AFS-UW-1102
June 2011

Benthic Macroinvertebrate Monitoring at Seahurst Park 2010: Year 5 Post-Restoration of South Seawall Removal and Baseline for North Seawall Removal

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Prepared for the City of Burien
Funded by the King Conservation District and the Estuary and Salmon Restoration Program

Executive Summary

This report describes monitoring of benthic invertebrates at Seahurst Park, located on Puget Sound in the City of Burien. A seawall on the south side of the park was removed in February 2005 and the intertidal beach restored. There is also a planned seawall removal scheduled to happen in 2011/12 on the north side of the park with similar restoration of the intertidal beach. Sampling at the south restored site and an adjacent reference beach has occurred pre-restoration in 2004, post-restoration in 2006, 2008, and now five years after restoration in 2010. Sampling at the north section in 2010 will serve as a baseline for future restoration and as a comparison to the south sites.

Shoreline armoring has altered many of the natural habitats in nearshore areas of Puget Sound. Efforts to restore intertidal areas have increased in recent years, with listing of Chinook salmon as threatened under the Endangered Species Act in 1999. Monitoring has been limited in many cases, leading to a lack of rigorous studies that measure effects of completed restorations and guide future efforts. Benthic macroinvertebrates living in beach sediments were used as a biological measure as they can be impacted by shoreline armoring and are important in intertidal beach ecology, including as prey for nearshore fish.

Year 5 post-restoration should serve as a good benchmark of how the benthic community has developed after the initial stages of restoration. Ideally, the south restoration site will one day closely match the reference site in terms of invertebrate densities, assemblages, and taxa richness. Increased densities would indicate that the numbers of invertebrates have increased since restoration, and improved assemblages and taxa richness would indicate that the types and diversity of taxa are similar to the reference beach. These improved conditions would presumably benefit juvenile salmon by providing increased prey resources for feeding.

Benthic cores were taken during three months (June, July, September) and at three tidal heights (+12, +8 and +5’ MLLW), identical to previous monitoring, at the south restored, south reference, and north seawall sites in 2010. Most aspects of the invertebrate community at the south restored site have improved since pre-restoration conditions and shifted towards those at the reference site, especially at higher tidal elevations. Other aspects are somewhat different from the reference site or exhibit high amounts of variance, notably at lower tidal elevations. Beach-wrack formation at high tidal elevations now occurs at the restored site, with development of invertebrate assemblages at +12 that are typical of the reference beach (beach-hopper amphipods). The +8 elevation that was previously at the base of the seawall has shown improved densities, taxa richness, and invertebrate assemblages that are more similar to the reference site. The +5 elevation seems to be most affected by the regrading of the beach, with distinct differences in invertebrate assemblages as compared to those from pre-restoration and reference beach samples. These assemblages are now characterized by polychaete worms instead of amphipod crustaceans. It is unknown whether this is indicative of an early restoration stage, or due to physical alterations caused by the seawall removal and beach regrade.

There is great restoration potential at the higher tidal elevations of the north seawall site. The +12 elevation had low invertebrate densities and taxa richness, with low numbers of beach-hopper amphipods, indicative of a depauperate beach-wrack community. Removal of the seawall and restoration of the beach should allow beach-wrack deposition to occur along with invertebrate assemblages, leading to recovery of the upper intertidal community as has happened at the south restoration site. The +8 elevation did not exhibit as many low metrics as did the +8 elevation at the south restoration site in 2004 before it was restored, although taxa richness was lower than the reference site, and this is a metric that has improved at the south site since restoration. At the +5 elevation taxa richness was high, and care should be taken to not adversely affect lower tidal elevations during the regrade of the beach, although the invertebrate community at this elevation is already different than the reference site.

The 164 taxa sampled in this monitoring detail the diversity that can be obtained within mid to upper intertidal realms, exclusive of lower intertidal elevations. Some are important in processing organic debris, such as talitrids (beach-hoppers) at higher elevations which live in and under the beach-wrack, and oligochaetes and nematodes which live within sediments. Others are good potential prey items for nearshore fish, including taxa of aquatic amphipods and polychaetes which are fed upon by juvenile salmonids.

In summary, a major goal of nearshore restoration in Puget Sound should be to establish and maintain connections between terrestrial riparian and aquatic intertidal zones. When this occurs, it facilitates development of secondary responses including natural feeding processes and assemblage interactions. Monitoring in this report has shown that although there are still some differences between the restored and reference sites at Seahurst Park, the restoration has resulted in a positive initial response of the benthic invertebrate community especially at tidal elevations where the seawall directly covered the intertidal zone. It will be important to continue to monitor in future years in order to assess long-term site development at south Seahurst Park (planned for year 10, 2015) and at north Seahurst Park as related to the timeline of the seawall removal. Such monitoring will be useful to help guide other restoration opportunities along shorelines of Puget Sound.

Representative Invertebrates

talitrid amphipod *Traskorchestia traskiana*

aquatic amphipod *Eogammarus confervicolus*

glycerid polychaete worm *Hemipodia simplex*

oligochaete and nematode worms

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Introduction

Shoreline armoring has become a common feature along developed shorelines in estuaries worldwide. In Puget Sound, an average of 27 percent of the natural shoreline is armored by artificial structures, increasing to approximately 65 percent near urban centers (Simenstad et al. 2011). Armoring is usually composed of vertical seawalls and riprap boulder fields. Assessing the physical and ecological effects of armoring can be complex, and our incorporation of these modified systems into the scientific and management understanding within the broader Puget Sound landscape is fairly recent (summarized in Shipman et al. 2010). Efforts to restore or enhance intertidal areas have increased in recent years, with listing of Chinook salmon (*Oncorhynchus tshawytscha*) as threatened under the Endangered Species Act in 1999. Juvenile Chinook and other juvenile salmonids in the Pacific Northwest use estuarine and nearshore habitats early in their outmigration and rearing period (Simenstad et al. 1982). Since these and other nearshore fishes utilize shoreline areas, different shoreline habitat types can affect fish abundance, distribution, and behavior patterns (Toft et al. 2007), and survival of eggs in beach spawning surf smelt (Rice 2006). Additionally, removal of supralittoral vegetation correspondent with armoring affects some nearshore fish species (Romanuk & Levings 2006). Negative impacts can also apply to invertebrates, which are an important prey component of many fish (Romanuk & Levings 2003; Sobocinski et al. 2010). Nearshore habitat restoration often emphasizes improving conditions for these important invertebrates, with the goal of enhancing their production to more natural levels and increasing ecological function.

Impacts of shoreline armoring on invertebrate assemblages have been shown to affect community patterns in other systems as well, predominantly in a negative way with decreased or altered assemblages, but with occasional positive interactions attributed to an increase in unique structures that can attract certain organisms (Glasby 1998: Peterson et al. 2000, Spalding & Jackson 2001; Davis et al. 2002; Chapman 2003; Chapman & Bulleri 2003; Cruz Motta et al. 2003). Underlying mechanisms for negative effects are often related to physical alterations associated with truncating and retaining the intertidal zone, such as degrading intertidal habitat and shoreline vegetation, limiting the sediment supply, and reflecting wave energy which can increase erosion and coarsen sediments (Shipman et al. 2010). Research has been lacking to test whether these altered systems can be restored towards natural conditions with removal of the modifications and enhancement of the intertidal beach (Toft et al. 2010).

This study describes 2010 year 5 post-restoration monitoring of the benthic invertebrates along the south shoreline at Seahurst Park in the City of Burien. Restoration activities completed in February 2005 replaced a 300-m section of seawall/riprap with a more gradual and natural slope, removing the seawall by barge and importing gravel and cobble, and planting riparian vegetation in the uplands (Figs. 1,2a; USCOE 2003). By incorporating a paired restored/reference sampling design and comparing to pre-restoration monitoring in 2004 (Toft 2005) and years 1 and 3 post-restoration monitoring in 2006 and 2008 (Toft 2007, 2009), we will be able to assess early stages of the restoration effort. Additionally, in 2010 we included baseline sampling of the north seawall (Fig. 2b), as it is scheduled to be removed and the beach restored in 2011/12 similar to that at the south restoration site.

Benthic invertebrates in Puget Sound have been shown to be closely linked to physical characteristics in the benthos, thus making them a suitable metric for analysis (Dethier & Schoch 2005). Benthic cores at Seahurst Park were taken during three months (June, July, September) and at three different tidal heights (+5, +8 and +12’ MLLW) in all years of sampling at the south restored and south reference site, and in 2010 at the north seawall site. Therefore, the main goal of this study was to compare the benthic macroinvertebrate assemblage structure at the south restoration site and a nearby reference beach in order to provide an initial measurement of restoration success, with an additional goal of applying this knowledge to the potential success of the north restoration site.

