0	0	0	0	0
Anisogammarus pugettensis	2.1	0	0	0	0	0
Anthopleura spp.	0.6	0.6	0.9	0.1	0	0
Armandia brevis	0	0	0	0	0	0
Axiothella rubrocincta	0	0	0	0	0	0
Bryozoa (miscellaneous)	0	0	0	0	0	0
Calliopius spp.	0	0	0	0	0	0
Cancer sp.	0	0	0	0	0	0
Cancer sp. Juvenile	0	0	0	0	0	0
Capitella capitata	0	0	0	0	0	0
Caulleriella ?pacifica	0	0	0	0	0	0
Ceramium sp.	0	0	0	0	0	0
Chondracanthus exasperata	0	0	0	0	0	0
Cirratulus multioculatus	0	0	0	0	0	0
Clinocardium nuttallii	0	0	0.1	0	0	0
Clinocardium nuttallii juveniles	0	0.2	0	0	0	0
Cobble percentage	7.5	15	9.5	8.5	0	0
Cottidae (sculpins)	0	0	0	0	0	0
Crangon franciscorum ssp. franciscorum	0	0	0	0	0	0
Crassostrea gigas	0	0	0	0	0	0
Crepidula dorsata	0	0	0	0	0	0
Cryptosiphonia woodii	0	0	0	0	0	0
Cumagloia andersonii	0	0	0	0	0	0
Dead barnacles (Class Cirripedia)	3.3	3	16	13	0	0.2
Delesseria sp.	0	0	0	0	0	0
Dendraster juv. in core	0	0	0	0	0	0
Desmarestia spp.	0	0	0	0	0	0
Diatoms, chain-forming	0.1	1.8	12.5	0.1	0	0
Diopatra ornata	0	0	0	0	0	0
Edwardsia sipunculoides	0	0	0	0	0	0
Epiactis prolifera	0	0	0	0	0	0
Eteone spp.	0	0	0	0	0	0
Euclymene spp.	0	0.2	0	0	0	0
Eulalia sanguinea	0	0	0	0	0	0
Evasterias troschelii	0	0	0	0	0	0
Exosphaeroma inornata	0	0	0	0	0	0
Family Hippolytidae	0	0	0	0	0	0
Flatworm (unident.)	0	0	0	0	0	0
Fleshy crust	2.7	2.9	1.2	0	0	79.2
Gammarid amphipods	27	59.8	4.7	0	0	0
Gelidium spp.	0	0	0	0	0	0
Glycera americana	0	0	0	0	0	0
Glycinde picta	0.4	0.1	0	0	0.2	0
Glycinde polygnatha	0	0	0	0	0	0
Gnorimosphaeroma oregonense	0	0	0	0	0	0
Gracilaria pacifica	0.1	0	0	0	0	0
Grateloupia sp.	0	0	0	0	0	0
Green filaments	0	0	0	0	0	0

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	Pt Wells Outfall				Outfall Pit	
Year	**2008**	**2008**	**2008**	**2008**	**2009**	**2010**
Intertidal Height (feet above MLLW)	**-2**	**0**	**2.8**	**6.6**	**-2.5**	**-2.5**
Haminoea vesicula	0	0	0	0	0	0
Harmothoe imbricata	0	0	0	0	0	0
Hemigrapsus nudus	0	0	0	0	0	0
Hemigrapsus oregonensis	0.2	0	0	0	0	0
Hemipodus borealis	0	2.3	5.9	0.2	0	0
Hermissenda crassicornis	0	0	0	0	0	0
Hiatella arctica	0	0	0	0	0	0
Protohyale (= Hyale) spp.	0.2	0.2	0.2	0	0	0
Idotea sp.	0	0	0	0	0	0
Ischyrocerus anguipes	0	0	0	0	0	0
Lacuna spp.	7.2	12.3	0	0	0	1
Saccharina latissima (=Laminaria saccharina)	0	0	0	0	0	16
Lepidochitona dentiens	0	0	0	0	0	0
Leptochelia dubia	0	0	0	0	0	0
Leptosynapta clarki	0	0	0	0	0	0
Littorina scutulata	0	0	0	19	0	0
Littorina sp.	0	0	5.7	41	0	0
Live barnacles (Class Cirripedia)	0.6	1	4.6	2	0	1
Lophopanopeus bellus bellus	0	0	0	0	0	0
Lottiid limpets	2	14	7.7	0	0	0
Lucina tenuisculpta	0	0	0	0	0	0
Lumbrineris zonata	0.6	1.4	0.1	0	0	0
Macoma inquinata	0	0	0.5	0	0	0
Macoma inquinata juveniles	0	0.1	0.7	0	0	0
Magelona hobsonae	0	0	0	0	0	0
Majid (spider) crab	0	0	0	0	0	0
Majid juvenile crab	0	0	0	0	0	0
Malacoceros glutaeus	0	0	0	0	0	0
Malmgreniella nigralba	0	0	0	0	0	0
Margarites sp.	0	0	0	0	0	0
Mastocarpus jardinii	0	0	0	0	0	0
Mastocarpus papillatus	0.8	2.1	0.7	0	0	0.2
Mazzaella heterocarpa/oregona	0	0	0	0	0	0
Mazzaella sp.	0	0	0	0	0	0
Mazzaella splendens	0.8	0	0	0	0	0
Mediomastus californiensis	0.5	5.9	13.7	0	0	0
Megalorchestia pugettensis	0	0	0	0	0	0
Melanochlamys diomedea	0	0	0	0	0	0
Metridium sp.	0	0	0	0	0	0
Microcladia borealis	0	0.1	0	0	0	0
Micropodarke dubia	0	0	0	0	0	0
Mopalia lignosa	0.9	0.2	0	0	0	0
Mopalia muscosa	0	0.1	0	0	0	0
Rochefortia tumida (=Mysella tumida)	0	0	0	0	0	0.2
Mytilus trossulus	0	0.3	5.2	0.5	0	0
Naineris dendritica	0	0	0	0	0	0
Nassarius sp.	0	0	0	0	0	0
Nemertean (unident.)	0.5	0.6	0	0	0	0.2
Neotrypaea californiensis	0	0	0	0	0	0

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	**Pt Wells Outfall**				**Outfall Pit**	
Year	**2008**	**2008**	**2008**	**2008**	**2009**	**2010**
Intertidal Height (feet above MLLW)	**-2**	**0**	**2.8**	**6.6**	**-2.5**	**-2.5**
Nephtys caeca	0	0	0	0	0	0
Nephtys caecoides	0	0	0	0	0.2	0
Nephtys ferruginea	0	0	0	0	0	0
Nereis procera	0	0.2	0	0	0	0
Nereis vexillosa	0.1	0.1	0	0.3	0.2	0
Notomastus lineatus	0	0	0	0	0	0
Notomastus tenuis	1.3	4.1	2.4	0.1	0.2	0
Nucella lamellosa	0	0.1	0.1	0	0	0
Ocenebra lurida	0	0	0	0	0	0
Odonthalia floccosa	0	0	0	0	0	0
Odostomia sp. (unident.)	0	0	0.1	0	0	0
Oenopota sp.	0	0	0	0	0	0
Onchidoris bilamellata	0	0	0	0	0	0
Onuphis elegans	0	0	0	0	0	0
Onuphis iridescens	0	0	0	0	0	0
Owenia fusiformis	0	0.6	0.1	0	0	0
Pagurus spp.	0.3	1.2	0.8	0	0	0
Paracalliopiella pratti	0.1	0	0	0	0	0
Petalonia fascia	0.1	1.1	0.6	0	0	0
Pholoe minuta	0	0	0.1	0	0	0
Phoronopsis harmeri	0	0.5	0.5	0	0	0
Photis spp.	0.1	0	0	0	0	0
Phyllaplysia taylori	0	0	0	0	0	0
Pinnixia faba	0	0	0	0	0	0
Pinnixia schmitti/occidentalis	0	0.1	0	0	0	0
Pinnotherid sp. (unident.)	0	0	0	0	0	0
Pisaster ochraceus	0	0	0	0	0	0
Platynereis bicanaliculata	1.1	0.1	0	0	0	0
Podarke pugettensis	0	0	0	0	0	0
Podarkeopsis glabrus	0	0	0	0	0	0
Pododesmus cepio	0	0	0	0	0	0
Euspira (=Polinices) lewisii	0	0	0	0	0	0
Polydora brachycephala	0	0.1	0.3	0	0	0
Polydora cardalia	0	0	0.2	0	0	0
Polydora columbiana	0	0	0.1	0	0	0
Polydora quadrilobata	0	0	0	0	0	0
Polyneura sp.	0	0	0	0	0	0
Polynoid (unident., in quadrat)	0	0	0	0	0	0
Polysiphonia sp.	0.1	0.4	0.7	0	0	0
Pontogeneia ivanovi	0.4	0	0.2	0	0	0
Porphyra sp.	1.7	3.3	3.2	0	0	0
Prionitis sp. (unident.)	0	0	0	0	0	0
Prionospio steenstrupi	0	0	0	0	0	0
Leukoma (=Protothaca) staminea	0	0	1.4	0	0	0
Leukoma staminea juv.	0.1	0.1	0.3	0	0	0
Pseudopolydora kempi japonica	0	0	0	0	0	0
Ptilohyale plumulosa	0	0	0	0	0	0
Pugettia gracilis	0	0	0	0	0	0
Sabellid (unident.)	0	0	0	0	0	0
Sand percentage	53.5	32	43.5	13	99	0

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	**Pt Wells Outfall**				**Outfall Pit**	
Year	**2008**	**2008**	**2008**	**2008**	**2009**	**2010**
Intertidal Height (feet above MLLW)	**-2**	**0**	**2.8**	**6.6**	**-2.5**	**-2.5**
Sarcodiotheca sp. (unid.)	0.1	0.1	0	0	0	0
Sargassum muticum	0	0	0	0	0	0
Saxidomus giganteus	0	0	0.5	0	0	0
Saxidomus giganteus juv.	0	0.4	0.7	0	0	0
Scleroplax granulata	0	0	0	0	0	0
Scolelepis squamata	0	0	0	0	0	0
Scytosiphon simplicissimus	0.1	0.7	0.2	0	0	0
Smithora naiadum	0	0	0	0	0	0
Sphaeromid isopods	0	0	0	0	0	0
Spio filicornis	0	0	0	0	0	0
Spiochaetopterus tube	0.1	0	0	0	0	0
Spiophanes bombyx	0	0	0	0	0	0
Stichaeidae (gunnels and pricklebacks)	0	0	0	0	0	0
Strongylocentrotus sp.	0	0	0	0	0	0
Tellina modesta	0.1	0	0	0	0.2	1.2
Tonicella lineata	0	0	0	0	0	0
Nutricola (= Transenella) tantilla	0	0	0	0	0	0
Tresus capax	0	0	0	0	0	0
Tresus capax juveniles	0	0	0	0	0	0
Ulvoids (unident.)	53	72	11	0.5	0	11
Urticina sp.	0	0	0	0	0	0
Zostera marina	21	0	0	0	0	0.2

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	**Outfall Edge**							
Year	**2009**	**2009**	**2009**	**2009**	**2010**	**2010**	**2010**	**2010**
Intertidal Height (feet above MLLW)	**-2**	**0**	**2.8**	**6.6**	**-2**	**0**	**2.8**	**6.6**
Acrosiphonia spp.	9	4.2	1.4	0	0.2	1.2	0	0
Allorchestes angusta	0	0.4	0	0	0	0.2	0.2	0
Ampithoe dalli	0.2	0	0	0	0	0	0	0
Ampithoe lacertosa	0	0	0	0	0	0	0	0
Anisogammarus pugettensis	0.2	0	0	0	0	0	0	0
Anthopleura spp.	0	0.4	1.4	0	0.2	0.6	1.2	0
Armandia brevis	9.6	0	0	0	0.4	0	0	0
Axiothella rubrocincta	0	0	0	0	0	0	0	0
Bryozoa (miscellaneous)	0	0	0	0	0	0	0	0
Calliopius spp.	0	0	0	0	0	0	0	0
Cancer sp.	0	0	0	0	0	0	0	0
Cancer sp. Juvenile	0	0	0	0	0.2	0	0	0
Capitella capitata	0.6	0	0	0	0	0	0	0
Caulleriella ?pacifica	0	0	0	0	0	0.4	0	0
Ceramium sp.	0	0	0	0	0	0	0	0
Chondracanthus exasperata	0	0	0	0	0	0	0	0
Cirratulus multioculatus	0	0	0	0	0	0	0	0
Clinocardium nuttallii	0.2	0	0	0	0	0	0	0
Clinocardium nuttallii juveniles	0.4	0	0	0	0	0	0	0
Cobble percentage	30	23	9	12	10	7	3	3
Cottidae (sculpins)	0	0	0	0	0	0	0	0
Crangon franciscorum ssp. franciscorum	0	0	0	0	0	0	0	0
Crassostrea gigas	0	0	0	0	0	0	0	0
Crepidula dorsata	0	0	0	0	0	0	0	0
Cryptosiphonia woodii	0	0	0	0	0	0	0	0
Cumagloia andersonii	0	0	0	0	0	0	0	0
Dead barnacles (Class Cirripedia)	2.6	3.8	2.6	0.8	4.6	2.6	1	0.7
Delesseria sp.	0	0	0	0	0	0	0	0
Dendraster juv. in core	0	0	0	0	0	0	0	0
Desmarestia spp.	0	0	0	0	0	0	0	0
Diatoms, chain-forming	2.6	0.2	0	0	0.2	0.4	1	0
Diopatra ornata	0	0	0	0	0	0	0	0
Edwardsia sipunculoides	0	0	0	0	0	0	0	0
Epiactis prolifera	0	0	0	0	0	0	0	0
Eteone spp.	0	0	0	0	0.4	0.2	0	0
Euclymene spp.	0	0	0	0	0	0.2	0	0
Eulalia sanguinea	0	0	0	0	0	0	0	0
Evasterias troschelii	0	0	0	0	0.2	0	0	0
Exosphaeroma inornata	0	0.6	0	0	0.6	1.8	0	0
Family Hippolytidae	0	0	0	0	0.5	0	0	0
Flatworm (unident.)	1.6	0	0	0	14.6	12	0.2	0
Fleshy crust	0.6	0.6	0.6	0	7	3.4	0.8	0
Gammarid amphipods	11	14.8	6.6	0	7.4	17.2	42	0
Gelidium spp.	0	0	0	0	0	0	0	0
Glycera americana	0	0	0	0	0.2	0	0	0
Glycinde picta	0.4	0	0	0	0.2	0.2	0	0
Glycinde polygnatha	0.2	0	0	0	0	0	0	0
Gnorimosphaeroma oregonense	0	0	0	0	0	0	0	0
Gracilaria pacifica	0	0	0	0	0	0	0	0
Grateloupia sp.	0	0	0	0	0	0	0	0
Green filaments	0	0	0	0	0	0	0	0