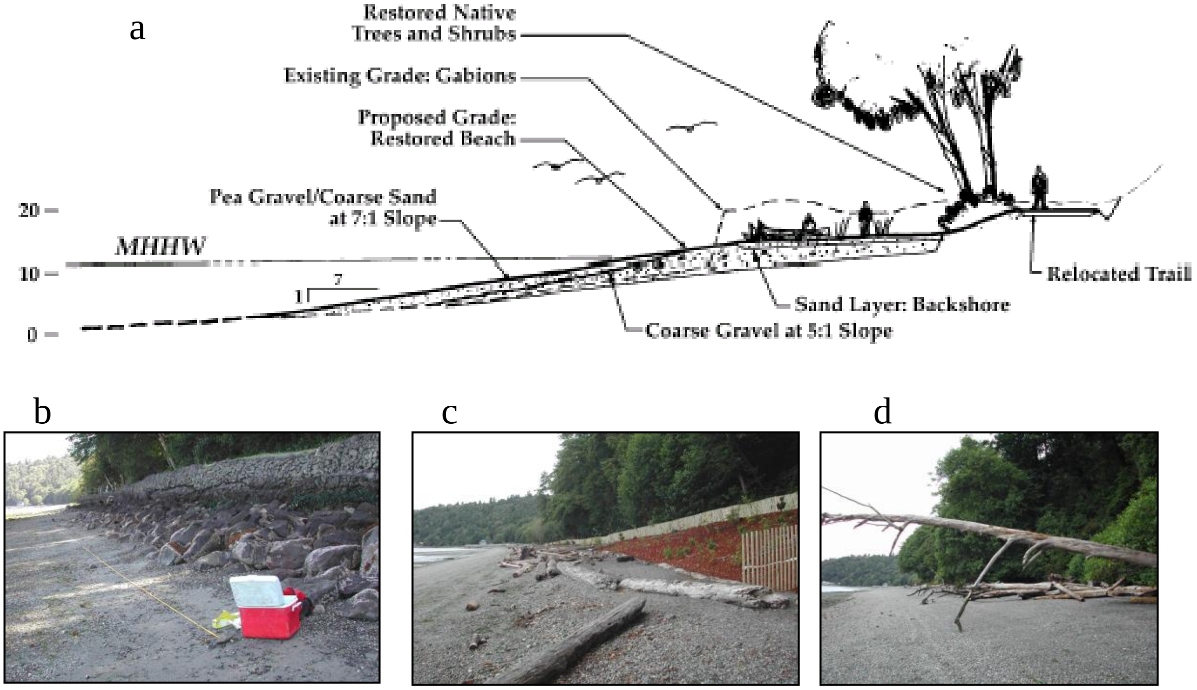

Figure 1. Typical cross section (a) of the plan for restoration at Seahurst Park (USCOE 2003), with photographs of the site pre-restoration (b), post-restoration (c), and reference beach (d).

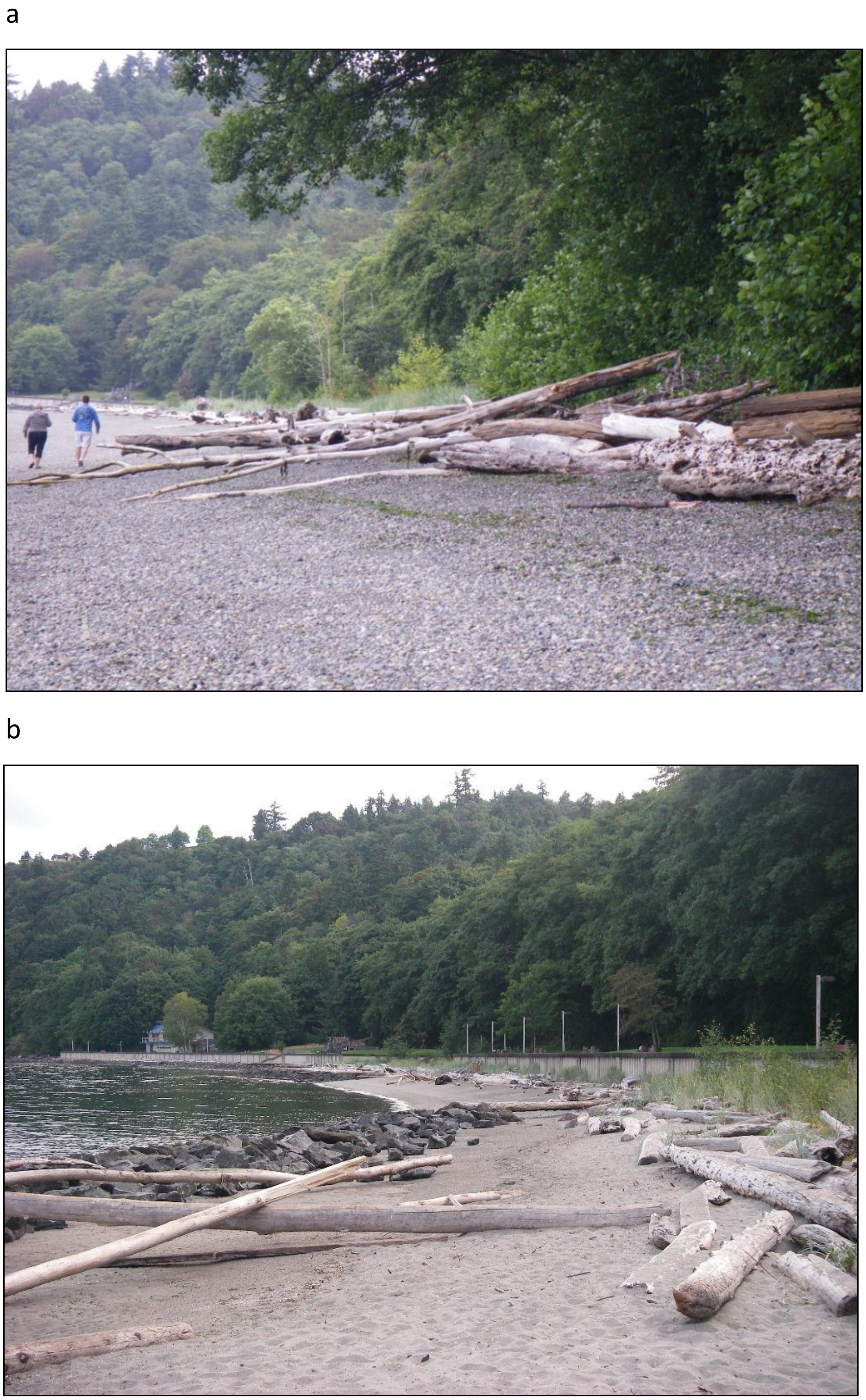

Figure 2. Photographs in 2010 of the south restored site (a), and the north seawall site (b).

Methods

Three sites were sampled in 2010: (1) the seawall removal restored site at south Seahurst Park (Rest), (2) the reference beach (Ref) immediately south (~200-m) of Seahurst Park, and (3) the north seawall site (Seawall) at Seahurst Park that is planned to be removed and restored (Fig. 3). Sampling was conducted in June, July and September 2010, identical to past years of sampling (2004, 2006, and 2008). June and July represent peak periods of juvenile Chinook and coho (*Oncorhynchus kisutch*) salmonid migration, and September typically represents higher beach-wrack depositions (the accumulation of debris deposited by an ebbing tide, consisting mostly of marine algae, eelgrass, and organic matter from terrestrial riparian sources such as wood and leaves). Invertebrates were collected at three different tidal heights that spanned the elevations affected by restoration:

(1) +12’ MLLW (hereafter +12), approximately the level of MHHW. This area is where beach-wrack is typically formed, and is at an elevation where seawall material was removed at the restored site. Thus, during pre-restoration monitoring only the reference site was sampled at +12, as there was no benthic substrate to sample at the restored site due to the seawall. At the north seawall site there is a section that was located above +12’, so this elevation was sampled in 2010.

(2) +8’ MLLW (hereafter +8), the approximate elevation at the foot of the previous shoreline armoring at the restored site. This elevation provides comparable data where the shoreline armoring interacted with the water.

(3) +5’ MLLW (hereafter +5), the low elevation of the beach regrade at the restored site.

Figure 3. Location of study sites at Seahurst Park: south reference, south restored, and north seawall. At the north seawall site the +8 and +5 MLLW tidal elevations were sampled at the lowest point of the seawall; the +12 elevation was sampled at a point where the seawall was placed higher than +12.

Seven samples were randomly collected with a benthic core along a 30-m transect at each site and tidal elevation. Benthic cores were 10 cm in diameter and taken to a depth of 15 cm. Samples were fixed in 10% formalin and dyed with rose-bengal to aid in sorting and identification. Cobble, mud, wood, and other detritus were removed to the extent possible with sieving at 500 microns, and macroinvertebrates were identified and counted using a dissecting microscope.

Data was entered into Microsoft Excel, and univariate ANOVA tests (alpha = 0.05) were used to analyze total invertebrate densities in the statistical program S-Plus (Zar 1996). Densities were log-transformed to satisfy assumptions of normality and homogeneous variances. Taxa richness was measured as the total number of taxa recorded at each site.

Invertebrate assemblages were analyzed using multivariate statistics: nonmetric multidimensional scaling (NMDS) ordination, analysis of similarity (ANOSIM), and similarity percentage (SIMPER) analysis (Primer version 6 software, Clarke and Warwick 2001). These analyses uncover patterns in multivariate groupings of the data, which is useful when analyzing assemblage datasets with multiple species compositions. Densities were log-transformed for ordination, and species that did not account for more than 3% of the total abundance of any one sample not included. NMDS was used to graphically plot differences in species assemblages onto two-dimensional charts in multidimensional space based on a Bray-Curtis similarity matrix. ANOSIM has been used for testing hypotheses about spatial differences and temporal changes in species assemblages as well as for detecting environmental impacts (Valesini et al. 2004; Wildsmith et al. 2005). ANOSIM gives a p-value similar to an ANOVA, with values of $p < 0.05$ indicating significance. ANOSIM also generates a value of R to determine biological importance. The R value is scaled between -1 and +1, with a value of zero representing no difference among a set of samples, and the closer the value to 1 the greater the biological importance of the differences. R values above 0.4 are typically found to have biological importance. If differences were found using ANOSIM, then SIMPER analysis was used for identifying which species primarily accounted for observed differences in invertebrate assemblages between sites. SIMPER generates a ranking of the percent contribution of the species that are most important to the significant differences between factors.

Results

General Taxa Composition

A total of 164 taxa were identified during the entire sampling regime. Graphs and analysis are grouped into major taxa categories, with discussion of species where appropriate. General classification of sampled taxa groupings and species with numerical percent of total numbers over all sampling is listed in Appendix I. For taxa grouped into general categories, the groups with the highest percent composition were oligochaetes, aquatic amphipods and isopods, terrestrial amphipods, polychaetes, nematodes, and nemertea/turbellaria (Fig. 4). Oligochaetes, nematodes, nemertea and turbellaria were relatively abundant across all sites. Densities of terrestrial amphipods (beach-hopper amphipods in the family Talitridae) were most abundant at the +12 elevation, with lower densities at +8, and only fifteen sampled at +5 in 2010. While juvenile talitrids usually dominated beach-hopper numbers, adults of three species occurred: *Traskorchestia georgiana, Traskorchestia traskiana,* and *Megalorchestia pugettensis* (listed in order of increasing maximum size). The two species of *Traskorchestia* were overall more abundant than *M. pugettensis*, although neither species of *Traskorchestia* occurred at the north seawall site, only *M. pugettensis*. As a group, insects (adults and larvae), arachnids (mites-acarina and spiders-araneae), and collembolans (springtails in families Hypogastruridae, Onychiuridae, Isotomidae, and Sminthuridae) had overall fairly low numbers, with insect adults and larvae occurring mostly at higher elevations. As would be expected, aquatic crustaceans were most abundant at the lower +5 tidal elevations, although the south reference site had fairly high abundances of aquatic amphipods and isopods at +8 in 2010. The north seawall site was unique in 2010 for having higher numbers of harpacticoid copepods, almost all the species *Huntemannia jadensis.* Similar to crustaceans, almost all polychaetes had highest densities at the +5 elevation, except for the small archiannelids which occurred mostly at +8. Bivalves also were present mostly at lower tidal elevations, although overall densities were low compared to other taxa.

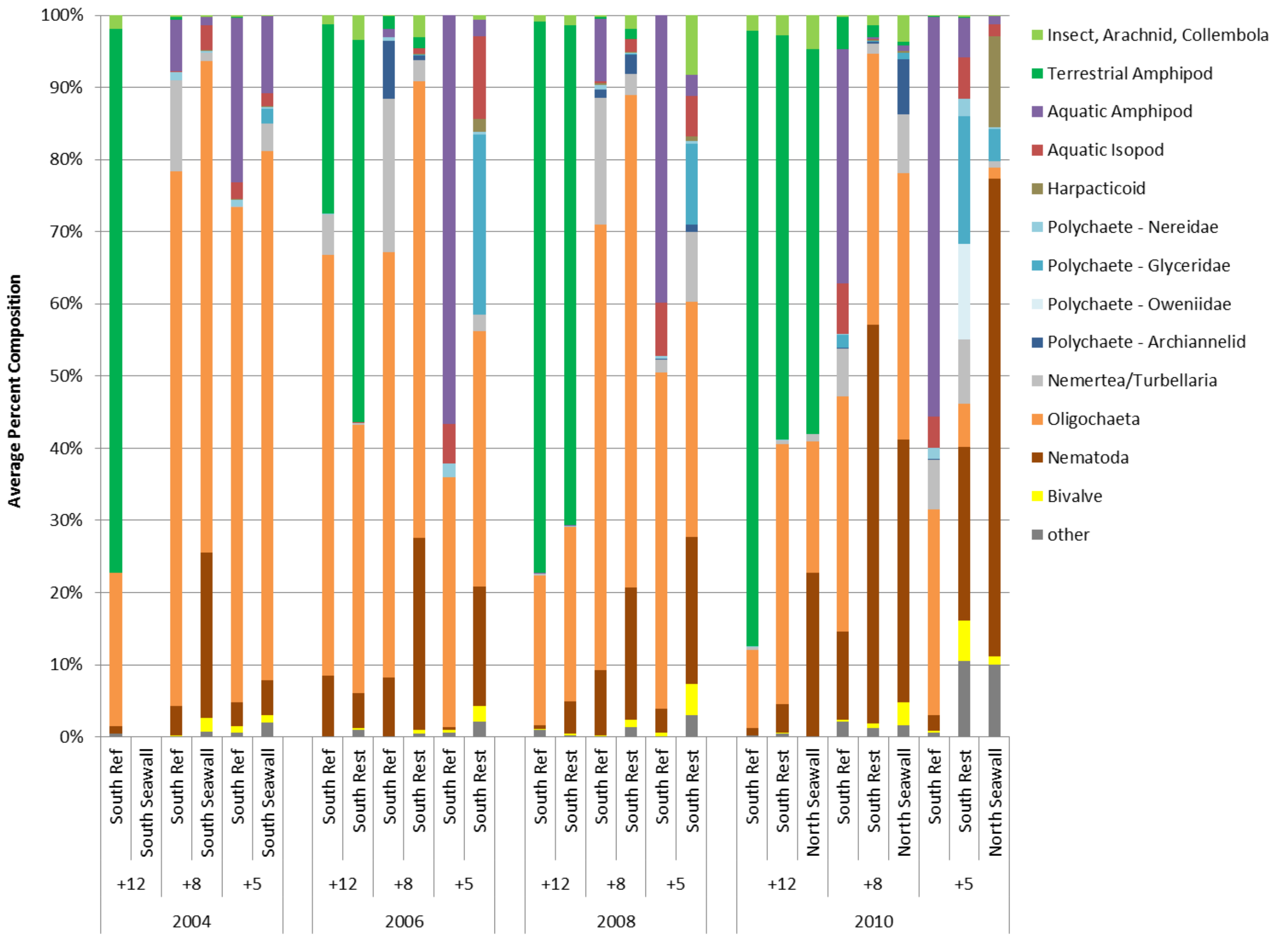

Figure 4. Numerical percent taxa composition of all sampled invertebrates, showing major taxa groups averaged over June, July, and September for each year. The order of taxa names in the legend reflects that in columns, Ref = Reference, Rest = Restored.

2010 Post-Restoration Invertebrates

Results from a 2-way site x month ANOVA with interactions on log-transformed total densities at each elevation in 2010 showed significant site differences at the +12 and +5 elevations, with no site differences at +8 (Table 1, Fig. 5). At +12, a tukey multiple comparison test showed that reference had the highest densities, with both reference and restored having higher densities than the north seawall. At +8 the interaction term was the only significant difference, illustrating variances between sites and months. At +5 both the site and interaction terms were significant, so separate ANOVAs were done for each month, showing the seasonal variability relating to site with no consistent pattern: June (SW > Ref > Rest), July (Ref > Rest > SW), September (Ref,SW > Rest). The reference site was greater than restored in all three months, and the seawall site was greater than the restored site in two of the months, although both the reference and restored site were greater than the seawall site in July. Month was significant only at +12, illustrating some seasonal differences in densities.

Patterns of taxa richness varied somewhat across the tidal elevations in 2010 (Fig. 6). At +12 the restored site had the highest taxa richness, with seawall having very low values, lower than any other measurement in all the years of sampling. At +8 values of taxa richness were highest at the reference site, with slightly lower values at the seawall and restored sites. At +5 the seawall and restored sites were greater than the reference site, but all values were higher than any other measurement in all the years of sampling.

Multivariate analysis of the 2010 benthic invertebrate assemblages based on densities proved to be a “useful” model according to statistical guidelines, showing a NMDS ordination 2-d stress of 0.17 (Fig. 7a). The three different elevations grouped distinctly, with large separation between the reference and both the restored and seawall sites at +5, some overlap between the sites at +8, and the seawall site grouping separately from the reference and restored sites at +12. Further analysis with a 1-way ANOSIM on site showed significant overall results on the Global test, with significant meaningful differences at the +5 and +12 elevations, as stated above (Table 2). Although the p-value was also significant between some of the other pairwise tests, the R-value was low (below 0.4) showing little biological importance, although at +8 the restored and seawall sites did have an R-value of 0.34. The subsequent SIMPER analysis details the taxa differences for these significant results (Table 3): (1) at +12 elevation, greater densities at the reference and restored sites than the seawall site of Talitridae (juveniles and the two species of *Traskorchestia*) and oligochaetes, with also minor increases in densities of acari at the reference site and nematodes at the restored site, and (2) at the +5 elevation, greater densities at the reference site than the restored and seawall site of amphipods (juveniles and the species *Eogammarus confervicolus*, and *Allorchestes* sp. as compared to the restored site) and oligochaetes, with less densities at the reference site of the Glyceridae polychaete *Hemipodia simplex*, and less nematodes as compared to the seawall site.