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	**Outfall Edge**							
Year	**2009**	**2009**	**2009**	**2009**	**2010**	**2010**	**2010**	**2010**
Intertidal Height (feet above MLLW)	**-2**	**0**	**2.8**	**6.6**	**-2**	**0**	**2.8**	**6.6**
Haminoea vesicula	0	0	0	0	0.6	0	0	0
Harmothoe imbricata	0.4	0	0	0	0.4	0	0	0
Hemigrapsus nudus	0	0	0	0	0	0	0	0
Hemigrapsus oregonensis	0	0	0	0.2	0	0	0.4	0
Hemipodus borealis	0	2.4	6.8	0.8	0	3.2	4.4	0
Hermissenda crassicornis	0	0	0	0	0.2	0.2	0	0
Hiatella arctica	0	0	0	0	0	0	0	0
Protohyale (= Hyale) spp.	0	0	0	0	0	0.8	0	0
Idotea sp.	0	3	0.4	0	0.2	0.6	0.6	0
Ischyrocerus anguipes	0	0	0	0	0	0	0	0
Lacuna spp.	61	36.6	1	0	120	125	0	0
Saccharina latissima (=Laminaria saccharina)	0.2	0	0	0	12.2	0	0	0
Lepidochitona dentiens	0	0	0	0	0	0	0	0
Leptochelia dubia	0	0	0	0	0	0	0	0
Leptosynapta clarki	0	0	0	0	0	0	0	0
Littorina scutulata	0	0	0	2.8	0	0	0	0
Littorina sp.	0	0	0	0	0	0	2	0
Live barnacles (Class Cirripedia)	45	70	40.2	5.2	19	43	27	0.2
Lophopanopeus bellus bellus	0	0	0	0	0	0	0	0
Lottiid limpets	5	13.4	8.2	0	12.6	37	29.6	0
Lucina tenuisculpta	0	0	0	0	0	0	0	0
Lumbrineris zonata	0.6	0.8	0	0	1.8	0.6	0	0
Macoma inquinata	0	0.4	0	0	0	0	0	0
Macoma inquinata juveniles	0.4	0.2	0	0	0.4	0.4	0	0
Magelona hobsonae	0	0	0	0	0	0	0	0
Majid (spider) crab	0.2	0	0	0	0	0	0	0
Majid juvenile crab	0	0	0	0	0	0	0	0
Malacoceros glutaeus	0	0	0	0	0	0	0	0
Malmgreniella nigralba	0	0	0	0	0	0	0	0
Margarites sp.	0	0	0	0	0	0	0	0
Mastocarpus jardinii	0	0	0	0	0	0	0	0
Mastocarpus papillatus	0.4	0.6	0.8	0	0.8	5.4	0.8	0
Mazzaella heterocarpa/oregona	0	0	0	0	0.2	0.4	0	0
Mazzaella sp.	0	0	0	0	0	0	0	0
Mazzaella splendens	0	0	0	0	5	0	0	0
Mediomastus californiensis	0	2.4	3.4	0	0	1.2	2.8	0
Megalorchestia pugettensis	0	0	0	0	0	0	0	0
Melanochlamys diomedea	0	0	0	0	0	0	0	0
Metridium sp.	0	0	0	0	0	0	0	0
Microcladia borealis	0	0	0	0	0	0	0	0
Micropodarke dubia	0	0	0	0	0	0	0	0
Mopalia lignosa	0.2	0.2	0.4	0	0	0.4	0	0
Mopalia muscosa	0	0	0	0	0	0	0	0
Rochefortia tumida (=Mysella tumida)	0	0	0	0	0	0	0	0
Mytilus trossulus	0.6	0.8	1.6	0.2	0.4	1	5.4	0
Naineris dendritica	0	0	0	0	0	0	0	0
Nassarius sp.	0	0	0	0	0	0	0	0
Nemertean (unident.)	1	0.4	0	0	0	0.2	0.2	0
Neotrypaea californiensis	0	0	0	0	0	0	0	0

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	**Outfall Edge**							
Year	**2009**	**2009**	**2009**	**2009**	**2010**	**2010**	**2010**	**2010**
Intertidal Height (feet above MLLW)	**-2**	**0**	**2.8**	**6.6**	**-2**	**0**	**2.8**	**6.6**
Nephtys caeca	0	0	0	0	0	0	0	0
Nephtys caecoides	0.2	0	0	0	0	0	0	0
Nephtys ferruginea	0	0	0	0	0	0	0	0
Nereis procera	0	0	0	0	0.4	0	0	0
Nereis vexillosa	0	1	0	0	0	0	0	0.1
Notomastus lineatus	0	0	0	0	0	0	0	0
Notomastus tenuis	0.2	1.4	0.8	0	3	3.4	1	0
Nucella lamellosa	0.6	2.2	0	0	0	0.4	0	0
Ocenebra lurida	0	0	0	0	0	0	0	0
Odonthalia floccosa	0	0	0	0	0	0	0	0
Odostomia sp. (unident.)	0	0	0	0	0	0	0	0
Oenopota sp.	0	0	0	0	0	0	0	0
Onchidoris bilamellata	11	2	0	0	0	0.2	0	0
Onuphis elegans	0	0	0	0	0	0	0	0
Onuphis iridescens	0	0	0	0	0	0	0	0
Owenia fusiformis	0	0	0	0	0.2	0.6	0	0
Pagurus spp.	0.8	1.8	0.8	0	6	5	5.2	0
Paracalliopiella pratti	0	0	0	0	0	0	0	0
Petalonia fascia	1.6	0.6	0.2	0	0.4	0.2	0.2	0
Pholoe minuta	0	0.2	0	0	0	0	0	0
Phoronopsis harmeri	0	0	0	0	0	0.4	0.2	0
Photis spp.	0.4	0	0	0	0.2	0	0	0
Phyllaplysia taylori	0.2	0	0	0	0	0	0	0
Pinnixia faba	0	0	0	0	0	0	0	0
Pinnixia schmitti/occidentalis	0	0	0	0	0	0	0	0
Pinnotherid sp. (unident.)	0	0	0	0	0	0	0	0
Pisaster ochraceus	0	0	0	0	0	0	0	0
Platynereis bicanaliculata	0	0	0	0	0	0	0	0
Podarke pugettensis	0	0	0	0	0	0	0	0
Podarkeopsis glabrus	0	0	0	0	0	0	0	0
Pododesmus cepio	0	0	0	0	0	0	0	0
Euspira (=Polinices) lewisii	0	0	0	0	0	0	0	0
Polydora brachycephala	0	0	0	0	0.2	0	0	0
Polydora cardalia	0	0	0.2	0	0	0	0	0
Polydora columbiana	0.4	0.6	0	0	0	0	0.2	0
Polydora quadrilobata	0	0	0	0	0	0	0	0
Polyneura sp.	0	0	0	0	0	0	0	0
Polynoid (unident., in quadrat)	0	0	0	0	0.2	0	0	0
Polysiphonia sp.	2	1.2	0.4	0	0.2	0.2	2.2	0
Pontogeneia ivanovi	0.6	0.2	0	0	0.4	0	0	0
Porphyra sp.	2.2	5.4	10	0.2	4.2	0.2	11	0
Prionitis sp. (unident.)	0	0	0	0	0	0	0	0
Prionospio steenstrupi	0	0	0	0	0.2	0	0	0
Leukoma (=Protothaca) staminea	0	0	1	0	0	0.6	0.6	0
Leukoma staminea juv.	0	0	0.6	0	0	0	0	0
Pseudopolydora kempi japonica	0	0	0	0	0	0	0	0
Ptilohyale plumulosa	0	0	0	0	0	0	0	0
Pugettia gracilis	0	0	0	0	0	0	0	0
Sabellid (unident.)	0	0	0	0	0	0	0	0
Sand percentage	24	20	25	19	25	11	9.4	15

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	**Outfall Edge**							
Year	**2009**	**2009**	**2009**	**2009**	**2010**	**2010**	**2010**	**2010**
Intertidal Height (feet above MLLW)	**-2**	**0**	**2.8**	**6.6**	**-2**	**0**	**2.8**	**6.6**
Sarcodiotheca sp. (unid.)	0.2	0	0	0	1.2	0	0	0
Sargassum muticum	0	0	0	0	0	0	0	0
Saxidomus giganteus	0	0.4	0.8	0	0	0	0.4	0
Saxidomus giganteus juv.	0.2	0	0.8	0	0.2	0.2	1.8	0
Scleroplax granulata	0	0	0	0	0	0	0	0
Scolelepis squamata	0	0.4	0	0	0	0	0	0
Scytosiphon simplicissimus	0	0	0	0	0	0	0	0
Smithora naiadum	0	0	0	0	0	0	0	0
Sphaeromid isopods	0	1	0	0	0	32	5.2	0
Spio filicornis	3.6	1.8	0.4	0	1.2	0.4	0.2	0
Spiochaetopterus tube	0	0	0	0	0	0	0	0
Spiophanes bombyx	0	0	0	0	0	0	0	0
Stichaeidae (gunnels and pricklebacks)	0.6	0.2	0	0	0	0	0	0
Strongylocentrotus sp.	0	0	0	0	0.2	0	0	0
Tellina modesta	0.2	0	0	0	0	0	0	0
Tonicella lineata	0	0	0	0	0	0	0	0
Nutricola (= Transenella) tantilla	0	0	0	0	0	0	0	0
Tresus capax	0	0.8	0.2	0	0	0.2	0	0
Tresus capax juveniles	1.6	0.2	0	0	0.2	0.4	0	0
Ulvoids (unident.)	65	72	40	5.2	89	87	20	0.1
Urticina sp.	0	0	0	0	0	0	0	0
Zostera marina	0	0	0	0	0	0	0	0

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	**Outfall Trench**						
Year	**2009**	**2009**	**2009**	**2009**	**2010**	**2010**	**2010**
Intertidal Height (feet above MLLW)	**-2**	**0**	**2.8**	**6.6**	**-2**	**0**	**2.8**
Acrosiphonia spp.	0	9	4.2	0	2.2	1.6	0.2
Allorchestes angusta	0	0	0	0	0	0	0
Ampithoe dalli	0	0	0	0	0	0	0.2
Ampithoe lacertosa	0	0	0	0	0	0	0
Anisogammarus pugettensis	0.2	0	0	0	0	0	0
Anthopleura spp.	0	0	0	0	0.2	0.2	0.4
Armandia brevis	0	2.6	0	0	0	0	0
Axiothella rubrocincta	0	0	0	0	0	0	0
Bryozoa (miscellaneous)	0	0	0	0	0	0	0
Calliopius spp.	0	0	0	0	0	0	0
Cancer sp.	0	0	0	0	0	0	0
Cancer sp. Juvenile	0	0	0	0	0	0	0
Capitella capitata	0.4	0.2	0	0	0	0	0
Caulleriella ?pacifica	0	0	0	0	0	0	0
Ceramium sp.	0	0	0	0	0	0	0
Chondracanthus exasperata	0	0	0	0	0	0	0
Cirratulus multioculatus	0	0	0	0	0	0	0
Clinocardium nuttallii	0	0	0	0	0	0.2	0
Clinocardium nuttallii juveniles	0	0.2	0	0	0	0	0
Cobble percentage	3	17	3	12	4	11	3
Cottidae (sculpins)	0	0	0	0	0	0	0
Crangon franciscorum ssp. franciscorum	0	0	0	0	0	0	0
Crassostrea gigas	0	0	0	0	0	0	0
Crepidula dorsata	0	0	0	0	0	0	0
Cryptosiphonia woodii	0	0	0	0	0	0	0
Cumagloia andersonii	0	0	0	0	0	0	0
Dead barnacles (Class Cirripedia)	1.6	1	1	0.2	4.2	3.4	1.8
Delesseria sp.	0	0	0	0	0	0	0
Dendraster juv. in core	0	0	0	0	0	0	0
Desmarestia spp.	0	0	0	0	0	0	0
Diatoms, chain-forming	0.2	0.2	0	0	0.2	0.6	0.2
Diopatra ornata	0	0	0	0	0	0	0
Edwardsia sipunculoides	0	0	0	0	0	0	0
Epiactis prolifera	0	0	0	0	0	0	0
Eteone spp.	0.2	0.6	0	0	0	0.2	0
Euclymene spp.	0	0	0	0	0	0	0
Eulalia sanguinea	0	0	0	0	0	0	0
Evasterias troschelii	0	0	0	0	0.2	0	0
Exosphaeroma inornata	0	0.2	0	0	0.4	0.2	0.2
Family Hippolytidae	0	0	0	0	0	0	0
Flatworm (unident.)	0.4	0.4	0	0	5.2	4.6	0
Fleshy crust	0.2	0.6	0.2	0	3	3.4	0.8
Gammarid amphipods	0	4.8	1	0	18.2	4.4	4
Gelidium spp.	0	0	0	0	0	0	0
Glycera americana	0	0	0	0	0	0	0
Glycinde picta	0.2	0.4	0	0	0.4	0.2	0
Glycinde polygnatha	0	0	0	0	0	0	0
Gnorimosphaeroma oregonense	0	0	0	0	0	0	0.4
Gracilaria pacifica	0	0	0	0	0	0	0
Grateloupia sp.	0	0	0	0	0	0	0
Green filaments	0	0	0	0	0	0	0

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	**Outfall Trench**						
Year	**2009**	**2009**	**2009**	**2009**	**2010**	**2010**	**2010**
Intertidal Height (feet above MLLW)	**-2**	**0**	**2.8**	**6.6**	**-2**	**0**	**2.8**
Haminoea vesicula	0	0	0	0	0	0	0
Harmothoe imbricata	0	0	0	0	0	0	0
Hemigrapsus nudus	0	0	0	0	0	0	0
Hemigrapsus oregonensis	0	0	0	0	0.2	0	0
Hemipodus borealis	0	2.6	1.2	1	0	0.2	1.6
Hermissenda crassicornis	0	0	0	0	0	0	0
Hiatella arctica	0	0	0	0	0	0	0
Protohyale (= Hyale) spp.	0	0	0	0	0.2	0.2	0
Idotea sp.	0	2	0	0	0.2	0.2	1
Ischyrocerus anguipes	0	0	0	0	0	0	0
Lacuna spp.	8	53	0.4	0	125	105	0
Saccharina latissima (=Laminaria saccharina)	0	0	0	0	45	3.2	0
Lepidochitona dentiens	0	0	0	0	0	0	0
Leptochelia dubia	0	0	0	0	0	0	0
Leptosynapta clarki	0	0	0	0	0	0	0
Littorina scutulata	0	0	0	0	0	0	0
Littorina sp.	0	0	0	0	0	0	10.4
Live barnacles (Class Cirripedia)	5	55	3.4	0.6	35	35	19
Lophopanopeus bellus bellus	0	0	0	0	0	0	0
Lottiid limpets	0.2	11.6	0.2	0	4.4	40	24
Lucina tenuisculpta	0	0	0	0	0	0	0
Lumbrineris zonata	0	0.6	0	0	3.4	1.8	0
Macoma inquinata	0	0.6	0	0	0	0	0
Macoma inquinata juveniles	0	0.6	0.2	0	0	0	0
Magelona hobsonae	0	0	0	0	0	0	0
Majid (spider) crab	0	0	0	0	0	0	0
Majid juvenile crab	0	0	0	0	0	0	0
Malacoceros glutaeus	0	0	0	0	0	0	0
Malmgreniella nigralba	0	0	0	0	0	0	0
Margarites sp.	0	0	0	0	0	0	0
Mastocarpus jardinii	0	0	0	0	0	0	0
Mastocarpus papillatus	0	0.2	0.2	0	2.2	3.4	1.2
Mazzaella heterocarpa/oregona	0	0	0	0	5	0.2	1
Mazzaella sp.	0	0	0	0	0	0	0
Mazzaella splendens	0	0	0	0	6	0	0
Mediomastus californiensis	0	0.2	1	0.8	0	0.4	0
Megalorchestia pugettensis	0	0	0	0	0	0	0
Melanochlamys diomedea	0	0	0	0	0	0	0
Metridium sp.	0	0	0	0	0	0	0
Microcladia borealis	0	0	0	0	0	0	0
Micropodarke dubia	0	0	0	0	0	0	0
Mopalia lignosa	0	0	0	0	0.6	0	0
Mopalia muscosa	0	0	0	0	0	0	0
Rochefortia tumida (=Mysella tumida)	0	0	0	0	0	0	0
Mytilus trossulus	0.2	1	0.6	0	0	0.8	9
Naineris dendritica	0	0	0	0	0	0	0
Nassarius sp.	0	0	0	0	0	0	0
Nemertean (unident.)	0	0	0	0	1.2	2.6	0
Neotrypaea californiensis	0	0	0	0	0	0	0