As an example of these post-restoration invertebrate assemblage characteristics, the same ordination plot in Figure 7a is shown with bubble plots of the densities of three key taxa identified in SIMPER results (juvenile Talitridae, the aquatic amphipod *Eogammarus confervicolus*, and the Glyceridae polychaete *Hemipodia simplex;* Fig. 7b). There is a clear separation at +5 between *E. confervicolus* at reference and Glyceridae at the restored and seawall sites. At +12, juvenile Talitridae amphipods are distributed more at the reference and restored sites than the seawall site.

2004/2010 Pre- and Post-Restoration Invertebrates

Results from a 1-way ANOVA of log-transformed total densities on year for each restored site elevation showed significant differences at all elevations (Table 1; Fig. 5). At +12, the comparison was made since restoration in 2006, as due to the seawall there was no benthic substrate to sample at this elevation in 2004. Densities at this elevation have increased, as 2010 had significantly greater densities than 2006. At +8, all years post-restoration were greater than 2004. At +5, both 2004 and 2010 were significantly greater than 2006 and 2008.

Taxa richness has continued to increase since restoration at the +12 elevation, and has continued to increase since pre-restored conditions at the +5 elevation (Fig. 6). The +8 elevation had higher values as compared to pre-restored conditions, but was slightly lower than values in 2008 and 2006.

Multivariate analysis of the benthic invertebrate assemblages pre- and post-restoration based on densities proved to be a “useful” model according to statistical guidelines, showing a NMDS ordination 2-d stress of 0.16 (Fig. 8). The three different elevations grouped distinctly, using restored sites from both 2004 and 2010 and Ref +12 from 2004, as there was not a comparable +12 restored site pre-restoration due to the seawall. The +12 restored site in 2010 clustered similar to the 2004 reference site and away from the 2004 pre-restored seawall +8 site. The +8 elevations had some overlap, and the +5 elevation had separate groupings for the 2010 restored and the 2004 seawall sites. Further analysis with a 1-way ANOSIM on site showed significant overall results on the Global test (Table 2). At Rest +12, there was no significant difference compared to Ref +12 pre-restoration, but there was compared to the pre-restored highest elevation Rest +8 2004. Rest +8 had few differences 2010 compared to 2004 (low R-value), and Rest +5 had sizeable meaningful differences (high R-value). The subsequent SIMPER analysis details the taxa differences for these significant results (Table 3), summarized as: (1) much higher densities of talitrid beach-hopper amphipods at Rest +12 2010 compared to the pre-restored highest elevation Rest +8 2004, and (2) at +5, more oligochaetes, turbellaria, and juvenile amphipods in 2004, and more of the Glyceridae *Hemipodia simplex* and nematodes in 2010.

Table 1. Summary ANOVA p-values of total invertebrate significant density differences, $p < 0.05$ in bold.

2010

2-way ANOVA on site x month

Elevation	Month	Site	Interaction
12'	**1.0E-07**	**1.0E-08** (Ref > Rest > SW)	0.32
8'	0.14	0.14	**0.001**
5'	0.67	**0.0000002**	**1.0E-08**

South Restored across 2004, 2006, 2008, and 2010

1-way ANOVA on site

Elevation	Year
Rest +12' (no 2004)	**0.006** (2010 > 2006)
Rest +8'	**1.9E-06** (all > 2004)
Rest +5'	**2.21E-06** (2004,2010 > 2006,2008)

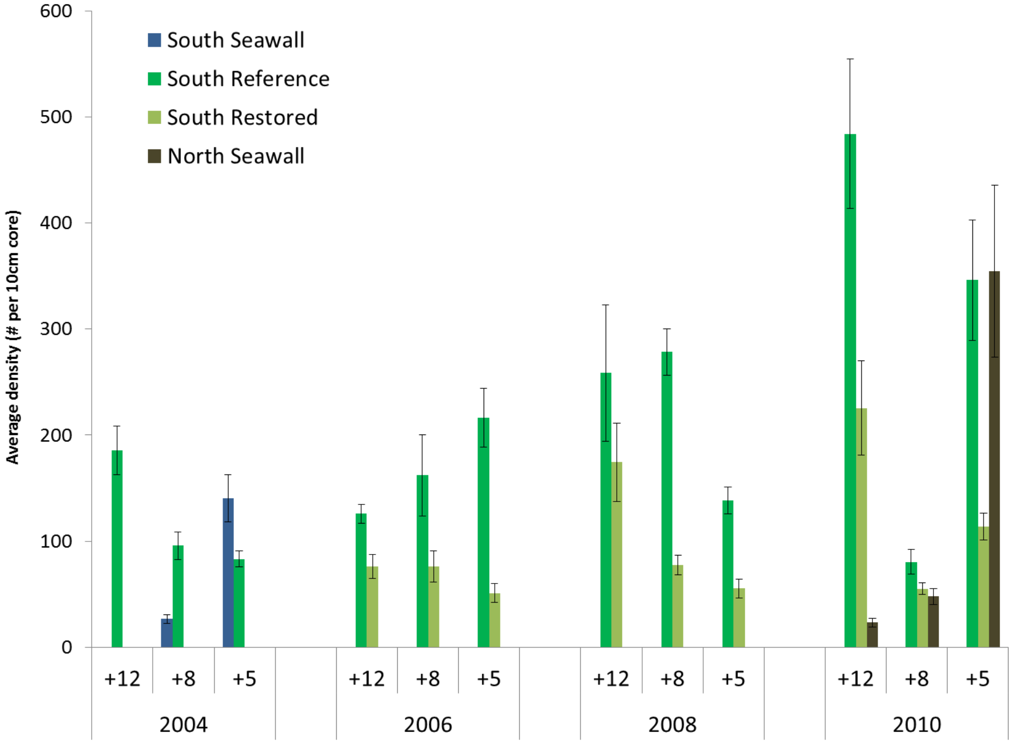

Figure 5. Total average invertebrate densities for all sites and years. Error bars represent Standard Error.

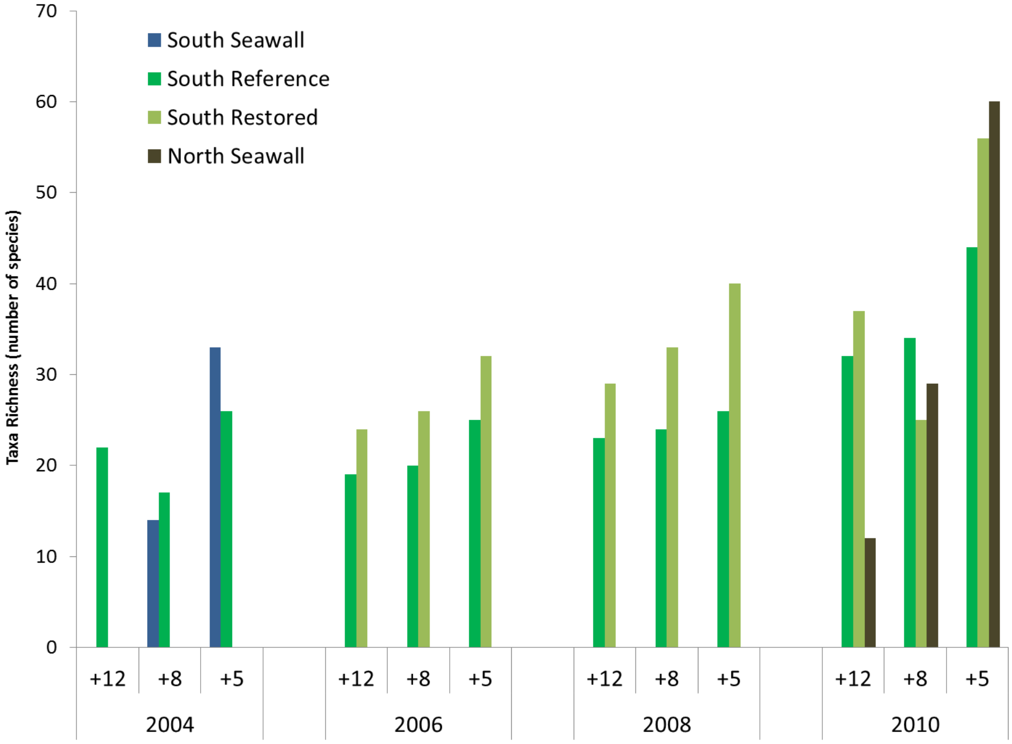

Figure 6. Overall taxa richness for all sites and years.

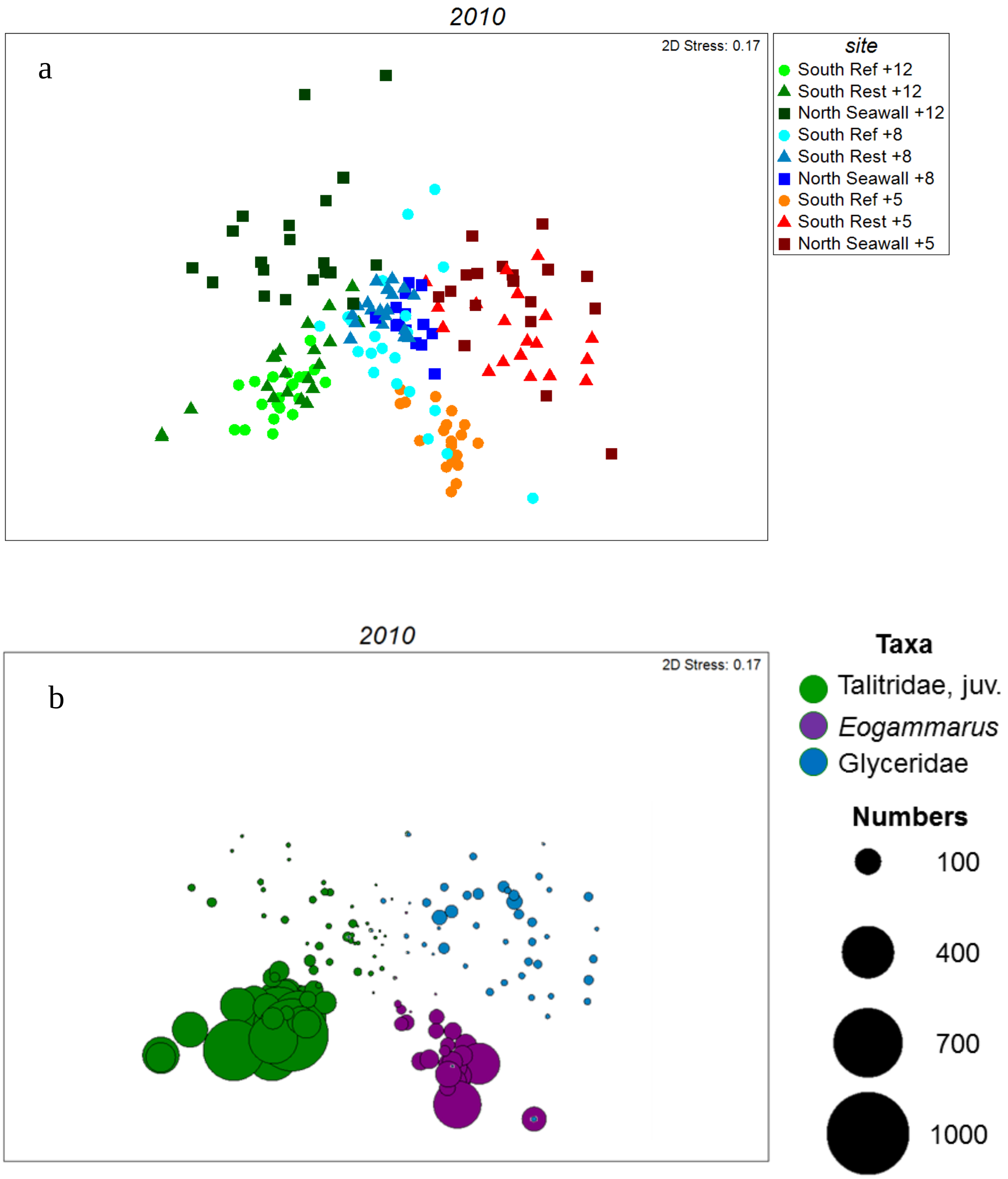

Figure 7. Multivariate analysis using NMDS ordination of the benthic invertebrate data (each symbol represents the invertebrate assemblage in a single sample) in (a) 2010, and (b) corresponding bubble plot of numbers of representative taxa, positions of bubbles correspond to points on 2010 NMDS ordination. Taxa: juvenile beach-hopper amphipods (Talitridae), aquatic amphipods (*Eogammarus confervicolus*), and the polychaete *Hemipodia simplex* (Glyceridae).

Table 2. Summary ANOSIM statistics using multivariate analysis on invertebrate assemblages. ANOSIM is equivalent to a univariate ANOVA, with high biological importance illustrated by $R > 0.4$ and significant differences $p < 0.05$. Bold indicates meaningful biological differences.

2010

Site Comparison	R-value	p-value
Global test	**0.66**	**0.001**
+12 Ref & Rest	0.10	0.002
Ref & Seawall	**0.73**	**0.001**
Rest & Seawall	**0.54**	**0.001**
+8 Ref & Rest	0.30	0.001
Ref & Seawall	0.10	0.051
Rest & Seawall	0.34	0.001
+5 Ref & Rest	**0.83**	**0.001**
Ref & Seawall	**0.88**	**0.001**
Rest & Seawall	0.24	0.001

Restored 2010 and 2004

Site Comparison	R-value	p-value
Global test	**0.62**	**0.001**
Rest+12 2010 & Ref+12 2004	0.02	0.16
Rest+12 2010 & Rest+8 2004	**0.65**	**0.001**
Rest+8 2010 & 2004	0.24	0.001
Rest+5 2010 & 2004	**0.73**	**0.001**

Table 3. Summary statistics using multivariate analysis on invertebrate assemblages. SIMPER analyzes the species that have the largest contributions to statistical differences (top 5 in each category included).

2010	Average log-densities		
+12 Seawall & Ref (avg. dissimilarity 72.5)	**Seawall**	**Reference**	% Contribution
Talitridae, juv.	1.44	5.48	22.3
Traskorchestia georgiana	0	3.09	16.2
Traskorchestia traskiana	0	2.82	15.1
Oligochaeta	1.25	3.63	13.1
Acari	0.07	1.43	7.0
+12 Seawall & Rest (avg. dissimilarity 68.1)	**Seawall**	**Restored**	% Contribution
Talitridae, juv.	1.44	3.68	18.3
Oligochaeta	1.25	3.23	16.6
Traskorchestia traskiana	0	2.34	15.9
Traskorchestia georgiana	0	2.03	13.3
Nematoda	1.15	1.57	9.7
+5 Ref & Rest (avg. dissimilarity 68.8)	**Reference**	**Restored**	% Contribution
Eogammarus confervicolus	4.34	0.4	13.3
Oligochaeta	4.32	1.37	9.9
Amphipod, juv.	2.53	0	7.8
Hemipodia simplex	0.04	2.19	7.3
Allorchestes sp.	2.54	0.92	6.7
+5 Ref & Seawall (avg. dissimilarity 74.1)	**Reference**	**Seawall**	% Contribution
Eogammarus confervicolus	4.34	0	13.4
Oligochaeta	4.32	1.42	9.0
Nematoda	1.98	4.53	8.3
Hemipodia simplex	0.04	2.37	7.7
Amphipod, juv.	2.53	0.2	7.1

Restored 2010 and 2004	Average log-densities		
Rest+12 2010 & Rest+8 2004 (avg. dissimilarity 69.6)	**2010**	**2004**	% Contribution
Talitridae, juv.	3.68	0	26.3
Traskorchestia traskiana	2.34	0	15.8
Traskorchestia georgiana	2.03	0	13.2
Oligochaeta	3.23	2.52	12.1
Nematoda	1.57	1.51	9.2
Rest +5 2010 & 2004 (avg. dissimilarity 75.4)	**2010**	**2004**	% Contribution
Oligochaeta	1.37	3.66	11.8
Hemipodia simplex	2.19	0.49	7.8
Nematoda	3	1.42	7.7
Turbellaria	0.13	1.4	6.0
Amphipod, juv.	0	1.42	5.6

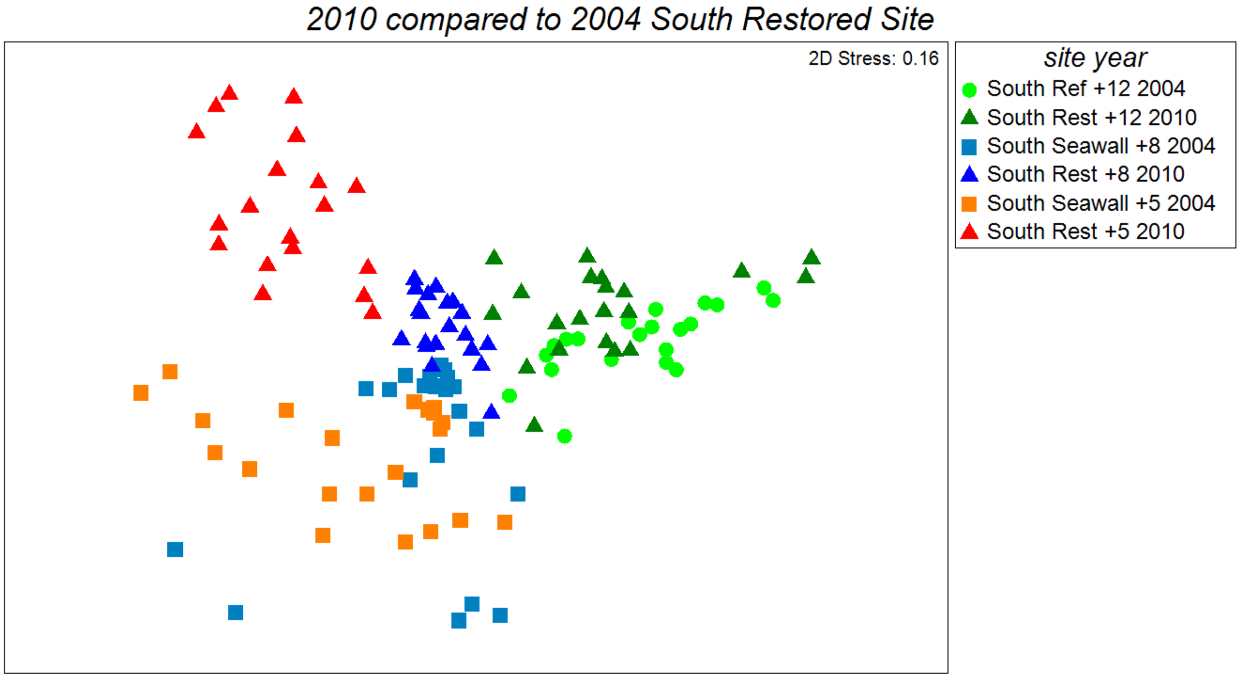

Figure 8. Multivariate analysis using NMDS ordination of the benthic invertebrate data for the restoration site in 2010 (post-restoration) versus 2004 (pre-restoration seawall), with Ref +12 2004 as a comparison since no Rest +12 site existed pre-restoration.