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	**Outfall Trench**						
Year	**2009**	**2009**	**2009**	**2009**	**2010**	**2010**	**2010**
Intertidal Height (feet above MLLW)	**-2**	**0**	**2.8**	**6.6**	**-2**	**0**	**2.8**
Nephtys caeca	0	0	0	0	0	0	0
Nephtys caecoides	0	0	0	0	0	0	0
Nephtys ferruginea	0	0	0	0	0	0	0
Nereis procera	0.4	0.2	0	0	0	0	0
Nereis vexillosa	0	4.4	0	0	0	0	0.2
Notomastus lineatus	0	0	0	0	0	0	0
Notomastus tenuis	0.6	0.2	0	0	0.6	0	0.2
Nucella lamellosa	0	0	0	0	0.2	4.2	0.4
Ocenebra lurida	0	0	0	0	0	0	0
Odonthalia floccosa	0	0	0	0	0	0	0
Odostomia sp. (unident.)	0	0	0	0	0	0	0
Oenopota sp.	0	0	0	0	0	0	0
Onchidoris bilamellata	0.4	5.6	0	0	0.4	0.4	0
Onuphis elegans	0	0	0	0	0	0	0
Onuphis iridescens	0	0	0	0	0	0	0
Owenia fusiformis	0	0	0	0	0	0	0
Pagurus spp.	0.4	1	0	0	2.4	5	5
Paracalliopiella pratti	0	0	0	0	0	0	0
Petalonia fascia	0	0.8	0	0	0.2	0.6	0
Pholoe minuta	0	0	0	0	0	0	0
Phoronopsis harmeri	0	0	0.2	0	0	0	0.2
Photis spp.	0.2	0	0	0	0.2	0	0
Phyllaplysia taylori	0	0	0	0	0	0	0
Pinnixia faba	0	0	0	0	0	0	0
Pinnixia schmitti/occidentalis	0	0	0	0	0	0	0
Pinnotherid sp. (unident.)	0	0	0	0	0	0	0
Pisaster ochraceus	0	0	0	0	0	0	0
Platynereis bicanaliculata	0	0	0	0	0.4	0	0.2
Podarke pugettensis	0	0	0	0	0	0	0
Podarkeopsis glabrus	0	0	0	0	0	0	0
Pododesmus cepio	0	0	0	0	0	0	0
Euspira (=Polinices) lewisii	0	0	0	0	0	0	0
Polydora brachycephala	0	0	0	0	0	0	0
Polydora cardalia	0	0	0	0	0	0	0
Polydora columbiana	0.2	0.4	0	0	0	0	0.2
Polydora quadrilobata	0	0	0	0	0	0	0
Polyneura sp.	0	0	0	0	0	0	0
Polynoid (unident., in quadrat)	0	0	0.2	0	0.2	0	0
Polysiphonia sp.	0.2	0	0	0	2	1.4	0.2
Pontogeneia ivanovi	0.2	0.2	0	0	1	0	0
Porphyra sp.	1	3.4	8	0.2	0.4	0	26
Prionitis sp. (unident.)	0	0	0	0	0	0	0
Prionospio steenstrupi	0	0	0	0	0	0	0
Leukoma (=Protothaca) staminea	0	0	0	0	0	0	0
Leukoma staminea juv.	0	0	0	0	0.2	0	0
Pseudopolydora kempi japonica	0	0	0	0	0	0	0
Ptilohyale plumulosa	0	0	0	0	0	0	0
Pugettia gracilis	0	0	0	0	0	0	0
Sabellid (unident.)	0	0	0	0	0	0	0
Sand percentage	94.2	11	24	25	36	29	12.2

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	**Outfall Trench**						
Year	**2009**	**2009**	**2009**	**2009**	**2010**	**2010**	**2010**
Intertidal Height (feet above MLLW)	**-2**	**0**	**2.8**	**6.6**	**-2**	**0**	**2.8**
Sarcodiotheca sp. (unid.)	0	0	0	0	0.2	0	0
Sargassum muticum	0	0	0	0	0	0	0
Saxidomus giganteus	0	0	0	0	0	0.4	0
Saxidomus giganteus juv.	0	0	0	0	0.4	0.4	0
Scleroplax granulata	0	0	0	0	0	0	0
Scolelepis squamata	0	0.2	0	0	0	0	0
Scytosiphon simplicissimus	0	0	0	0	0	0	0
Smithora naiadum	0	0	0	0	0	0	0
Sphaeromid isopods	0	0.2	0	0	7	27	12
Spio filicornis	0.6	11	0	0	0.2	0	0.2
Spiochaetopterus tube	0	0	0	0	0	0	0
Spiophanes bombyx	0	0	0	0	0	0	0
Stichaeidae (gunnels and pricklebacks)	0.4	0	0	0	0	0	0
Strongylocentrotus sp.	0	0	0	0	0	0	0
Tellina modesta	0	0	0	0	0	0	0
Tonicella lineata	0	0	0	0	0	0	0
Nutricola (= Transenella) tantilla	0	0	0	0	0	0	0
Tresus capax	0	0	0	0	0	0.2	0
Tresus capax juveniles	0	0.2	0	0	0.2	0	0
Ulvoids (unident.)	3.4	85	22	2.2	73	85	17
Urticina sp.	0	0	0	0	0	0	0
Zostera marina	0	0	0	0	0	0	0

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	**Pt Wells North**									
Year	**2006**	**2006**	**2006**	**2006**	**2007**	**2007**	**2007**	**2007**	**2008**	**2008**
Intertidal Height (feet above MLLW)	**-2**	**0**	**2.8**	**6.6**	**-2**	**0**	**2.8**	**6.6**	**-2**	**0**
Acrosiphonia spp.	0.3	1.9	0	0	1.5	1	0.2	0	0.2	7.2
Allorchestes angusta	0	0	0	0	0	0	0	0	0	0.4
Ampithoe dalli	0	0	0	0	0	0	0	0	0	0
Ampithoe lacertosa	0	0	0	0	0	0	0	0	0	0
Anisogammarus pugettensis	0	0	0	0	0	0	0	0	1.4	0
Anthopleura spp.	0.1	1.3	0	0	0.1	0.6	0.1	0	0.1	1
Armandia brevis	0	0	0	0	0.3	0.6	0	0	0	0
Axiothella rubrocincta	0	0	0	0	0	0	0	0	0	0
Bryozoa (miscellaneous)	0	0	0	0	0	0	0	0	0	0
Calliopius spp.	0	0	0	0	0	0	0	0	0	0
Cancer sp.	0	0.8	0	0	0.1	0	0.1	0	0	0
Cancer sp. Juvenile	2.7	0.2	0	0	0.1	0	0.1	0	0	0
Capitella capitata	0	0	0	0	0.1	0.2	0	0	0	0
Caulleriella ?pacifica	0	0	0	0	0	0	0	0	0	0
Ceramium sp.	0	0	0	0	0	0	0	0	0	0
Chondracanthus exasperata	0	0	0	0	0	0	0	0	0	0
Cirratulus multioculatus	0	0	0	0	0	0	0	0	0	0
Clinocardium nuttallii	0	0.1	0	0	0	0	0	0	0	0
Clinocardium nuttallii juveniles	0	0.3	0	0	0	0	0	0	0	0.1
Cobble percentage	48.5	48	0	2.5	28.5	26	25	5	16	15
Cottidae (sculpins)	0.3	0	0	0	0	0	0	0	0	0
Crangon franciscorum ssp. franciscorum	0	0	0	0	0	0	0	0	0.1	0
Crassostrea gigas	0	0	0	0	0	0	0	0	0	0
Crepidula dorsata	0	0	0	0	0	0	0	0	0	0
Cryptosiphonia woodii	0	0	0	0	0	0	0	0	0	0
Cumagloia andersonii	0.1	0	0	0	0	0	0	0	0	0
Dead barnacles (Class Cirripedia)	2.2	8	0.2	0	4.4	3.3	4.8	0	4.2	2.2
Delesseria sp.	0	0	0	0	0	0	0	0	0	0
Dendraster juv. in core	0	0	0	0	0	0	0	0	0	0
Desmarestia spp.	0	0	0	0	0	0	0	0	0	0
Diatoms, chain-forming	0.1	2.3	0	0	1.1	1.4	0	0	1.7	0.7
Diopatra ornata	0	0	0	0	0	0	0	0	0	0
Edwardsia sipunculoides	0.1	0	0	0	0.1	0	0	0	0	0
Epiactis prolifera	0	0	0	0	0	0	0	0	0	0
Eteone spp.	0	0.1	0	0	0	0.1	0	0	0	0
Euclymene spp.	0	0	0	0	0	0	0	0	0	0
Eulalia sanguinea	0	0	0	0	0	0	0	0	0	0
Evasterias troschelii	0	0	0	0	0	0	0	0	0	0
Exosphaeroma inornata	0	0	0	0	0	0	0	0	0	0
Family Hippolytidae	0.05	0	0	0	0	0	0	0	0	0
Flatworm (unident.)	0	0	0	0	0.5	1.6	0	0	0	0
Fleshy crust	1.7	1.2	0.3	0	0.7	0.4	0.1	0	4.8	5.2
Gammarid amphipods	2.9	0.6	0	0	0	0.2	0.2	0	22	16.2
Gelidium spp.	0	0	0	0	0	0	0	0	0	0
Glycera americana	0	0	0	0	0	0	0	0	0	0
Glycinde picta	0	0	0	0	1.2	0.4	0	0	0	0.2
Glycinde polygnatha	0	0	0	0	0	0	0	0	0	0
Gnorimosphaeroma oregonense	0	0	0	0	0	0	0	0	0	0
Gracilaria pacifica	0	0	0	0	0	0	0	0	0	0.1
Grateloupia sp.	0	0	0	0	0	0	0	0	0	0
Green filaments	0	0	0	0	0	0	0	0	0	0

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	Pt Wells North									
Year	**2006**	**2006**	**2006**	**2006**	**2007**	**2007**	**2007**	**2007**	**2008**	**2008**
Intertidal Height (feet above MLLW)	**-2**	**0**	**2.8**	**6.6**	**-2**	**0**	**2.8**	**6.6**	**-2**	**0**
Haminoea vesicula	0	0	0	0	0	0	0	0	0	0
Harmothoe imbricata	0	0	0	0	0	0	0	0	0	0
Hemigrapsus nudus	0	0	0	0	0	0	0	0	0	0
Hemigrapsus oregonensis	0	0.2	0	0	0	0.6	0	0	0	0
Hemipodus borealis	0	2	2.1	0	0.2	2.7	3.7	0.125	0.2	3.8
Hermissenda crassicornis	0.3	0	0	0	0.6	0.4	0.1	0	0	0.1
Hiatella arctica	0	0	0	0	0	0	0	0	0	0
Protohyale (= Hyale) spp.	0	0	0	0	0	0	0	0	0	0.9
Idotea sp.	0	0	0	0	0	0.1	0.2	0	0	0
Ischyrocerus anguipes	0	0	0	0	0	0	0	0	0	0
Lacuna spp.	1	1.3	0	0	15.5	6.9	0.1	0	13	14
Saccharina latissima (=Laminaria saccharina)	5	0	0	0	0.5	0	0	0	2.7	0
Lepidochitona dentiens	0	0	0	0	0	0	0	0	0	0
Leptochelia dubia	0	0	0	0	0	0	0	0	0	0
Leptosynapta clarki	0	0	0	0	0.1	0.3	0	0	0.2	0
Littorina scutulata	0	0	0	0.1	0	0	0.1	0	0	0
Littorina sp.	0	0	0	0	0	0	0	0	0	3
Live barnacles (Class Cirripedia)	0.5	0.2	0	0	25	43	10.6	0.125	0.6	0.7
Lophopanopeus bellus bellus	0	3.1	0	0	0	0	0	0	0.1	0.1
Lottiid limpets	0.4	2.4	0	0	1.8	0.4	0	0	0.9	5.2
Lucina tenuisculpta	0	0	0	0	0	0	0	0	0	0
Lumbrineris zonata	0.2	0.1	0	0	0	0	0	0	0.3	0
Macoma inquinata	0	0	0	0	0	0	0	0	0	0
Macoma inquinata juveniles	0.1	0.1	0	0	0	0	0	0	0	0
Magelona hobsonae	0	0	0	0	0	0	0	0	0	0
Majid (spider) crab	0	0	0	0	0.2	0	0	0	0	0
Majid juvenile crab	0	0	0	0	0	0	0	0	0	0.1
Malacoceros glutaeus	0	0	0	0	0	0	0	0	0	0
Malmgreniella nigralba	0	0.1	0	0	0	0.1	0	0	0	0
Margarites sp.	0	0	0	0	0	0	0	0	0	0
Mastocarpus jardinii	0	0	0	0	0	0	0	0	0	0
Mastocarpus papillatus	0.3	0.8	0	0	1.2	0.1	0	0	0.5	1.5
Mazzaella heterocarpa/oregona	0	0	0	0	0	0	0	0	0	0
Mazzaella sp.	0	0	0	0	0.1	0	0	0	0	0
Mazzaella splendens	0	0	0	0	0	0	0	0	0.6	0.5
Mediomastus californiensis	0.4	5.2	0.1	0	0.9	3.7	0.3	0.5	0	5.5
Megalorchestia pugettensis	0.1	0	0	0	0	0	0.1	0	0	0
Melanochlamys diomedea	0	0	0	0	0	0	0	0	0	0
Metridium sp.	0	0.1	0	0	0	0	0	0	0	0
Microcladia borealis	0	0.1	0	0	0	0	0	0	0	0
Micropodarke dubia	0	0	0	0	0	0	0	0	0	0
Mopalia lignosa	1.6	1.2	0	0	2.2	0.7	0	0	1.3	0.1
Mopalia muscosa	0	0.1	0	0	0	0	0	0	0.1	0.1
Rochefortia tumida (=Mysella tumida)	0	0	0	0	0	0	0.1	0	0	0
Mytilus trossulus	0	0	0	0	0.7	1	0.5	0	0	0.2
Naineris dendritica	0	0	0	0	0	0	0	0	0	0
Nassarius sp.	0	0	0	0	0	0	0	0	0	0
Nemertean (unident.)	0.2	0.5	0	0	1.3	0.5	0	0	0.2	0.1
Neotrypaea californiensis	0	0	0	0	0	0.1	0	0	0	0