Discussion

It is clear that after the fifth year of beach restoration at south Seahurst Park that many aspects of the invertebrate community have improved since pre-restoration conditions and shifted towards those at the reference site, especially at higher tidal elevations. Other aspects appear to be still in development, or exhibit a high amount of variance, notably at lower tidal elevations. Before restoration, the seawall truncated the supratidal and high intertidal zone, causing lack of shoreline riparian vegetation and preventing formation of beach-wrack deposition that is typical of a natural gradual sloping beach. After restoration, upon completion of the seawall removal and restoration of the natural beach gradient along with plantings of terrestrial vegetation, the processes that were negated by the presence of the seawall were allowed to re-develop. Beach-wrack formation at high tidal elevations now occurs at the restored site, with development of invertebrate assemblages that are typical of the reference beach and unique to those at the highest tidal elevation. High values of taxa richness at the restored site signify a diverse colonization of invertebrates that have formed the building blocks of the patterns of restoration through time. Intertidal biota along the shoreline of Seahurst Park has been found to be more depauperate than it was 40 years ago (Dethier and Berry 2010), so signs that the restoration has increased values of taxa richness is encouraging.

Results of the invertebrate sampling at the south restoration and reference sites can best be discussed in relation to the different tidal elevations characterized by the restoration activities at each elevation. At the +12 elevation, there was previously a seawall that prevented wrack formation and a benthic assemblage prior to restoration. Since restoration, taxa richness has increased in every year and has consistently been greater than the reference site, with similar invertebrate assemblages to the reference site although with lower overall densities. Densities have improved as compared to initial restored densities in 2006. Terrestrial amphipods (beach-hoppers in the family Talitridae) are typical of this elevation, thriving on beach wrack deposition. This wrack-dependent community has been found to be unique in other systems as well, with important links to terrestrial zone productivity (Dugan et al. 2003; Ince et al. 2007). Overall, invertebrate assemblages at this elevation have been restored to the conditions at the reference beach, with the only possible improvement being the continued increase in overall densities.

The +8 elevation was previously the location at the base of the seawall, and therefore subject to physical alterations in sediments and wave activity that altered the invertebrate community. Taxa richness was low, and invertebrate assemblages were different than comparable elevations at the reference site, with lower densities (Toft 2007). Invertebrates have occupied this elevation since restoration, resulting in values of taxa richness that are greater than pre-restored levels but in 2010 were not as high as the reference site, which was different than years 2006 and 2008 when the restored site did have higher values than the reference site. It is likely that the initial pulse of taxa into the restored site at this elevation has stabilized since restoration. Overall densities have improved since restoration, and were equal to that at the reference site with similar invertebrate assemblages. Overall, invertebrate assemblages at this elevation have been restored to the conditions at the reference beach, with the only possible improvement being a slight increase in values of taxa richness.

The +5 elevation was below the base of the seawall, at the low level of the regrade of the restored beach. There were no major significant differences between densities or assemblages before restoration, with taxa richness actually being highest at the seawall site. This could possibly be due to invertebrate colonization being hindered by physical alterations at the base of the seawall at +8 and thereby occupying lower tidal elevations, additionally supported by sediment samples which showed higher sediment sizes (gravel) at the +8 seawall site than at the reference site (medium sand; Sobocinksi 2010). The necessary regrade of the beach at this elevation as part of the restoration affected the invertebrate community, initially leading to reduced densities and a dramatic shift in invertebrate assemblages, albeit with high taxa richness. These trends have continued in 2010, although densities have now improved to be similar to that as in 2004 before the beach regrade. In all years of monitoring post-restoration, invertebrate assemblages at the restored site had less amphipods and oligochaetes and more Glyceridae polychaete worms. The reasons for these alterations in the invertebrate community are unknown, and could still be indicative of an early restoration stage. However, the differences could also be the result of different habitat qualities specific to the restored and reference sites, such as physical alterations caused by the seawall removal, beach regrade, and changes in sediment size. Physical properties sampled at the beach have shown that beach profiles and sediments are similar between the restored and reference beaches, with minor changes over time (Johannessen and Waggoner 2011a). The same report noted that this elevation is at the upper extent of freshwater seepage, so interchange between freshwater and saltwater environments may be different between the two sites and may have increased at the restored site when the seawall was removed, although this appears to have stabilized in recent years due to completion of construction along the trail and drainage ditch above the beach. Future sampling could help to explain these types of differences: if invertebrate communities converge with time, or if more physical data can be collected at this elevation. Overall, invertebrate assemblages at this elevation have only been partially restored to the conditions at the reference beach, as there could still be improvements in overall densities and in the composition of the invertebrate community.

Incorporating the north seawall site with the 2010 sampling allows for comparison with the south restored and reference sites and also serves as a baseline for future restoration. Differences were most extreme at the +12 elevation, where the north seawall site had much lower densities and taxa richness than the south restored and reference sites. Beach-hopper amphipods were rare at this elevation, and adults of only one species (*M. pugettensis*) were present, indicative of there not being as much beach-wrack deposition and possibly different physical characteristics (Johannessen and Waggoner 2011b). Trends at the +8 elevation were similar to that at the south seawall site in 2004, with lower taxa richness than the reference site, although overall densities were not significantly lower as they were in 2004, and assemblages were fairly similar. At the +5 elevation below the seawall location, taxa richness was greater than the reference site, as was the case with the south seawall site in 2004. However, densities were variable, and invertebrate communities were different than the reference site and similar to the south restored site, characterized by Glyceridae polychaete worms and lacking amphipods and oligochaetes. Overall, there is great restoration potential at higher tidal elevations after seawall removal at the north site, and care should be taken to not adversely affect lower tidal elevations during the regrade of the beach.

Now that sampling of the benthic invertebrate community has been completed throughout a seven year timeline, we can address the stability of the initial trends based on the pre-restoration monitoring in 2004, seawall removal and restoration in 2005, and post-restoration monitoring in 2006, 2008, and now 2010. A conceptual model summarizing the monitoring data collected during armored and restored conditions is presented in Figure 9 (as modified from Toft et al. 2010), and may serve as a guide to other efforts of seawall removal and restoration of beach processes in Puget Sound. A seven-year timeline has been suitable for documenting success of the seawall removal especially at upper tidal elevations which were at the location of the previous seawall. It is clear that long-term monitoring will be necessary to completely gauge aspects of restoration success or failure at the lower +5 elevation, due to the shifts in the invertebrate community from one characterized by amphipod crustaceans to one characterized by polychaete worms. The causal mechanism of this invertebrate shift remains a question, and further research could seek to uncover whether this can be expected of other beach regrades, or if it is specific to the physical conditions at south Seahurst Park. It will be interesting to see if a similar shift happens with the future regrade at north Seahurst Park, although the invertebrate community at this site is already different than the reference site.

Initial responses of nearshore beach restoration may be comparable to those of beach nourishment, in which sediment is added to beaches in order to prevent erosion of coastal habitats. Research on impacts of beach nourishment has shown mixed results (Nordstrom 2005), with effects on sediments and invertebrates being linked to local conditions (Colosio et al. 2007). It remains unknown whether beach restorations such as at Seahurst Park will require additional beach nourishment over time, or if sediments and beach slope will remain stable. However, physical monitoring has indicated that beach renourishment should not be required in the near future based on current rates of sediment transport (Johannessen and Waggoner 2011a). This stability in the sediment structure will be conducive to the stability of the invertebrate community.

Since the removal of the seawall, presumably both benthic invertebrates and terrestrial insects have been made more available to juvenile salmonids and other nearshore fish as potential prey items. The type of indirect measure of productivity measured with invertebrate assemblages in our study can be said to increase the “opportunity” that juvenile salmon have to access and benefit from the site (Simenstad & Cordell 2000). Datasets from fish netting in the surrounding area have shown major prey items of juvenile Chinook salmon to be epibenthic/benthic invertebrates and terrestrial insects (Brennan et al. 2004), with a decrease in riparian insect feeding when shorelines have artificial retainments (Toft et al. 2007). Additionally, data from snorkel surveys at Seahurst Park have observed high proportions of juvenile salmonid feeding behavior (Heerhartz 2010). This entire context places emphasis on restoration of nearshore processes, in order to increase the opportunity of nearshore feeding by juvenile salmonids.

Two large scale organizations have recently been initiated to help guide the restoration of Washington State's Puget Sound waters: The Puget Sound Partnership (PSP), and the Puget Sound Nearshore Ecosystem Restoration Partnership (PSNERP). Both list shoreline armoring as a major threat to the health of Puget Sound. The goal of PSP is to create a comprehensive action agenda to restore Puget Sound by the year 2020, and they list shoreline armoring as one of the major threats to ecosystem processes in Puget Sound (PSP 2009). PSNERP also is creating guidelines and conceptual models at the ecosystem processes level, and they further state that shoreline armoring is a source of stress to the nearshore and that bulkhead removal should be a focus of restoration actions (Simenstad et al. 2006). It is clear that a more complete understanding of shoreline armoring removal and restoration of the nearshore will add greatly to the knowledge of whether the goals of these programs can be reached.

In summary, it becomes apparent that a major goal of nearshore restoration in Puget Sound should be to establish and maintain connections between terrestrial riparian and aquatic intertidal zones (Toft et al. 2010). When this occurs, it facilitates development of secondary responses including natural feeding processes and assemblage interactions. Monitoring in this report has shown that although there are still some differences between the restored and reference sites at Seahurst Park, the restoration has resulted in a positive initial response of the benthic invertebrate community especially at tidal elevations where the seawall directly covered the intertidal zone. It will be important to continue to monitor in future years in order to assess long-term site development at south Seahurst Park (planned for year 10, 2015) and at north Seahurst Park as related to the timeline of the seawall removal. Such monitoring will be useful to help guide other restoration opportunities along shorelines of Puget Sound.

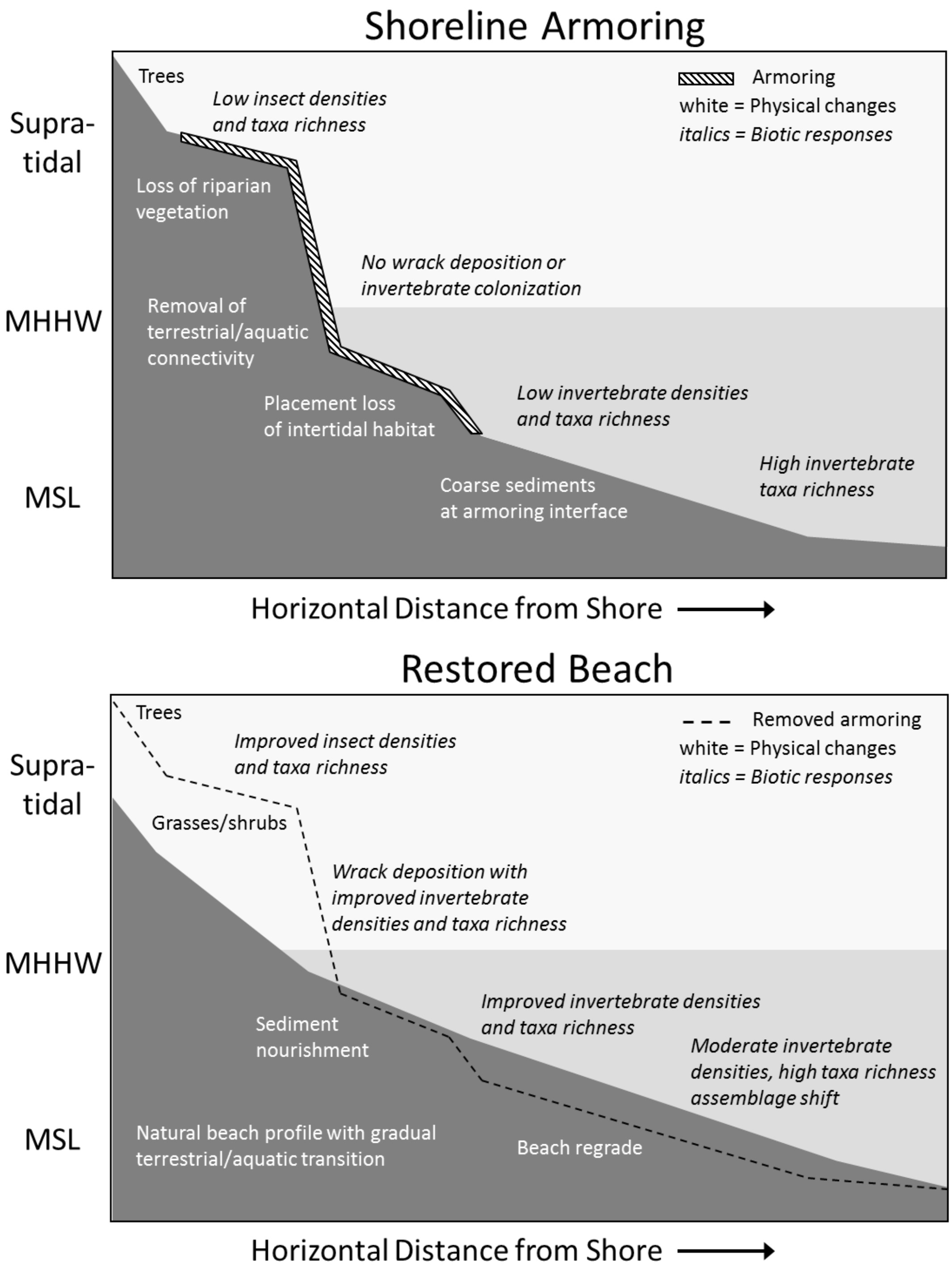

Figure 9. Conceptual model of Seahurst Park monitoring, summarized from armored and restored conditions (modified from Toft et al. 2010). Mean Higher High Water (MHHW) represents the approximate high-tide line, and Mean Sea Level (MSL) the approximate mid-tide elevation on the beach profiles. Main invertebrate datasets summarized from this report, with ‘armored’ insects and sediments from Sobocinski et al. 2010, ‘restored’ insects from Armbrust et al. 2009, and physical profile outlines based on Johannessen and Waggoner, 2011.

Acknowledgements

Funding for this study was provided by the King Conservation District, the Estuary and Salmon Restoration Program, and the City of Burien. Numerous people provided logistic support and discussions that helped the development of this project, including: Steve Roemer, Charles Simenstad, and Jeffery Cordell who also took the invertebrate photographs. Beth Armbrust, Claire Levy, Erin Morgan, Sarah Heerhartz, and Jessica Randall assisted with fieldwork and laboratory processing of benthic samples.

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Appendix I: Listing of taxa and percent of numbers within each column