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	**Pt Wells North**									
Year	**2006**	**2006**	**2006**	**2006**	**2007**	**2007**	**2007**	**2007**	**2008**	**2008**
Intertidal Height (feet above MLLW)	**-2**	**0**	**2.8**	**6.6**	**-2**	**0**	**2.8**	**6.6**	**-2**	**0**
Nephtys caeca	0	0	0	0	0	0	0	0	0	0
Nephtys caecoides	0	0	0	0	0	0	0	0	0	0
Nephtys ferruginea	0	0	0	0	0.1	0	0	0	0	0
Nereis procera	0.1	0	0	0	0.8	0.4	0	0	0.2	0.4
Nereis vexillosa	0	0	0	0	0	0	0.1	0	0	0
Notomastus lineatus	0	0	0	0	0	0	0	0	0	0
Notomastus tenuis	1.7	2.4	0.1	0	5	5.3	0.2	0.125	2.2	5.7
Nucella lamellosa	3.2	2	0	0	0.8	0.3	0.1	0	0.3	0.7
Ocenebra lurida	0	0	0	0	0	0	0	0	0	0
Odonthalia floccosa	0	0	0	0	0	0	0	0	0	0
Odostomia sp. (unident.)	0	0	0	0	0	0	0	0	0	0.1
Oenopota sp.	0	0	0	0	0	0	0	0	0	0
Onchidoris bilamellata	0	0	0	0	3.1	5	0	0	0	0
Onuphis elegans	0	0	0	0	0.1	0	0	0	0	0
Onuphis iridescens	0	0	0	0	0	0	0	0	0	0
Owenia fusiformis	0	6.7	0	0	0	0.3	0	0	0	0.5
Pagurus spp.	2.2	0.1	0	0	2.9	2.4	0.3	0	0.8	3.2
Paracalliopiella pratti	0	0	0	0	0	0	0	0	0	0
Petalonia fascia	0.3	0.1	0	0	2.9	3.2	0	0	0.5	0.4
Pholoe minuta	0	0	0	0	0	0	0	0	0	0
Phoronopsis harmeri	0.2	1.5	0.1	0	0	1.6	0	0	0.1	0.3
Photis spp.	0	0	0	0	0.2	0	0	0	0.1	0
Phyllaplysia taylori	0	0	0	0	0	0	0	0	0	0
Pinnixia faba	0	0	0	0	0	0	0	0	0	0
Pinnixia schmitti/occidentalis	0	0	0	0	0	0	0	0	0	0
Pinnotherid sp. (unident.)	0	0	0	0	0	0	0	0	0	0
Pisaster ochraceus	0	0	0	0	0	0	0	0	0	0
Platynereis bicanaliculata	0.2	0	0	0	0	0	0	0	0.6	0.1
Podarke pugettensis	0	0	0	0	0	0	0	0	0	0
Podarkeopsis glabrus	0	0	0	0	0	0	0	0	0	0
Pododesmus cepio	0	0	0	0	0	0	0	0	0	0
Euspira (=Polinices) lewisii	0	0	0	0	0	0.1	0	0	0	0
Polydora brachycephala	0	0	0	0	0	0	0	0	0	0
Polydora cardalia	0	0	0	0	0	0	0	0	0	0
Polydora columbiana	0	0	0	0	0	0	0	0	0	0
Polydora quadrilobata	0	0	0	0	0	0	0	0	0	0
Polyneura sp.	0	0	0	0	0	0	0	0	0	0
Polynoid (unident., in quadrat)	0	0	0	0	0.4	0.1	0	0	0	0.1
Polysiphonia sp.	0.1	0	0	0	0.2	0.6	0	0	0.1	0.1
Pontogeneia ivanovi	0	0	0	0	0	0	0	0	0.3	1.9
Porphyra sp.	3.6	4.2	0	0	2.2	1.8	1.1	0	1.1	5.1
Prionitis sp. (unident.)	0.1	0	0	0	0	0	0	0	0	0
Prionospio steenstrupi	0	0	0	0	0	0	0	0	0.1	0
Leukoma (=Protothaca) staminea	0	0.2	0	0	0	0	0	0	0	0
Leukoma staminea juv.	0	0.1	0	0	0	0	0	0	0	0.2
Pseudopolydora kempi japonica	0	0	0	0	0	0.2	0	0	0	0
Ptilohyale plumulosa	0	0	0	0	0	0	0	0	0	0
Pugettia gracilis	0	0.4	0	0	0	0	0	0	0	0
Sabellid (unident.)	0	0	0	0	0	0.1	0	0	0.2	0.1
Sand percentage	22.5	30	88.3	57	43	19.6	9	21.375	40	45.5

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	**Pt Wells North**									
Year	**2006**	**2006**	**2006**	**2006**	**2007**	**2007**	**2007**	**2007**	**2008**	**2008**
Intertidal Height (feet above MLLW)	**-2**	**0**	**2.8**	**6.6**	**-2**	**0**	**2.8**	**6.6**	**-2**	**0**
Sarcodiotheca sp. (unid.)	0	0.1	0	0	0.9	0	0	0	0	0
Sargassum muticum	0	0	0	0	0	0.1	0	0	0	0
Saxidomus giganteus	0	0	0	0	0	0	0	0	0	0.1
Saxidomus giganteus juv.	0.1	0.1	0	0	0.1	0	0.1	0	0	0.4
Scleroplax granulata	0	0	0	0	0	0	0	0	0	0
Scolelepis squamata	0	0	0	0	0	0	0	0	0	0
Scytosiphon simplicissimus	0	0.3	0	0	0	0	0	0	0.9	0.7
Smithora naiadum	0	0	0	0	0	0	0	0	0	0
Sphaeromid isopods	0	0	0	0	0	0	0.1	0	0	0
Spio filicornis	0	0	0	0	0.4	0.9	0	0	0	0
Spiochaetopterus tube	0	0.1	0	0	0	0.2	0	0	0.1	0.1
Spiophanes bombyx	0	0	0	0	0	0	0	0	0	0
Stichaeidae (gunnels and pricklebacks)	0.2	0	0	0	0.1	0	0	0	0	0
Strongylocentrotus sp.	0	0	0	0	0	0	0	0	0	0
Tellina modesta	0	0	0	0	0	0	0	0	0	0
Tonicella lineata	0	0	0	0	0	0	0	0	0	0
Nutricola (= Transenella) tantilla	0	0	0	0	0	0	0	0	0	0
Tresus capax	1.1	0.1	0	0	0.2	0.2	0	0	0	0
Tresus capax juveniles	0	0	0	0	0.2	1.4	0	0	0	0.1
Ulvoids (unident.)	95.2	41.5	0.8	0	71.5	87	27.4	0.375	63.5	76
Urticina sp.	0	0	0	0	0	0	0	0	0	0
Zostera marina	0	0	0	0	0	0	0	0	0.1	0

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	Pt Wells North									
Year	**2008**	**2008**	**2009**	**2009**	**2009**	**2009**	**2010**	**2010**	**2010**	**2010**
Intertidal Height (feet above MLLW)	**2.8**	**6.6**	**-2**	**0**	**2.8**	**6.6**	**-2**	**0**	**2.8**	**6.6**
Acrosiphonia spp.	0	0	1.2	5.8	0	0	0.3	1.2	0.1	0
Allorchestes angusta	0.2	0	0	0	0	0	0	0	0	0
Ampithoe dalli	0	0	0.1	0	0	0	0	0	0	0
Ampithoe lacertosa	0	0	0	0	0	0	0	0	0	0
Anisogammarus pugettensis	0	0	0	0	0	0	0	0	0	0
Anthopleura spp.	0.1	0	0.5	0.9	0.3	0	0.2	1	0.2	0
Armandia brevis	0	0	5.3	1.2	0.1	0	0.3	0.5	0	0
Axiothella rubrocincta	0	0	0	0	0	0	0.1	0	0	0
Bryozoa (miscellaneous)	0	0	0	0	0	0	0.1	0	0	0
Calliopius spp.	0	0	0	0.3	0.1	0	0	0	0	0
Cancer sp.	0	0	0	0.1	0	0	0.2	0.2	0	0
Cancer sp. Juvenile	0	0	0.4	0	0	0	0.1	0.1	0	0
Capitella capitata	0	0	0.2	0	0	0	0	0	0	0
Caulleriella ?pacifica	0	0	0.1	0	0	0	0	0.6	0	0
Ceramium sp.	0	0	0.2	0.5	0	0	0	0	0	0
Chondracanthus exasperata	0	0	0	0	0	0	0	0	0	0
Cirratulus multioculatus	0	0	0	0	0	0	0	0.1	0	0
Clinocardium nuttallii	0	0	0	0	0	0	0.1	0	0	0
Clinocardium nuttallii juveniles	0	0	0.4	0	0	0	0	0	0	0
Cobble percentage	13.5	1	34	50	14.5	2.5	16	16	7	0
Cottidae (sculpins)	0	0	0	0	0	0	0.1	0.1	0	0
Crangon franciscorum ssp. franciscorum	0	0	0	0	0	0	0	0	0	0
Crassostrea gigas	0	0	0	0	0	0	0	0	0	0
Crepidula dorsata	0	0	0	0	0	0	0	0	0	0
Cryptosiphonia woodii	0	0	0	0	0	0	0	0	0	0
Cumagloia andersonii	0	0	0	0	0	0	0	0	0	0
Dead barnacles (Class Cirripedia)	9.1	0	1.8	2.6	3.9	0	3.8	2.2	2.2	0
Delesseria sp.	0	0	0	0	0	0	0.1	0	0	0
Dendraster juv. in core	0	0	0	0	0	0	0	0	0	0
Desmarestia spp.	0	0	0	0	0	0	0	0	0	0
Diatoms, chain-forming	6	0	1.9	1	0	0	1.3	1.6	0.5	0
Diopatra ornata	0	0	0	0	0	0	0	0	0	0
Edwardsia sipunculoides	0	0	0	0	0	0	0.1	0	0	0
Epiactis prolifera	0	0	0	0	0	0	0	0	0	0
Eteone spp.	0	0	0.1	0	0	0	0.4	0.7	0	0
Euclymene spp.	0	0	0	0	0	0	0	0.5	0	0
Eulalia sanguinea	0	0	0	0	0	0	0	0	0	0
Evasterias troschelii	0	0	0	0	0	0	0.1	0	0	0
Exosphaeroma inornata	0	0	0.3	0.2	0.2	0	0	0.6	0	0
Family Hippolytidae	0	0	0	0	0	0	0.15	0.1	0	0
Flatworm (unident.)	0	0	5.3	5.6	0	0	4.5	8.6	0	0
Fleshy crust	0.2	0	0.5	1.2	0.4	0	4.4	4	0.6	0
Gammarid amphipods	0.9	0	0	1.2	2.3	0	5.5	4.9	3.3	0
Gelidium spp.	0	0	0	0	0	0	0	0	0	0
Glycera americana	0	0	0	0.1	0	0	0.2	0	0	0
Glycinde picta	0	0	1	0.5	0	0	0.8	0.3	0	0
Glycinde polygnatha	0	0	0	0	0	0	0	0	0	0
Gnorimosphaeroma oregonense	0	0	0	0	0	0	0	0	0	0
Gracilaria pacifica	0	0	0	0	0	0	0	0	0	0
Grateloupia sp.	0	0	0	0	0	0	0	0	0	0
Green filaments	0	0	0	0	0	0	0	0	0	0

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	Pt Wells North									
Year	**2008**	**2008**	**2009**	**2009**	**2009**	**2009**	**2010**	**2010**	**2010**	**2010**
Intertidal Height (feet above MLLW)	**2.8**	**6.6**	**-2**	**0**	**2.8**	**6.6**	**-2**	**0**	**2.8**	**6.6**
Haminoea vesicula	0	0	0.2	0	0	0	0	0	0	0
Harmothoe imbricata	0	0	0.3	0	0	0	0	0.2	0	0
Hemigrapsus nudus	0	0	0	0	0	0	0	0	0	0
Hemigrapsus oregonensis	0.1	0	0	0.1	0.2	0	0	0.2	0.1	0
Hemipodus borealis	4	0	0.9	2.1	2.6	0.1	0.1	1.5	2.6	0.1
Hermissenda crassicornis	0	0	0	0	0	0	0.5	0	0	0
Hiatella arctica	0	0	0.1	0	0	0	0	0	0	0
Protohyale (= Hyale) spp.	0	0	0	0	0	0	0	0.1	0	0
Idotea sp.	0	0	0	0.9	0.2	0	0	0	0.1	0
Ischyrocerus anguipes	0	0	0	0	0	0	0	0	0	0
Lacuna spp.	0.1	0	17	73	0.5	0	48.5	59.5	0	0
Saccharina latissima (=Laminaria saccharina)	0	0	0.1	0	0	0	56	0.2	0	0
Lepidochitona dentiens	0	0	0	0	0	0	0	0	0	0
Leptochelia dubia	0	0	0.1	0.1	0	0	0	0	0	0
Leptosynapta clarki	0	0	0.2	0.1	0	0	0	0	0.1	0
Littorina scutulata	0.5	0	2.5	0	1.5	0	0	0	0	0
Littorina sp.	0.6	0	0	0	0	0	0	0	3.4	0
Live barnacles (Class Cirripedia)	1	0	23.5	71	6.4	0.1	23	20.5	3.4	0
Lophopanopeus bellus bellus	0	0	0	0	0	0	0	0	0	0
Lottiid limpets	0	0	6.8	35.5	1.7	0	1.3	4.1	7.1	0
Lucina tenuisculpta	0	0	0	0	0	0	0	0	0	0
Lumbrineris zonata	0	0	0.3	0.8	0	0	0.8	1.2	0	0
Macoma inquinata	0	0	0	0	0	0	0	0	0	0
Macoma inquinata juveniles	0	0	0	0.2	0.2	0	0.5	1.2	0.2	0
Magelona hobsonae	0	0	0	0	0	0	0	0	0	0
Majid (spider) crab	0	0	0.1	0	0	0	0.1	0.1	0	0
Majid juvenile crab	0	0	0	0	0	0	0	0	0	0
Malacoceros glutaeus	0	0	0	0	0	0	0	0	0	0
Malmgreniella nigralba	0	0	0	0	0	0	0	0	0	0
Margarites sp.	0	0	0	0	0	0	0	0	0	0
Mastocarpus jardinii	0	0	0	0	0	0	0	0	0	0
Mastocarpus papillatus	0	0	1.8	0.9	0	0	0.5	2.4	0	0
Mazzaella heterocarpa/oregona	0	0	0	0	0	0	0.1	1.6	0	0
Mazzaella sp.	0	0	0	0	0	0	0	0	0	0
Mazzaella splendens	0	0	0.5	0	0	0	1.1	0.5	0	0
Mediomastus californiensis	0.6	0	0.3	2.6	0.5	0	0	3.6	0.6	0
Megalorchestia pugettensis	0	0	0	0	0	0	0	0	0	0
Melanochlamys diomedea	0	0	0	0	0	0	0	0	0	0
Metridium sp.	0	0	0	0	0.1	0	0	0.1	0	0
Microcladia borealis	0	0	0	0.1	0	0	0	0	0	0
Micropodarke dubia	0	0	0	0.1	0	0	0	0	0	0
Mopalia lignosa	0	0	4.3	1.3	0	0	0.8	0.4	0	0
Mopalia muscosa	0	0	0	0	0.1	0	0	0	0	0
Rochefortia tumida (=Mysella tumida)	0.1	0	0.1	0	0	0	0	0.3	0	0
Mytilus trossulus	2	0	0.8	1	0.3	0	0	0.3	2.4	0
Naineris dendritica	0	0	0	0	0	0	0	0	0	0
Nassarius sp.	0.2	0	0	0	0	0	0	0	0	0
Nemertean (unident.)	0	0	1.2	0.1	0	0	0.5	0.8	0	0
Neotrypaea californiensis	0	0	0	0	0	0	0	0	0	0

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	Pt Wells North									
Year	**2008**	**2008**	**2009**	**2009**	**2009**	**2009**	**2010**	**2010**	**2010**	**2010**
Intertidal Height (feet above MLLW)	**2.8**	**6.6**	**-2**	**0**	**2.8**	**6.6**	**-2**	**0**	**2.8**	**6.6**
Nephtys caeca	0	0	0	0	0	0	0	0	0	0
Nephtys caecoides	0	0	0.1	0	0	0	0	0	0	0
Nephtys ferruginea	0	0	0	0	0	0	0	0	0	0
Nereis procera	0	0	0.8	0.3	0	0	0.6	0.1	0.1	0
Nereis vexillosa	0.1	0	0	1	0.2	0	0	0	0	0
Notomastus lineatus	0	0	0	0	0	0	0	0	0	0
Notomastus tenuis	0.7	0	6	8.8	0.3	0	2.4	6.4	0.4	0
Nucella lamellosa	0	0	0.6	1.5	0	0	0.7	2	0.1	0
Ocenebra lurida	0	0	0	0	0	0	0	0	0	0
Odonthalia floccosa	0	0	0	0	0	0	0	0	0	0
Odostomia sp. (unident.)	0	0	0	0	0	0	0	0	0	0
Oenopota sp.	0	0	0	0	0	0	0	0	0	0
Onchidoris bilamellata	0	0	11.2	18.9	0	0	0.5	0.1	0	0
Onuphis elegans	0	0	0	0	0	0	0	0	0	0
Onuphis iridescens	0	0	0	0	0	0	0	0	0	0
Owenia fusiformis	0.1	0	0.3	0.2	0	0	0.1	1.3	0.1	0
Pagurus spp.	0.3	0	1.3	2.1	0.7	0	2.3	5.1	1.2	0
Paracalliopiella pratti	0	0	0	0	0	0	0	0	0	0
Petalonia fascia	0	0	3	0.8	0	0	0.3	0.5	0.1	0
Pholoe minuta	0	0	0	0	0	0	0	0	0	0
Phoronopsis harmeri	0.6	0	0	0.5	0.6	0	0.1	1.4	1.7	0
Photis spp.	0	0	1.2	0	0	0	0	0.2	0	0
Phyllaplysia taylori	0	0	0	0	0	0	0	0	0	0
Pinnixia faba	0	0	0	0	0	0	0	0	0	0
Pinnixia schmitti/occidentalis	0	0	0	0	0	0	0	0	0	0
Pinnotherid sp. (unident.)	0	0	0	0	0	0	0	0.1	0	0
Pisaster ochraceus	0	0	0	0	0	0	0	0	0	0
Platynereis bicanaliculata	0	0	0.2	0	0	0	0.1	0	0	0
Podarke pugettensis	0	0	0.1	0	0	0	0	0	0	0
Podarkeopsis glabrus	0	0	0	0	0	0	0	0	0	0
Pododesmus cepio	0	0	0	0	0	0	0	0	0	0
Euspira (=Polinices) lewisii	0	0	0	0	0	0	0	0	0	0
Polydora brachycephala	0	0	0	0	0	0	0	0	0	0
Polydora cardalia	0	0	0	0.2	0	0	0	0	0	0
Polydora columbiana	0	0	1.5	0.4	0	0	0	0	0	0
Polydora quadrilobata	0.1	0	0	0	0	0	0	0	0	0
Polyneura sp.	0	0	0	0	0	0	0.1	0	0	0
Polynoid (unident., in quadrat)	0	0	0.2	0.2	0	0	0	0	0	0
Polysiphonia sp.	0	0	2.4	0.6	0.2	0	0.6	0.6	0.7	0
Pontogeneia ivanovi	0	0	0.2	0	0	0	0.2	0.4	0	0
Porphyra sp.	0	0	4.2	3.7	0.1	0	0.2	0.5	0.3	0
Prionitis sp. (unident.)	0	0	0	0	0	0	0	0	0	0
Prionospio steenstrupi	0	0	0	0	0	0	0	0.2	0	0
Leukoma (=Protothaca) staminea	0	0	0	0.1	0	0	0	0	0	0
Leukoma staminea juv.	0.1	0	0	0	0	0	0	0.3	0.2	0
Pseudopolydora kempi japonica	0	0	0	0	0	0	0	0	0	0
Ptilohyale plumulosa	0	0	0	0	0	0	0	0	0	0
Pugettia gracilis	0	0	0	0	0	0	0	0	0	0
Sabellid (unident.)	0	0	0	0	0	0	0	0	0	0
Sand percentage	35	92.8	19.5	8	19.1	63.5	31	15	26.5	33.5

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	**Pt Wells North**									
Year	**2008**	**2008**	**2009**	**2009**	**2009**	**2009**	**2010**	**2010**	**2010**	**2010**
Intertidal Height (feet above MLLW)	**2.8**	**6.6**	**-2**	**0**	**2.8**	**6.6**	**-2**	**0**	**2.8**	**6.6**
Sarcodiotheca sp. (unid.)	0	0	0	0.2	0	0	0.3	0	0	0
Sargassum muticum	0	0	0	0	0	0	0	0	0	0
Saxidomus giganteus	0	0	0	0.2	0	0	0.1	0	0	0
Saxidomus giganteus juv.	0	0	0.3	0.1	0	0	0.1	0.9	0.4	0
Scleroplax granulata	0	0	0	0	0	0	0	0	0	0
Scolelepis squamata	0	0	0	0	0	0	0	0	0	0
Scytosiphon simplicissimus	0	0	0.1	0.1	0	0	0	0	0	0
Smithora naiadum	0	0	0	0	0	0	0	0	0	0
Sphaeromid isopods	0.1	0	0	0.2	0.5	0	0	0.1	3.8	0
Spio filicornis	0	0	4.8	7.9	0.2	0	1.8	2	0.3	0
Spiochaetopterus tube	0	0	0.1	0.2	0	0	0	0.3	0	0
Spiophanes bombyx	0	0	0	0	0	0	0	0	0	0
Stichaeidae (gunnels and pricklebacks)	0	0	0.3	0	0.1	0	0.5	0	0	0
Strongylocentrotus sp.	0	0	0	0	0	0	0	0	0	0
Tellina modesta	0	0	0.2	0	0	0	0.1	0	0	0
Tonicella lineata	0	0	0	0	0	0	0	0	0	0
Nutricola (= Transenella) tantilla	0	0	0.1	0	0	0	0	0	0	0
Tresus capax	0.1	0	0	0.1	0	0	0	0.8	0	0
Tresus capax juveniles	0	0	0.3	0.3	0	0	0.7	1.1	0	0
Ulvoids (unident.)	18.5	0	61	81.5	31.5	0.5	67.5	91	22	0
Urticina sp.	0	0	0	0	0	0	0	0	0	0
Zostera marina	0	0	0	0	0	0	0.2	0	0	0

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	**Pt Wells South**									
Year	**2006**	**2007**	**2007**	**2007**	**2008**	**2008**	**2008**	**2009**	**2009**	**2009**
Intertidal Height (feet above MLLW)	**-2**	**-2**	**0**	**2.8**	**-2**	**0**	**2.8**	**-2**	**0**	**2.8**
Acrosiphonia spp.	0.5	0.8	2.6	8.2	1.6	4.1	1.5	0.7	1	0.2
Allorchestes angusta	0	0	0	1.2	0.1	0	0.1	0	0	0.1
Ampithoe dalli	0	0	0	0	0	0	0	0	0	0
Ampithoe lacertosa	0	0	0	0	0	0	0	0	0	0
Anisogammarus pugettensis	0	0	0	0	0.5	0.1	0	2	0	0
Anthopleura spp.	0.5	0.1	0.2	2	0.1	0.3	0.6	0.5	1.2	4
Armandia brevis	0	0.7	0.3	0.9	0	0	0	1.3	0.8	0.1
Axiothella rubrocincta	0	0	0	0	0	0	0	0.1	0	0
Bryozoa (miscellaneous)	0	0	0	0	0.1	0	0	0	0	0
Calliopius spp.	0	0	0	0	0.1	0	0.2	0	0	0
Cancer sp.	0.8	0	0	0	0.1	0.1	0	0	0	0
Cancer sp. Juvenile	0.4	0	0	0	0	0	0	0	0	0
Capitella capitata	0	0.9	1.2	0.3	0	0.1	0	0	0.4	0
Caulleriella ?pacifica	0	0	0	0	0	0	0	0.2	0	0
Ceramium sp.	0	0	0	0	0	0	0	0	0.1	0
Chondracanthus exasperata	0	0	0	0	0	0	0	0	0	0
Cirratulus multioculatus	0	0	0	0	0	0	0	0	0	0
Clinocardium nuttallii	0	0	0.1	0	0.1	0	0.1	0.2	0.2	0
Clinocardium nuttallii juveniles	0	0.1	0	0	0	0.1	0.2	0	0	0
Cobble percentage	16.5	37	30.5	27.5	10	6.6	7.2	30.5	39	12
Cottidae (sculpins)	0	0	0	0	0	0	0	0	0	0
Crangon franciscorum ssp. franciscorum	0	0	0	0	0	0	0	0	0	0
Crassostrea gigas	0	0	0	0	0	0	0	0	0	0
Crepidula dorsata	0	0	0	0	0	0	0	0	0	0
Cryptosiphonia woodii	0	0	0	0	0	0	0	0	0	0
Cumagloia andersonii	0.1	0	0	0	0	0	0	0	0	0
Dead barnacles (Class Cirripedia)	4.8	8	4.4	3	5	5.2	9.6	5.8	2.2	2.2
Delesseria sp.	0	0	0	0	0	0	0	0	0	0
Dendraster juv. in core	0	0	0	0	0	0	0	0	0	0.1
Desmarestia spp.	0	0	0	0	0	0	0	0	0	0
Diatoms, chain-forming	0.8	3.3	0.7	0.5	0.4	0	1.7	3.6	0.2	2.1
Diopatra ornata	0	0	0	0	0	0	0	0	0	0
Edwardsia sipunculoides	0	0	0	0	0	0	0	0	0	0
Epiactis prolifera	0	0	0	0	0.1	0	0	0	0	0
Eteone spp.	0	0	0.3	0.1	0	0	0	0.1	0	0
Euclymene spp.	0.2	0.2	0	0	0	0	0	0.1	0	0
Eulalia sanguinea	0	0	0	0	0	0	0	0	0	0
Evasterias troschelii	0	0	0	0	0	0	0	0	0	0
Exosphaeroma inornata	0	0	0	0	0	0	0.3	0	0.3	0
Family Hippolytidae	0	0	0	0	0	0	0	0	0	0
Flatworm (unident.)	0	2.6	0	0.4	0	0	0.1	0.3	1.6	0
Fleshy crust	2.5	2.1	0.8	0.3	4.2	4.2	1.1	1.5	0.8	0.2
Gammarid amphipods	0.1	0.4	0	1.2	34	100	19	16.7	7.8	11.5
Gelidium spp.	0	0	0	0	0	0	0	0	0	0
Glycera americana	0	0	0	0	0	0.1	0	0.1	0	0
Glycinde picta	0	0.5	0.5	0.2	0.3	0.1	0.1	0.1	0.1	0.3
Glycinde polygnatha	0	0	0	0	0	0	0	0	0	0
Gnorimosphaeroma oregonense	0	0	0	0	0	0	0	0	0	0
Gracilaria pacifica	0	0.1	0	0	0.3	0	0	0	0	0
Grateloupia sp.	0	0	0	0	0	0	0	0	0	0
Green filaments	0	0	0	0	0	0	0	0	0	0

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	Pt Wells South									
Year	**2006**	**2007**	**2007**	**2007**	**2008**	**2008**	**2008**	**2009**	**2009**	**2009**
Intertidal Height (feet above MLLW)	**-2**	**-2**	**0**	**2.8**	**-2**	**0**	**2.8**	**-2**	**0**	**2.8**
Haminoea vesicula	0	0	0	0	0	0	0	0	0	0
Harmothoe imbricata	0	0.1	0	0.1	0	0	0	0	0	0
Hemigrapsus nudus	0	0	0	0	0	0.1	0	0	0	0
Hemigrapsus oregonensis	0	0	1.4	5.4	0	0.1	0.1	0	0.7	3.5
Hemipodus borealis	0.1	0	0.3	6	0	1.4	4.6	0.2	3.2	4.2
Hermissenda crassicornis	0	0.4	0	0.3	0	0	0	0	0	0
Hiatella arctica	0	0	0	0	0	0	0	0	0	0
Protohyale (= Hyale) spp.	0	0	0	0	0.3	0.2	0	0	0.2	0
Idotea sp.	0	0	0	0.2	0	0	0	0	1.4	1
Ischyrocerus anguipes	0	0	0	0	0	0	0	0	0	0
Lacuna spp.	0.1	38.3	27.6	3	10.6	16.5	0	43.5	22.6	5
Saccharina latissima (=Laminaria saccharina)	1.1	3.2	0	0	11	2	0	0.7	0	0
Lepidochitona dentiens	0	0	0	0	0	0	0	0	0	0
Leptochelia dubia	0	0	0	0	0	0	0	0	0	0
Leptosynapta clarki	0	0	0	0	0	0	0	0	0	0
Littorina scutulata	0	0	0	8	0	0	0	0	0	0.2
Littorina sp.	0	0	0	0	0	0	26.1	0	0	0
Live barnacles (Class Cirripedia)	0.5	37	45.5	76	0.2	0.8	3	18.6	73	70
Lophopanopeus bellus bellus	0	0	0	0	0	0	0	0	0	0
Lottiid limpets	0	0.7	2.4	14	5	8.9	19.6	4.9	16.9	18.3
Lucina tenuisculpta	0.1	0	0	0	0	0	0	0.3	0	0
Lumbrineris zonata	0	0.2	0	0	0.8	1	0	0.7	1	0.1
Macoma inquinata	0	0	0.1	0.2	0.1	0.7	0.3	0.5	0	0
Macoma inquinata juveniles	0	0	0	0.2	0.2	0.2	0.9	1.8	2.1	3.7
Magelona hobsonae	0	0	0	0	0	0	0	0	0	0
Majid (spider) crab	0	0	0	0	0	0	0	0	0	0
Majid juvenile crab	0	0	0	0	0	0	0	0	0	0
Malacoceros glutaeus	0	0	0	0	0	0	0	0	0	0
Malmgreniella nigralba	0	0	0	0	0	0	0	0	0	0
Margarites sp.	0	0	0	0	0	0	0	0	0	0
Mastocarpus jardinii	0	0	0	0	0	0	0	0	0	0
Mastocarpus papillatus	0.5	1.2	0.7	0.8	0.7	1.8	1.4	1.4	1.6	1.3
Mazzaella heterocarpa/oregona	0.5	0	0	0	0	0	0.5	0	0	0
Mazzaella sp.	0	0	0	0	0	0	0	0	0	0
Mazzaella splendens	0	0.5	0	0	4.6	0.6	0	3.7	0.5	0
Mediomastus californiensis	0.4	0	1.3	6.6	0.2	0	10.8	2.9	2.3	14.1
Megalorchestia pugettensis	0	0	0	0	0	0	0	0	0	0
Melanochlamys diomedea	0	0	0	0	0	0	0	0	0.7	0
Metridium sp.	0	0	0	0	0	0	0	0.1	0	0
Microcladia borealis	0	0	0	0	0	0	0	0	0	0
Micropodarke dubia	0	0	0	0	0	0	0	0	0	0
Mopalia lignosa	0	0.6	0.4	0	1.5	0.2	0	1	0.4	0.1
Mopalia muscosa	0.1	0	0	0	0	0	0	0	0.1	0.1
Rochefortia tumida (=Mysella tumida)	0	0.1	0.3	0.4	0.1	0	0.2	0.1	0.1	0.1
Mytilus trossulus	0	0.7	2.1	5	0.1	0	21.3	0.5	1	6.1
Naineris dendritica	0	0	0	0	0	0	0.1	0	0	0.1
Nassarius sp.	0	0	0	0	0	0	0	0	0	0
Nemertean (unident.)	0.1	7.1	0.3	0.2	0.1	0.5	0.1	0.4	0.3	0.1
Neotrypaea californiensis	0	0	0	0	0	0	0	0	0	0

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	**Pt Wells South**									
Year	**2006**	**2007**	**2007**	**2007**	**2008**	**2008**	**2008**	**2009**	**2009**	**2009**
Intertidal Height (feet above MLLW)	**-2**	**-2**	**0**	**2.8**	**-2**	**0**	**2.8**	**-2**	**0**	**2.8**
Nephtys caeca	0	0	0	0	0	0	0	0	0	0
Nephtys caecoides	0.1	0	0.1	0	0	0	0	0	0.2	0
Nephtys ferruginea	0	0	0	0	0	0	0	0	0	0
Nereis procera	0.2	0.1	0	0.1	0	0	0	0.9	0.2	0
Nereis vexillosa	0	0	0	0	0	0	0	0	0.6	0.2
Notomastus lineatus	0	0	0	0	0	0	0	0	0	0
Notomastus tenuis	2.4	0.5	0.5	2.7	1	0.1	1.7	1	0.9	2
Nucella lamellosa	0.1	1.5	0.7	0.6	0	1.6	0.1	0.1	0.8	0.1
Ocenebra lurida	0	0	0	0	0	0	0	0	0	0
Odonthalia floccosa	0	0	0	0	0	0	0	0	0	0
Odostomia sp. (unident.)	0	0	0	0	0	0	0	0	0	0.3
Oenopota sp.	0	0	0	0	0	0	0	0	0	0
Onchidoris bilamellata	0	2.2	1.2	3.2	0	0	0	6.3	0.6	0
Onuphis elegans	0	0	0	0	0	0	0	0	0	0
Onuphis iridescens	0.1	0	0	0	0	0	0	0.1	0	0
Owenia fusiformis	0	0	0.3	0	0	0	0	0	0.2	0
Pagurus spp.	0.4	0.6	1.9	4.9	0.1	7.8	2.9	4.1	4.8	3.6
Paracalliopiella pratti	0	0	0	0	0.1	0	0	0	0	0
Petalonia fascia	0	1.9	1.8	1.3	0	0.4	0.6	1.2	1	0.6
Pholoe minuta	0	0	0	0.1	0	0	0	0	0.1	0.2
Phoronopsis harmeri	0.3	0	0.1	0.1	0.1	0	0	0	0.1	0
Photis spp.	0	0.4	0	0	0.5	0	0	0	0	0
Phyllaplysia taylori	0	0	0	0	0	0	0	0	0	0
Pinnixia faba	0	0	0	0	0	0	0	0	0	0
Pinnixia schmitti/occidentalis	0	0	0	0	0	0	0	0	0	0
Pinnotherid sp. (unident.)	0	0	0	0	0	0	0	0	0	0
Pisaster ochraceus	0	0	0	0	0	0.1	0	0	0	0
Platynereis bicanaliculata	0	0	0	0	1.2	0.1	0	0.2	0	0
Podarke pugettensis	0	0	0	0	0	0	0	0	0	0
Podarkeopsis glabrus	0	0	0	0	0	0	0.1	0	0	0
Pododesmus cepio	0.1	0	0	0	0	0	0	0	0	0
Euspira (=Polinices) lewisii	0	0.1	0	0	0	0	0	0	0	0
Polydora brachycephala	0	0	0	0	0	0	0	0	0	0
Polydora cardalia	0	0	0	0.1	0	0	0	0	0	0.5
Polydora columbiana	0	0.6	0.6	0	0	0	0.1	0	0.4	0.4
Polydora quadrilobata	0	0	0	0	0	0	0.3	0	0	0
Polyneura sp.	0	0	0	0	0	0	0	0	0	0
Polynoid (unident., in quadrat)	0	0.7	0	0.3	0	0	0	0	0.1	0
Polysiphonia sp.	0	1	0.4	0.1	0	0	0.8	0.2	0.4	4.7
Pontogeneia ivanovi	0.1	0	0	0	0.9	0.3	0	0.1	0.1	0.1
Porphyra sp.	1	2.3	1.4	8.7	4	4.2	3.1	1.4	5.8	5.2
Prionitis sp. (unident.)	0	0	0	0	0	0	0	0	0	0
Prionospio steenstrupi	0	0	0	0	0	0	0	0	0	0
Leukoma (=Protothaca) staminea	0	0	0	0.1	0	0	0.5	0.8	0.2	0.1
Leukoma staminea juv.	0	0	0	0	0	0.2	0.5	0	0	0.6
Pseudopolydora kempi japonica	0	0	0	0	0	0	0	0	0	0
Ptilohyale plumulosa	0	0	0	0	0	0	0	0	0	0
Pugettia gracilis	0	0.2	0	0	0	0	0	0	0	0
Sabellid (unident.)	0	0.1	0	0	0	0	0	0.1	0	0
Sand percentage	82.5	40.5	46.5	26.3	38.3	27	40.5	47	13.9	26

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	**Pt Wells South**									
Year	**2006**	**2007**	**2007**	**2007**	**2008**	**2008**	**2008**	**2009**	**2009**	**2009**
Intertidal Height (feet above MLLW)	**-2**	**-2**	**0**	**2.8**	**-2**	**0**	**2.8**	**-2**	**0**	**2.8**
Sarcodiotheca sp. (unid.)	0.2	1.7	0	0.1	0.2	0	0	1.4	0	0
Sargassum muticum	0	0	0	0	0	0	0	0	0	0
Saxidomus giganteus	0	0	0	0.5	0	0.2	0.3	1.2	0.3	0.2
Saxidomus giganteus juv.	0	0	0.2	0.3	0	0.3	0.5	0.1	0.9	1.1
Scleroplax granulata	0	0	0	0	0	0	0	0	0	0
Scolelepis squamata	0	0	0	0	0	0	0	0	0	0
Scytosiphon simplicissimus	0	0.1	0.2	0.2	0.1	0.3	0.4	0.1	0	0
Smithora naiadum	0.1	2.5	0	0	0	0	0	0	0	0
Sphaeromid isopods	0	0	0	0	0	0	0	0.4	10.2	1.8
Spio filicornis	0	0.6	0.4	1.3	0	0	0	1.9	3.2	2.9
Spiochaetopterus tube	0	0.1	0	0	0	0.1	0.4	0	0.2	0
Spiophanes bombyx	0	0	0	0	0	0	0	0	0	0.1
Stichaeidae (gunnels and pricklebacks)	0	0.1	0	0	0.1	0	0	0.1	0	0
Strongylocentrotus sp.	0	0	0	0	0	0	0	0	0	0
Tellina modesta	0	0	0	0.1	0	0	0	0.1	0	0
Tonicella lineata	0	0	0	0	0.1	0	0	0	0	0
Nutricola (= Transenella) tantilla	0	0	0	0	0	0	0	0	0	0
Tresus capax	0	0.8	0	0	0	0	0.1	0.2	0.1	0.1
Tresus capax juveniles	0	2.2	1.1	0.5	0	0.1	0	0.3	1.6	0.1
Ulvoids (unident.)	80.9	71	66	69.4	14.5	70	17.5	48.6	48.5	44
Urticina sp.	0	0	0	0	0	0	0	0	0	0
Zostera marina	0.1	7.5	0.5	0	15.4	0	0	17.5	0	0

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	Pt Wells South			Richmond Beach			
Year	**2010**	**2010**	**2010**	**2006**	**2006**	**2006**	**2006**
Intertidal Height (feet above MLLW)	**-2**	**0**	**2.8**	**-2**	**0**	**2.8**	**6.6**
Acrosiphonia spp.	0.4	0.8	0	2.5	3.3	0	0
Allorchestes angusta	0	0	0	0.1	0	0	0
Ampithoe dalli	0	0.1	0	0	0	0	0
Ampithoe lacertosa	0	0	0	0	0	0	0
Anisogammarus pugettensis	0	0	0	0	0	0	0
Anthopleura spp.	0	0.1	2.4	0.2	0.6	8.6	0.7
Armandia brevis	0.2	0	0	0	0	0	0
Axiothella rubrocincta	0	0	0	0	0	0	0
Bryozoa (miscellaneous)	0	0	0	3.1	0	0	0
Calliopius spp.	0	0	0	0	0	0	0
Cancer sp.	0.2	0.1	0	0.4	0	0	0
Cancer sp. Juvenile	0.1	0	0	0.1	0	0	0
Capitella capitata	0	0	0	0	0	0	0.1
Caulleriella ?pacifica	0	0	0	0.2	0	0	0
Ceramium sp.	0	0	0.4	0.1	0	0	0
Chondracanthus exasperata	0	0	0	0	0	0	0
Cirratulus multioculatus	0	0	0	0	0	0	0
Clinocardium nuttallii	0	0	0	0	0	0	0
Clinocardium nuttallii juveniles	0	0	0.1	0	0	0	0
Cobble percentage	9.5	5	7.5	85.3	95	85	90
Cottidae (sculpins)	0	0	0	0	0	0	0
Crangon franciscorum ssp. franciscorum	0	0	0	0	0	0	0
Crassostrea gigas	0	0	0	0	0	0	0
Crepidula dorsata	0	0	0	0.1	0	0	0
Cryptosiphonia woodii	0	0	0	0	0	0	0
Cumagloia andersonii	0	0	0	0	0	0	0
Dead barnacles (Class Cirripedia)	3.8	3	2.2	13	8	7	3
Delesseria sp.	0	0	0	0	0	0	0
Dendraster juv. in core	0	0	0	0	0	0	0
Desmarestia spp.	0	0	0	0	0	0	0
Diatoms, chain-forming	0.8	0	0.5	5.7	2.1	2.1	0
Diopatra ornata	0	0	0	0	0	0	0
Edwardsia sipunculoides	0	0	0	0	0	0	0
Epiactis prolifera	0	0	0	0	0	0	0
Eteone spp.	0.1	0	0	0	0	0	0
Euclymene spp.	0	0	0	0	0	0	0
Eulalia sanguinea	0	0	0	0.1	0	0	0
Evasterias troschelii	0.4	0	0	0.2	0	0	0
Exosphaeroma inornata	0.1	1.8	2.3	0	0	0.2	0
Family Hippolytidae	0.05	0	0	0.25	0	0	0
Flatworm (unident.)	9.9	2.7	4.1	0	0.1	2.5	0
Fleshy crust	6.8	5.8	0.8	6.6	7.6	4.4	0.7
Gammarid amphipods	7.1	39.2	3.6	3.3	16	0.1	0
Gelidium spp.	0.1	0.1	0	0	0	0	0
Glycera americana	0	0	0	0	0	0	0
Glycinde picta	0.3	0	0	0	0	0	0
Glycinde polygnatha	0	0	0	0	0	0	0
Gnorimosphaeroma oregonense	0	0	0.2	0	0.1	0	0
Gracilaria pacifica	0	0	0	0	0	0	0
Grateloupia sp.	0	0.1	0	0	0	0	0
Green filaments	0	0	0	0	0	0	0

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	**Pt Wells South**			**Richmond Beach**			
Year	**2010**	**2010**	**2010**	**2006**	**2006**	**2006**	**2006**
Intertidal Height (feet above MLLW)	**-2**	**0**	**2.8**	**-2**	**0**	**2.8**	**6.6**
Haminoea vesicula	0	0	0	0	0	0	0
Harmothoe imbricata	0	0	0	0	0	0	0
Hemigrapsus nudus	0	0	0	0	0.1	0.6	1.2
Hemigrapsus oregonensis	0	0.3	2.7	0.9	7.2	5.7	0.3
Hemipodus borealis	0.1	0.8	4.6	0.5	3.6	0.4	0
Hermissenda crassicornis	0.1	0.1	0	0.3	0	0	0
Hiatella arctica	0	0.1	0	0	0	0	0
Protohyale (= Hyale) spp.	0	0.5	0	0	0.3	0.1	0
Idotea sp.	0.1	0.2	0.9	0	0.1	0	0
Ischyrocerus anguipes	0	0	0	0	0	0	0
Lacuna spp.	50.5	73	0	3.3	0.8	0	0
Saccharina latissima (=Laminaria saccharina)	25.5	5	0	0	0	0	0
Lepidochitona dentiens	0	0	0	0	0	0	0
Leptochelia dubia	0.1	0	0	0.1	0	0	0
Leptosynapta clarki	0	0.1	0	0	0	0	0
Littorina scutulata	0	0	0	0	0.9	423	105
Littorina sp.	0	0	6.7	0	0	0	0
Live barnacles (Class Cirripedia)	11.6	18.5	50.5	7.6	12	6	4.6
Lophopanopeus bellus bellus	0	0	0	0.2	0	0	0
Lottiid limpets	3	20	58	3.3	18.9	16	0.1
Lucina tenuisculpta	0.1	0.1	0	0	0	0	0
Lumbrineris zonata	0.9	0.8	0	0.2	0	0	0
Macoma inquinata	0.2	0.1	0.4	0.1	0	0	0
Macoma inquinata juveniles	0.7	0.5	1.2	0.1	0.1	0	0
Magelona hobsonae	0	0	0	0	0	0	0
Majid (spider) crab	0.2	0.1	0	0	0	0	0
Majid juvenile crab	0	0	0	0.1	0	0	0
Malacoceros glutaeus	0	0	0	0	0	0	0
Malmgreniella nigralba	0	0	0	0	0	0	0
Margarites sp.	0	0	0	0	0	0	0
Mastocarpus jardinii	0	0	0	0	0	0	0
Mastocarpus papillatus	0.9	6.2	1.6	4.4	11	0.9	0
Mazzaella heterocarpa/oregona	0.1	1	0	0.1	1.5	0	0
Mazzaella sp.	0	0	0	0	0	0	0
Mazzaella splendens	2.2	0.5	0	2.4	0	0	0
Mediomastus californiensis	0.3	0.5	6.8	1.2	0	0	0
Megalorchestia pugettensis	0	0	0	0	0.1	0	0
Melanochlamys diomedea	0	0	0	0	0	0	0
Metridium sp.	0.1	0	0	0	0	0	0
Microcladia borealis	0	0	0	0	0	0	0
Micropodarke dubia	0	0	0	0.1	0	0	0
Mopalia lignosa	0.6	0.2	0	1.1	0	0	0
Mopalia muscosa	0	0	0	0.2	0	0	0
Rochefortia tumida (=Mysella tumida)	0	0.2	0	0	0	0	0
Mytilus trossulus	0.1	0.9	10	0	1.4	0.4	0
Naineris dendritica	0	0	0.7	0	0	0	0
Nassarius sp.	0	0	0	0	0	0	0
Nemertean (unident.)	0.3	0.3	0	0.2	0	0.1	0.1
Neotrypaea californiensis	0	0	0	0	0	0	0

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	**Pt Wells South**			**Richmond Beach**			
Year	**2010**	**2010**	**2010**	**2006**	**2006**	**2006**	**2006**
Intertidal Height (feet above MLLW)	**-2**	**0**	**2.8**	**-2**	**0**	**2.8**	**6.6**
Nephtys caeca	0	0.1	0	0	0	0	0
Nephtys caecoides	0	0	0	0	0	0	0
Nephtys ferruginea	0	0	0	0	0	0	0
Nereis procera	0.6	0	0	0.1	0	0	0
Nereis vexillosa	0	0	0	0	0	0.1	0.1
Notomastus lineatus	0	0	0	0	0	0	0
Notomastus tenuis	1.5	0.6	1.2	7.3	2.1	0.2	0
Nucella lamellosa	0.2	1.3	1.2	2.2	5.9	0	0
Ocenebra lurida	0	0	0	0	0	0	0
Odonthalia floccosa	0	0	0	0.7	0	0	0
Odostomia sp. (unident.)	0	0.2	0	0	0	0	0
Oenopota sp.	0	0	0	0	0	0	0
Onchidoris bilamellata	0	0	0	0	0	0	0
Onuphis elegans	0	0	0	0	0	0	0
Onuphis iridescens	0	0	0	0	0	0	0
Owenia fusiformis	0.2	0.1	0.2	0.1	0	0	0
Pagurus spp.	25.1	24.3	51	2.7	1.9	0.1	0
Paracalliopiella pratti	0.2	0.2	0	0	0	0	0
Petalonia fascia	0.2	0.4	0	0.2	0.1	0	0
Pholoe minuta	0	0	0.1	0	0	0	0
Phoronopsis harmeri	0.1	0	0.2	0	0	0	0.1
Photis spp.	0	0	0	0	0	0	0
Phyllaplysia taylori	0	0	0	0	0	0	0
Pinnixia faba	0	0	0	0.2	0	0	0
Pinnixia schmitti/occidentalis	0	0	0	0.1	0	0	0
Pinnotherid sp. (unident.)	0	0	0	0	0	0	0
Pisaster ochraceus	0	0	0	0	0	0	0
Platynereis bicanaliculata	0	0	0	0.1	0	0	0
Podarke pugettensis	0	0.1	0	0	0	0	0
Podarkeopsis glabrus	0	0	0	0	0	0	0
Pododesmus cepio	0	0	0	2.4	0.9	0	0
Euspira (=Polinices) lewisii	0	0	0	0	0	0	0
Polydora brachycephala	0	0	0	0	0	0	0
Polydora cardalia	0	0	0	0	0	0	0
Polydora columbiana	0	0	0	0	0	0	0
Polydora quadrilobata	0	0	0	0	0	0	0
Polyneura sp.	0	0	0	0	0	0	0
Polynoid (unident., in quadrat)	0.2	0	0.1	0	0	0	0
Polysiphonia sp.	0.2	0.8	6.6	0.1	0	0	0
Pontogeneia ivanovi	0.1	0	0.2	0	0	0	0
Porphyra sp.	0.1	0.8	2.2	0.2	1.7	18.6	0
Prionitis sp. (unident.)	0	0	0	0.1	0	0	0
Prionospio steenstrupi	0	0	0	1.1	0	0	0
Leukoma (=Protothaca) staminea	0	0.1	0.2	0	0	0	0
Leukoma staminea juv.	0	0.5	0	0	0.1	0	0
Pseudopolydora kempi japonica	0	0	0	0	0	0	0
Ptilohyale plumulosa	0	0	0	0	0	0	0
Pugettia gracilis	0	0	0	0	0	0	0
Sabellid (unident.)	0	0	0	0	0	0	0
Sand percentage	47.4	25.5	13.5	10.9	2.2	4.8	5.6

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	**Pt Wells South**			**Richmond Beach**			
Year	**2010**	**2010**	**2010**	**2006**	**2006**	**2006**	**2006**
Intertidal Height (feet above MLLW)	**-2**	**0**	**2.8**	**-2**	**0**	**2.8**	**6.6**
Sarcodiotheca sp. (unid.)	1.1	0.3	0	0.7	0	0	0
Sargassum muticum	1.5	0	0	0	0	0	0
Saxidomus giganteus	0.1	0	0.4	0.1	0.1	0	0
Saxidomus giganteus juv.	0.4	0.9	0.7	0	0.3	0	0
Scleroplax granulata	0	0	0	0	0	0	0
Scolelepis squamata	0	0	0	0	0	0	0
Scytosiphon simplicissimus	0	0	0	0	0.4	0	0
Smithora naiadum	0	0	0	0	0	0	0
Sphaeromid isopods	1.7	30.5	9	0	0.7	0	0
Spio filicornis	1.4	0.2	0.6	0	0	0	0
Spiochaetopterus tube	0.1	0.2	0	0	0	0	0
Spiophanes bombyx	0	0	0	0	0	0	0
Stichaeidae (gunnels and pricklebacks)	0	0.1	0	0.5	0	0	0
Strongylocentrotus sp.	0	0	0	0	0	0	0
Tellina modesta	0.1	0	0	0	0	0	0
Tonicella lineata	0	0	0	0.2	0	0	0
Nutricola (= Transenella) tantilla	0.4	0	0	0	0	0	0
Tresus capax	0.3	0.2	0	0.1	0	0	0
Tresus capax juveniles	1.1	0.5	0	0.1	0.1	0	0
Ulvoids (unident.)	73.5	81.5	11	77	45	15.6	0
Urticina sp.	0	0	0	0	0	0	0
Zostera marina	0	0	0	0	0	0	0

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	Richmond Control									
Year	**2007**	**2007**	**2007**	**2007**	**2008**	**2008**	**2008**	**2008**	**2009**	**2009**
Intertidal Height (feet above MLLW)	**-2**	**0**	**2.8**	**6.6**	**-2**	**0**	**2.8**	**6.6**	**-2**	**0**
Acrosiphonia spp.	2.5	2.4	0.2	0	0.6	3.3	0	0	2.2	11
Allorchestes angusta	0	0	0	0	0.1	0	0	0	0	0.1
Ampithoe dalli	0	0	0	0	0	0	0	0	0	0.2
Ampithoe lacertosa	0	0	0	0	0.1	0	0	0	0	0.1
Anisogammarus pugettensis	0	0	0	0	0	0	0	0	0	0
Anthopleura spp.	0.5	0.7	0.2	0	0.1	0.8	0	0.1	0	1.1
Armandia brevis	0.5	0.4	0	0	0	0	0	0	0.5	1.1
Axiothella rubrocincta	0	0	0	0	0	0	0	0	0	0
Bryozoa (miscellaneous)	1	0	0	0	2.9	0.1	0	0	0.6	0
Calliopius spp.	0	0	0	0	0	0	0	0	0	0.1
Cancer sp.	0.2	0	0	0	0	0	0	0	0	0
Cancer sp. Juvenile	0	0	0	0	0	0	0	0	0	0
Capitella capitata	0.1	0.2	0	0	0	0	0	0	1.2	0.1
Caulleriella ?pacifica	0	0	0	0	0	0.1	0	0	0	0
Ceramium sp.	0	0	0	0	0	0	0	0	0	0
Chondracanthus exasperata	0	0	0	0	0	0	0	0	0	0
Cirratulus multioculatus	0	0	0	0	0	0	0	0	0.1	0
Clinocardium nuttallii	0	0	0	0	0	0	0	0	0.1	0
Clinocardium nuttallii juveniles	0	0.1	0	0	0	0	0	0	0	0
Cobble percentage	40.5	42	40.5	15	45	38	28	12.3	37	62.5
Cottidae (sculpins)	0	0	0	0	0	0.1	0	0	0	0
Crangon franciscorum ssp. franciscorum	0	0	0	0	0	0	0	0	0	0
Crassostrea gigas	0	0	0	0	0	0	0.1	0	0	0
Crepidula dorsata	0	0	0	0	0	0	0	0	0	0
Cryptosiphonia woodii	0	0.1	0	0	0	0.6	0	0	0.1	0.1
Cumagloia andersonii	0	0	0	0	0	0	0	0	0	0
Dead barnacles (Class Cirripedia)	11	6.6	5.6	0.2	1.3	5.8	5.7	0.7	5.2	12
Delesseria sp.	0	0	0	0	0	0	0	0	0	0
Dendraster juv. in core	0	0	0	0	0	0	0	0	0	0
Desmarestia spp.	0	0	0	0	0	0	0	0	0	0
Diatoms, chain-forming	1.6	0.4	0	0	6.7	2.5	0.7	0	4.8	2
Diopatra ornata	0	0	0	0	0	0.1	0	0	0	0
Edwardsia sipunculoides	0	0	0	0	0	0	0	0	0	0
Epiactis prolifera	0	0	0	0	0	0	0	0	0	0
Eteone spp.	0.2	0	0	0	0	0	0	0	0.1	0
Euclymene spp.	0	0	0	0	0	0	0	0	0	0
Eulalia sanguinea	0	0	0	0	0	0	0	0	0	0
Evasterias troschelii	0	0	0	0	0	0	0	0	0	0
Exosphaeroma inornata	0	0	0	0	0.1	0	0.1	0	0	0.6
Family Hippolytidae	0	0	0	0	0	0	0	0	0	0
Flatworm (unident.)	0.5	0.2	0	0	0	0	0	0	0.4	0.4
Fleshy crust	4	2	0.4	0	26.5	7.2	0.2	0	2.8	4
Gammarid amphipods	0.7	0.5	0.5	0	0.2	11.2	1	0.5	5.6	1.6
Gelidium spp.	0	0	0	0	0	0	0	0	0	0
Glycera americana	0	0	0	0	0	0	0	0	0	0
Glycinde picta	0.2	0.4	0	0	0.1	0	0	0	0.4	0.5
Glycinde polygnatha	0	0	0	0	0	0	0	0	0	0
Gnorimosphaeroma oregonense	0	0	0	0	0	0	0	0	0	0
Gracilaria pacifica	0	0	0	0	0	0	0	0	0	0
Grateloupia sp.	0	0	0	0	0	0	0	0	0	0
Green filaments	0	0	11	0.5	0	0	0	0	0	0

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	**Richmond Control**									
Year	**2007**	**2007**	**2007**	**2007**	**2008**	**2008**	**2008**	**2008**	**2009**	**2009**
Intertidal Height (feet above MLLW)	**-2**	**0**	**2.8**	**6.6**	**-2**	**0**	**2.8**	**6.6**	**-2**	**0**
Haminoea vesicula	0	0	0	0	0.1	0	0	0	0	0
Harmothoe imbricata	0	0	0	0	0	0	0	0	0	0
Hemigrapsus nudus	0	0	0	0	0	0	0	0	0	0
Hemigrapsus oregonensis	0	0	0.6	0	0	0	0	0	0	0.1
Hemipodus borealis	0.8	3.3	0.3	0.1	0.5	1.4	1	0	0.7	1.3
Hermissenda crassicornis	0.1	0.4	0	0	0	0	0	0	0.1	0
Hiatella arctica	0	0	0	0	0	0	0	0	0	0
Protohyale (= Hyale) spp.	0	0	0	0	0	0	0	0	0	0
Idotea sp.	0	0	0.3	0	0	0	0	0	0.2	0.1
Ischyrocerus anguipes	0	0	0	0	0	0	0	0	0	0
Lacuna spp.	31	13.3	0	0	16.5	9.3	0	0	98	135
Saccharina latissima (=Laminaria saccharina)	1.5	0	0	0	2.6	0.5	0	0	0.1	0
Lepidochitona dentiens	0	0	0	0	0	0	0	0	0	0.1
Leptochelia dubia	0.1	0	0	0	0	0	0	0	0	0.1
Leptosynapta clarki	0	0	0	0	0	0	0	0	0	0
Littorina scutulata	0	0	1.4	0	0	0	6.5	5.6	0	0
Littorina sp.	0	0	0	0	0	0	0	0	0	0
Live barnacles (Class Cirripedia)	14	34.5	20	1.1	0.2	0.5	1.8	0.2	28	41.5
Lophopanopeus bellus bellus	0	0	0	0	0	0	0	0	0	0
Lottiid limpets	7.1	12.3	1.1	0	2.3	2.8	0	0	9.1	21
Lucina tenuisculpta	0	0	0	0	0	0	0	0	0	0
Lumbrineris zonata	0	0	0	0	0	0	0	0	0	0
Macoma inquinata	0.1	0	0	0	0	0	0	0	0	0
Macoma inquinata juveniles	0.4	0.1	0	0	0	0	0	0	0	0.2
Magelona hobsonae	0	0	0	0	0	0	0	0	0	0
Majid (spider) crab	0	0	0	0	0	0.3	0	0	0	0
Majid juvenile crab	0	0	0	0	0	0	0	0	0.1	0.1
Malacoceros glutaeus	0	0	0	0	0	0	0	0	0	0
Malmgreniella nigralba	0	0	0	0	0	0	0	0	0	0
Margarites sp.	0.1	0	0	0	0	0	0	0	0.4	0.1
Mastocarpus jardinii	0	0	0	0	0	0	0	0	0	0
Mastocarpus papillatus	7.2	2.5	0.1	0	8	3	0.2	0	12.1	2.2
Mazzaella heterocarpa/oregona	1.1	0.5	0	0	1.7	3.7	0	0	1.7	3.3
Mazzaella sp.	0	0	0	0	0	0	0	0	0	0
Mazzaella splendens	1.6	1	0	0	5.6	1.2	0	0	0	0
Mediomastus californiensis	0.1	1.4	0	0	0.2	0.4	0	0	1.4	2.3
Megalorchestia pugettensis	0	0	0	0	0	0.1	0.1	0	0	0
Melanochlamys diomedea	0	0	0	0	0	0	0	0	0	0
Metridium sp.	0.2	0	0	0	0.3	0.2	0	0	0	0
Microcladia borealis	0	0	0	0	0	0	0	0	0.1	0
Micropodarke dubia	0	0	0	0	0	0	0	0	0	0
Mopalia lignosa	1.1	0.6	0	0	0.1	0.3	0	0	0.9	0.3
Mopalia muscosa	0.1	0	0	0	0.2	0.1	0	0	0	0.1
Rochefortia tumida (=Mysella tumida)	0	0	0	0	0	0	0	0	0	0
Mytilus trossulus	0.7	0.9	0.4	0	0	0	0.7	0.1	0.8	2.9
Naineris dendritica	0	0	0	0	0	0	0	0	0	0
Nassarius sp.	0	0	0	0	0	0	0	0	0	0
Nemertean (unident.)	0.8	0.3	0	0	0.1	0.1	0	0	1.7	0.5
Neotrypaea californiensis	0	0	0	0	0	0	0	0	0	0

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	Richmond Control									
Year	**2007**	**2007**	**2007**	**2007**	**2008**	**2008**	**2008**	**2008**	**2009**	**2009**
Intertidal Height (feet above MLLW)	**-2**	**0**	**2.8**	**6.6**	**-2**	**0**	**2.8**	**6.6**	**-2**	**0**
Nephtys caeca	0	0	0	0	0	0	0	0	0	0
Nephtys caecoides	0	0	0	0	0.1	0	0	0	0.3	0.3
Nephtys ferruginea	0	0	0	0	0	0	0	0	0	0
Nereis procera	0.1	0	0	0	0.1	0	0	0	0.1	0
Nereis vexillosa	0	0	0.1	0.1	0	0	0	0.1	0	0
Notomastus lineatus	0	0	0	0	0	0	0	0	0	0
Notomastus tenuis	3.8	4.6	0.2	0.1	2.9	2.1	0.4	0	2.5	4.6
Nucella lamellosa	0.5	0.8	0	0	0.1	0.3	0	0	0	0.6
Ocenebra lurida	0	0	0	0	0	0	0	0	0.1	0
Odonthalia floccosa	0.7	0.1	0	0	4.3	0.1	0	0	0.8	0.6
Odostomia sp. (unident.)	0	0	0	0	0	0	0	0	0	0
Oenopota sp.	0	0	0	0	0	0	0	0	0.1	0
Onchidoris bilamellata	6.1	0.4	0	0	0	0	0	0	8.8	5
Onuphis elegans	0.6	0.2	0	0	0	0	0	0	0	0
Onuphis iridescens	0	0	0	0	0	0	0	0	0	0
Owenia fusiformis	0	0.5	0	0	0	0.6	0	0	0.4	0.2
Pagurus spp.	2.5	1.5	0	0	0.5	0.7	0	0	0.8	0.9
Paracalliopiella pratti	0	0	0	0	0	0	0	0	0	0
Petalonia fascia	0.6	1.3	0	0	1.2	0.6	0	0	0.1	0.4
Pholoe minuta	0	0	0	0	0	0	0	0	0	0
Phoronopsis harmeri	0	0.1	0	0	0.1	0.1	0	0	0.1	0.2
Photis spp.	0	0	0	0	0	0	0	0	0.6	0.1
Phyllaplysia taylori	0	0	0	0	0	0	0	0	0	0
Pinnixia faba	0	0	0	0	0	0	0	0	0	0.1
Pinnixia schmitti/occidentalis	0	0	0	0	0	0	0	0	0	0
Pinnotherid sp. (unident.)	0	0	0	0	0	0	0	0	0	0
Pisaster ochraceus	0	0	0	0	0.2	0.2	0	0	0	0
Platynereis bicanaliculata	0	0	0	0	0.4	0	0.1	0	0	0.1
Podarke pugettensis	0	0	0	0	0	0	0	0	0	0
Podarkeopsis glabrus	0	0	0	0	0	0	0	0	0	0
Pododesmus cepio	0.3	0	0	0	0	0	0	0	0	0
Euspira (=Polinices) lewisii	0	0	0	0	0	0	0	0	0	0
Polydora brachycephala	0	0	0	0	0	0	0	0	0	0
Polydora cardalia	0	0	0	0	0	0	0	0	0	0.1
Polydora columbiana	0.1	0.6	0	0	0	0	0	0	0	0.7
Polydora quadrilobata	0	0	0	0	0	0	0	0	0	0
Polyneura sp.	0	0	0	0	0	0	0	0	0	0
Polynoid (unident., in quadrat)	0.1	0	0	0	0	0	0	0	0.3	0.1
Polysiphonia sp.	3.9	4	0	0	2.2	5.8	0	0	0.8	4.5
Pontogeneia ivanovi	0.2	0	0	0	0	0	0	0	0.2	0.1
Porphyra sp.	1.5	1	0.7	0	0.8	0.2	0	0	0.9	1.9
Prionitis sp. (unident.)	0.1	0	0	0	0.6	0	0	0	0	0
Prionospio steenstrupi	0	0	0	0	0	0	0	0	0.1	0
Leukoma (=Protothaca) staminea	0	0	0	0	0	0.1	0	0	0	0
Leukoma staminea juv.	0	0	0	0	0	0	0	0	0.2	0.1
Pseudopolydora kempi japonica	0	0	0	0	0	0	0	0	0	0
Ptilohyale plumulosa	0	0	0	0	0	0	0	0.1	0	0
Pugettia gracilis	0	0	0	0	0	0	0	0	0	0
Sabellid (unident.)	0.3	0.2	0	0	1	0.6	0	0	0	0
Sand percentage	55	49.5	29.7	65	50	49	61.9	1.4	63	33

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	**Richmond Control**									
Year	**2007**	**2007**	**2007**	**2007**	**2008**	**2008**	**2008**	**2008**	**2009**	**2009**
Intertidal Height (feet above MLLW)	**-2**	**0**	**2.8**	**6.6**	**-2**	**0**	**2.8**	**6.6**	**-2**	**0**
Sarcodiotheca sp. (unid.)	0	0	0	0	0.8	0	0	0	0.2	0
Sargassum muticum	0	0	0	0	2.1	0	0	0	4.1	0
Saxidomus giganteus	0	0	0	0	0	0.1	0	0	0	0
Saxidomus giganteus juv.	0.6	1.1	0	0	0.7	0.5	0	0	1.3	1.5
Scleroplax granulata	0	0	0	0	0	0	0	0	0.1	0
Scolelepis squamata	0	0	0	0	0	0	0	0	0	0
Scytosiphon simplicissimus	0.1	0	0	0	0.2	0.5	0	0	0.1	0
Smithora naiadum	0	0	0	0	0	0	0	0	0	0
Sphaeromid isopods	0	0.7	0	0	0	0	0	0	0	0.4
Spio filicornis	1.4	2.2	0	0	0	0	0	0	2.5	11.7
Spiochaetopterus tube	0.3	0.2	0	0	0.2	0.1	0	0	0.3	0.1
Spiophanes bombyx	0	0	0	0	0	0	0	0	0	0.2
Stichaeidae (gunnels and pricklebacks)	0.1	0	0	0	0	0	0	0	0	0.1
Strongylocentrotus sp.	0	0	0	0	0	0	0	0	0	0
Tellina modesta	0.2	0.1	0	0	0.4	0	0	0	0.1	0.1
Tonicella lineata	0	0	0	0	0.1	0	0	0	0	0
Nutricola (= Transenella) tantilla	0.1	0	0	0	0	0	0	0	0	0
Tresus capax	0.1	0.2	0	0	0	0.2	0	0	0	0
Tresus capax juveniles	4	3.1	0	0	0.2	0.3	0	0	2.7	5.3
Ulvoids (unident.)	30	64.5	13.8	0.8	35.5	67	6.2	0	38	56
Urticina sp.	0.4	0	0	0	1.1	0.5	0	0	0.1	0.1
Zostera marina	0	0	0	0	0	0	0	0	0	0

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	Richmond Control					
Year	**2009**	**2009**	**2010**	**2010**	**2010**	**2010**
Intertidal Height (feet above MLLW)	**2.8**	**6.6**	**-2**	**0**	**2.8**	**6.6**
Acrosiphonia spp.	0	0	0.2	0.6	0.2	0
Allorchestes angusta	0.5	0	0	0	0	0
Ampithoe dalli	0	0	0	0	0	0
Ampithoe lacertosa	0	0	0	0	0	0
Anisogammarus pugettensis	0	0	0	0	0	0
Anthopleura spp.	0.2	0	0.1	0.7	0.3	0
Armandia brevis	0	0	0.1	0.1	0	0
Axiothella rubrocincta	0	0	0	0	0	0
Bryozoa (miscellaneous)	0	0	1.7	0.2	0	0
Calliopius spp.	0	0	0	0.1	0	0
Cancer sp.	0	0	0	0	0	0
Cancer sp. Juvenile	0	0	0	0	0	0
Capitella capitata	0	0	0	0	0	0
Caulleriella ?pacifica	0	0	0.1	0.2	0	0
Ceramium sp.	0	0	0	0.5	0	0
Chondracanthus exasperata	0	0	0.5	0	0	0
Cirratulus multioculatus	0	0	0	0	0	0
Clinocardium nuttallii	0	0	0	0.1	0	0
Clinocardium nuttallii juveniles	0	0	0	0.1	0	0
Cobble percentage	58.5	39.5	21	29.5	36.5	19
Cottidae (sculpins)	0	0	0	0	0	0
Crangon franciscorum ssp. franciscorum	0	0	0	0	0	0
Crassostrea gigas	0	0	0	0	0	0
Crepidula dorsata	0	0	0	0	0	0
Cryptosiphonia woodii	0	0	0.1	0	0	0
Cumagloia andersonii	0	0	0	0	0	0
Dead barnacles (Class Cirripedia)	4.6	1.2	1.2	4.2	4.8	0.3
Delesseria sp.	0	0	0	0	0	0
Dendraster juv. in core	0	0	0	0	0	0
Desmarestia spp.	0	0	0	0	0	0
Diatoms, chain-forming	0.1	0	3.3	7.6	0.1	0
Diopatra ornata	0	0	0	0	0	0
Edwardsia sipunculoides	0	0	0	0	0	0
Epiactis prolifera	0	0	0	0	0	0
Eteone spp.	0	0	0.2	0.1	0	0
Euclymene spp.	0	0	0	0	0	0
Eulalia sanguinea	0	0	0	0	0	0
Evasterias troschelii	0	0	0.3	0	0	0
Exosphaeroma inornata	0.2	0	0	0	0.2	0
Family Hippolytidae	0	0	0.05	0	0	0
Flatworm (unident.)	0	0	0.1	0.5	0	0
Fleshy crust	0.4	0	11.6	13	0.5	0
Gammarid amphipods	2.1	0	12.2	16.7	2.5	0
Gelidium spp.	0	0	0	0	0	0
Glycera americana	0	0	0	0	0	0
Glycinde picta	0	0	0.2	0.1	0	0
Glycinde polygnatha	0	0	0	0	0	0
Gnorimosphaeroma oregonense	0	0	0	0	0	0
Gracilaria pacifica	0	0	0	0	0	0
Grateloupia sp.	0	0	0	0	0	0
Green filaments	0	0	0	0	0	0

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	Richmond Control					
Year	**2009**	**2009**	**2010**	**2010**	**2010**	**2010**
Intertidal Height (feet above MLLW)	**2.8**	**6.6**	**-2**	**0**	**2.8**	**6.6**
Haminoea vesicula	0	0	0	0	0	0
Harmothoe imbricata	0	0	0	0	0	0
Hemigrapsus nudus	0	0	0	0	0	0
Hemigrapsus oregonensis	0.1	0	0	0	0	0
Hemipodus borealis	2.7	0.3	0.2	1.8	3	0.2
Hermissenda crassicornis	0	0	0.3	0.1	0	0
Hiatella arctica	0.1	0	0	0	0	0
Protohyale (= Hyale) spp.	0	0	0	0	0	0
Idotea sp.	0	0	0	0	0	0
Ischyrocerus anguipes	0	0	0	0.2	0	0
Lacuna spp.	0.1	0	47	182.5	2.2	0
Saccharina latissima (=Laminaria saccharina)	0	0	0.5	0.1	0	0
Lepidochitona dentiens	0	0	0	0	0	0
Leptochelia dubia	0	0	0.1	0.1	0	0
Leptosynapta clarki	0	0	0	0	0	0
Littorina scutulata	8.6	3.6	0	0	0	0
Littorina sp.	0	0	0	0	1.2	0.6
Live barnacles (Class Cirripedia)	19.3	2	7.8	19	19.3	1.1
Lophopanopeus bellus bellus	0	0	0	0	0	0
Lottiid limpets	4.4	0.1	1	4.4	0.8	0
Lucina tenuisculpta	0	0	0	0	0	0
Lumbrineris zonata	0	0	0	0.1	0	0
Macoma inquinata	0	0	0	0	0	0
Macoma inquinata juveniles	0	0	0.1	0.2	0	0
Magelona hobsonae	0	0	0	0	0	0
Majid (spider) crab	0	0	0	0.1	0	0
Majid juvenile crab	0	0	0	0	0	0
Malacoceros glutaeus	0	0	0	0.1	0	0
Malmgreniella nigralba	0	0	0	0	0	0
Margarites sp.	0	0	0	0	0	0
Mastocarpus jardinii	0	0	0	0	0	0
Mastocarpus papillatus	0.4	0	4.5	7.4	0.3	0
Mazzaella heterocarpa/oregona	0	0	2	2.2	0	0
Mazzaella sp.	0	0	0	0	0	0
Mazzaella splendens	0	0	4	3.5	0	0
Mediomastus californiensis	0	0	0.4	2.2	0	0
Megalorchestia pugettensis	0	0	0	0	0	0
Melanochlamys diomedea	0	0	0	0	0	0
Metridium sp.	0	0	0.1	0.2	0	0
Microcladia borealis	0	0	0	0	0	0
Micropodarke dubia	0	0	0	0	0	0
Mopalia lignosa	0	0	0.2	0	0	0
Mopalia muscosa	0	0	0	0	0	0
Rochefortia tumida (=Mysella tumida)	0	0	0	0	0	0
Mytilus trossulus	1	0.1	0	0.3	1	0
Naineris dendritica	0	0	0	0	0	0
Nassarius sp.	0	0	0	0	0	0
Nemertean (unident.)	0	0	0.1	0.2	0	0
Neotrypaea californiensis	0	0	0	0	0	0

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	**Richmond Control**					
Year	**2009**	**2009**	**2010**	**2010**	**2010**	**2010**
Intertidal Height (feet above MLLW)	**2.8**	**6.6**	**-2**	**0**	**2.8**	**6.6**
Nephtys caeca	0	0	0	0	0	0
Nephtys caecoides	0	0	0	0	0	0
Nephtys ferruginea	0	0	0	0	0	0
Nereis procera	0	0	0.1	0.1	0	0
Nereis vexillosa	0.2	0	0	0	0	0
Notomastus lineatus	0	0	0	0.1	0	0
Notomastus tenuis	0.2	0	3.2	2.6	0.2	0
Nucella lamellosa	0	0	0	0.3	0	0
Ocenebra lurida	0	0	0	0	0	0
Odonthalia floccosa	0	0	4.6	1.7	0	0
Odostomia sp. (unident.)	0	0	0.1	0	0	0
Oenopota sp.	0	0	0	0	0	0
Onchidoris bilamellata	0	0	0	0	0	0
Onuphis elegans	0	0	0	0	0	0
Onuphis iridescens	0	0	0	0	0	0
Owenia fusiformis	0	0	0	0.6	0	0
Pagurus spp.	0	0	0.3	0.4	0	0
Paracalliopiella pratti	0	0	0	0	0	0
Petalonia fascia	0.1	0	0.8	1.6	0	0
Pholoe minuta	0	0	0	0	0	0
Phoronopsis harmeri	0	0	0.1	0.1	0	0
Photis spp.	0	0	0.1	0	0	0
Phyllaplysia taylori	0	0	0	0	0	0
Pinnixia faba	0	0	0	0	0	0
Pinnixia schmitti/occidentalis	0	0	0	0	0	0
Pinnotherid sp. (unident.)	0	0	0	0	0	0
Pisaster ochraceus	0	0	0	0	0	0
Platynereis bicanaliculata	0	0	0	0	0	0
Podarke pugettensis	0	0	0	0	0	0
Podarkeopsis glabrus	0	0	0	0	0	0
Pododesmus cepio	0	0	0.4	0.1	0	0
Euspira (=Polinices) lewisii	0	0	0	0.1	0	0
Polydora brachycephala	0	0	0	0	0	0
Polydora cardalia	0	0	0	0.1	0	0
Polydora columbiana	0	0	0	0	0	0
Polydora quadrilobata	0	0	0	0	0	0
Polyneura sp.	0	0	0	0	0	0
Polynoid (unident., in quadrat)	0	0	0.1	0.3	0	0
Polysiphonia sp.	0	0	2.3	2.8	0.1	0
Pontogeneia ivanovi	0	0	0.1	0	0	0
Porphyra sp.	0.6	0.1	0	0.5	0.6	0
Prionitis sp. (unident.)	0	0	0	0	0	0
Prionospio steenstrupi	0	0	0	0	0	0
Leukoma (=Protothaca) staminea	0	0	0	0	0	0
Leukoma staminea juv.	0	0	0.1	0.1	0	0
Pseudopolydora kempi japonica	0	0	0	0	0	0
Ptilohyale plumulosa	0	0	0	0	0	0
Pugettia gracilis	0	0	0	0	0	0
Sabellid (unident.)	0	0	0.3	0.8	0	0
Sand percentage	7.4	2.7	74.8	55	25.6	10.2

Appendix 1. Mean Abundance of Species Found (by site, intertidal height, and year).

Site	**Richmond Control**					
Year	**2009**	**2009**	**2010**	**2010**	**2010**	**2010**
Intertidal Height (feet above MLLW)	**2.8**	**6.6**	**-2**	**0**	**2.8**	**6.6**
Sarcodiotheca sp. (unid.)	0	0	0.2	0	0	0
Sargassum muticum	0	0	14.8	0.2	0	0
Saxidomus giganteus	0	0	0	0	0	0
Saxidomus giganteus juv.	0	0	0.3	1.6	0	0
Scleroplax granulata	0	0	0	0	0	0
Scolelepis squamata	0	0	0	0	0	0
Scytosiphon simplicissimus	0	0	0.2	0.8	0	0
Smithora naiadum	0	0	0	0	0	0
Sphaeromid isopods	0.8	0	0	0.1	0.3	0
Spio filicornis	0	0	1	0.9	0	0
Spiochaetopterus tube	0	0	0.2	0.3	0	0
Spiophanes bombyx	0	0	0	0	0	0
Stichaeidae (gunnels and pricklebacks)	0	0	0.1	0	0	0
Strongylocentrotus sp.	0	0	0	0	0	0
Tellina modesta	0	0	0.6	0.1	0	0
Tonicella lineata	0	0	0	0	0	0
Nutricola (= Transenella) tantilla	0	0	0	0	0	0
Tresus capax	0	0	0	0.1	0	0
Tresus capax juveniles	0	0	1.2	2.9	0	0
Ulvoids (unident.)	23.4	0.7	56	89	19.8	0
Urticina sp.	0	0	0.1	0	0	0
Zostera marina	0	0	0	0	0	0