			+12								+8									+5								
			South Ref				South Rest			North SW	South Ref				South Rest				North SW	South Ref				South Rest				North SW
Main Taxa Grouping	Secondary Taxa Grouping	Taxa	2004	2006	2008	2010	2006	2008	2010	2010	2004	2006	2008	2010	2004	2006	2008	2010	2010	2004	2006	2008	2010	2004	2006	2008	2010	2010
Anthozoa	Anthozoa	Anthozoa																							0.1%		0.1%	
Aquatic crustacean	Aquatic Amphipod	Allorchestes sp.											0.02%	2.72%	0.71%			0.27%	0.15%	0.11%	12.43%	6.44%	7.42%	3.49%	0.65%	1.89%	4.59%	0.97%
		Americorophium salmonis																										0.02%
		Americorophium sp.																				0.07%						0.02%
		Americorophium spinicorne																										0.02%
		Amphipod, juv.			0.06%						0.10%	0.03%		0.35%	0.18%			0.09%	0.15%	7.32%	3.57%		16.59%	5.36%	0.47%			0.09%
		Corophiidae, juv.																	0.15%		0.09%	0.03%	0.05%				0.05%	0.03%
		Eogammarus confervicolus									0.20%	0.09%	1.69%	21.41%	0.36%				0.30%	14.87%	37.26%	28.74%	30.92%	1.80%	1.21%	1.03%	0.74%	
		Grandidierella japonica	0.03%		0.02%			0.03%																				
		Monocorophium acherusicum																			0.09%							
		Monocorophium sp., juv.																					0.03%					
		Paramoera sp.						0.14%			6.86%	0.97%	6.91%	7.92%						0.46%	3.15%	4.54%	0.40%	0.03%			0.09%	
		Photis sp.																			0.02%							
		Themisto pacifica																					0.02%					
	Aquatic Isopod	Dynamenella glabra																										0.03%
		Epicaridea														0.06%												
		Exosphaeroma inornata												2.90%		0.62%	1.54%				1.54%	2.13%	0.84%		11.35%	4.04%	0.56%	0.88%
		Exosphaeroma sp.																				0.03%				0.17%		
		Gnorimosphaeroma insulare											0.21%									1.58%				0.09%	0.28%	
		Gnorimosphaeroma oregonense			0.02%						0.05%			4.02%	3.37%	0.06%	0.18%			2.40%	3.96%	3.58%	1.69%	1.76%	0.19%	1.29%	3.94%	
		Gnorimosphaeroma, juv.																									0.05%	
		Idotea sp.																						0.03%				
		Idotea wosnesenskii																								0.09%	0.05%	
		Isopod, juv.					0.12%											0.09%										
		Sphaeromatidae, juv.		0.04%										0.06%									1.73%				0.79%	0.78%
		Valvifera, juv.			0.02%			0.03%																				
	Caprellidea	Caprellidae																0.09%										
	Crangonidae	Crangonidae, juv.															0.06%									0.69%		
	Cumacea	Cumella vulgaris				0.01%		0.05%									0.06%						0.06%	0.03%	0.09%	0.09%	0.14%	0.58%
	Cyclopoid	Cyclopoid																					0.02%					0.39%
	Decapod	Paguroidea, juv.																										0.02%
	Euphausiacea	Euphausiacea zoea														0.31%												
	Grapsid crab	Hemigrapsus oregonensis																		0.23%	0.29%			0.37%	0.93%	0.09%	0.05%	
	Harpacticoid	Amonardia perturbata																							0.47%			
		Amphiascus cinctus																							0.19%			
		Diosacchus spinatus														0.06%									0.37%			
		Ectinosomatidae											0.07%													0.34%		
		Harpacticoid							0.02%					0.06%			0.18%	0.09%	0.15%				0.06%				0.05%	1.52%
		Harpacticus sp.																							0.09%			
		Harpacticus sp. A													0.18%									0.07%				
		Huntemannia jadensis																	0.15%	0.06%		0.03%	0.05%			0.09%		11.10%
		Laophontidae											0.02%									0.03%				0.09%		
		Leptastacidae																								0.09%		
		Nitokra sp.											0.15%															
		Paralaophonte sp.																							0.28%			
		Parathalestris californica																			0.02%				0.19%			
		Porcellidium																						0.07%				
		Zaus sp.																							0.09%			
	Ostracoda	Ostracoda					0.06%						0.02%				0.31%			0.06%	0.04%	0.03%	0.03%	0.10%	0.09%	0.60%	0.19%	0.13%
	Tanaidacea	Leptochelia dubia																					0.03%				0.09%	
		Leptochelia savignyi					0.06%																					
Echinodermata	Dendrasteridae	Dendraster excentricus, juv.																									2.04%	2.02%
	Echinoidea	Sea urchin							0.02%																			
Foraminifera	Foraminifera	Foraminifera														0.06%			0.15%				0.02%				0.05%	0.03%
Insect, Arachnid, Collembola	Arachnid	Acari	0.90%	0.87%	0.39%	1.21%	0.69%	0.41%	0.74%	0.41%		0.06%	0.19%	0.06%		0.44%	0.62%	0.36%	0.15%							1.29%	0.14%	
		Arachnida																										0.02%
		Araneae		0.04%					0.02%																			
	Chilopoda	Chilopoda							0.04%																			
	Coleoptera	Coleoptera												0.06%														
	Collembola	Collembola			0.04%		0.06%																					
		Hypogastruridae					0.19%		0.93%					0.12%		1.43%	0.18%	0.45%	0.45%						0.28%	0.17%		
		Isotomidae	0.10%	0.04%		0.07%		0.03%	0.11%		0.05%			0.12%	0.18%		0.80%		0.15%					0.03%	0.09%	6.53%	0.05%	
		Onychiuridae							0.08%																			
		Sminthuridae										0.03%																
	Insect adult	Aphididae										0.03%												0.03%				
		Chironomidae adult		0.04%	0.02%	0.01%	0.06%	0.05%			0.05%	0.03%				0.19%									0.09%			
		Cicadellidae		0.04%																								
		Coccinellidae						0.08%	0.02%																			
		Coleoptera	0.10%														0.12%	0.18%	1.79%									
		Diptera	0.03%																									
		Empididae adult			0.10%			0.05%																				

			+12								+8									+5								
			South Ref				South Rest			North SW	South Ref				South Rest				North SW	South Ref				South Rest				North SW
Main Taxa Grouping	Secondary Taxa Grouping	Taxa	2004	2006	2008	2010	2006	2008	2010	2010	2004	2006	2008	2010	2004	2006	2008	2010	2010	2004	2006	2008	2010	2004	2006	2008	2010	2010
		Ephydridae adult			0.04%	0.06%		0.11%			0.05%					0.06%												
		Formicidae						0.03%																				
		Hydrophilidae				0.02%		0.03%	0.06%																			
		Psocoptera	0.05%			0.01%			0.02%																			
		Sphaeroceridae				0.08%	0.37%		0.25%								0.06%											
		Staphylinidae	0.08%	0.08%	0.14%	0.16%	0.50%	0.14%	0.08%	0.41%						0.44%	0.06%	0.27%	1.04%				0.02%		0.09%	0.09%		0.02%
		Sternorrhyncha						0.03%																				
	Insect larvae	Anthomyiidae larvae							0.02%																			
		Ceratopogonidae larvae	0.03%																									
		Chironomidae larvae	0.08%	0.04%		0.28%	0.19%						0.02%						0.15%	0.11%	0.02%		0.06%	0.03%		0.17%	0.05%	0.03%
		Chironomidae pupae																		0.06%			0.02%	0.03%				
		Coleoptera larvae	0.31%		0.10%	0.06%	0.25%	0.14%	0.04%	0.41%						0.44%												
		Diptera larvae	0.03%						0.11%																			
		Diptera pupae	0.03%			0.04%			0.04%	0.20%										0.06%								
		Empididae larvae	0.10%		0.08%	0.02%		0.08%			0.05%																	
		Ephydridae larvae		0.08%		0.16%	0.75%		0.23%	3.07%						0.06%	0.06%											
		Insect pupae	0.03%					0.19%																				
		Muscidae larvae					0.37%											0.09%										
		Scathophagidae larvae								0.20%																		
Mollusk	Bivalve	Bivalve, juv.			0.02%	0.01%			0.02%					0.06%			0.18%		0.15%				0.09%			0.95%	1.53%	1.08%
		Cardiidae, juv.		0.04%																								
		Clam, juv.									0.05%				0.36%	0.19%				0.17%				0.68%	0.74%			
		Mussel, juv.			0.06%	0.01%	0.25%	0.16%	0.04%		0.20%	0.03%	0.12%		1.60%	0.31%	0.55%			0.51%	0.31%	0.07%		0.34%	1.21%	1.55%		
		Mytilus edulis				0.01%			0.06%			0.03%	0.05%	0.18%			0.18%	0.54%	2.99%	0.17%	0.04%	0.41%	0.14%		0.19%	1.89%	3.52%	0.14%
		Rochefortia tumida																					0.03%				0.42%	
		Tellinidae																									0.05%	
	Gastropod	Alvania compacta																					0.05%					0.02%
		Fartulum sp.																									0.05%	
		Gastropoda															0.06%	0.09%	0.15%	0.06%		0.03%	0.06%			0.34%		0.08%
		Lacuna sp.							0.02%																			
		Littorina scutulata																			0.02%							
		Littorina scutulata egg case																0.09%				0.03%					0.05%	0.03%
		Lottiidae				0.01%			0.02%				0.02%	0.12%						0.06%			0.02%				0.14%	0.11%
		Nutricola lordi																									0.19%	0.03%
		Sacoglossa																					0.02%					
Nematoda	Nematoda	Nematoda	1.05%	8.48%	0.48%	1.02%	4.81%	4.53%	3.95%	22.70%	4.03%	8.16%	9.00%	12.24%	22.91%	26.62%	18.33%	55.34%	36.42%	3.37%	0.40%	3.30%	2.24%	4.92%	16.56%	20.36%	24.09%	66.14%
Nemertea/ Turbellaria	Nemertea	Nemertea		4.01%	0.25%	0.16%	0.25%	0.03%	0.55%	0.82%		2.20%	5.20%	6.56%		0.75%	0.31%	1.36%	8.21%		0.04%	0.14%	5.83%		2.23%	3.26%	8.66%	0.80%
	Turbellaria	Turbellaria	0.03%	1.67%		0.32%		0.05%	0.02%	0.20%	12.58%	19.11%	12.42%	0.12%	1.24%	2.12%	2.58%	0.09%		0.17%		1.69%	1.05%	3.83%	0.09%	6.44%	0.28%	0.02%
Oligochaeta	Oligochaeta	Oligochaeta	21.28%	58.25%	20.80%	10.74%	37.14%	24.14%	35.89%	18.20%	74.14%	58.93%	61.75%	32.58%	68.03%	63.28%	68.33%	37.50%	36.87%	68.61%	34.55%	46.57%	28.49%	73.27%	35.35%	32.56%	5.97%	1.61%
		Oligochaete eggcase							0.08%																			
Phoronida	Phoronida	Phoronida																						0.03%			0.09%	0.09%
		Phoronopsis harmeri																									1.44%	
Polychaete	Archiannelida	Archiannelida																	7.31%									
		Nerilla sp.																								0.09%		
		Protodriloides chaetifer										7.93%	1.11%	0.06%		0.69%	2.64%	0.27%	0.30%			0.10%	0.09%			0.86%		
	Capitellidae	Capitellidae			1.01%		0.06%					0.03%				0.06%			0.30%		0.26%				0.65%		3.33%	1.93%
	Chrysopetalidae	Paleanotus bellis																									0.09%	
		Paleanotus occidentale															0.06%									0.09%		
	Glyceridae	Glycera americana																										0.02%
		Glyceridae																						0.85%	0.09%	0.17%	9.12%	0.17%
		Hemipodia simplex												1.83%		0.12%	0.18%	0.09%	0.90%			0.07%	0.02%	1.22%	24.84%	11.08%	8.52%	4.27%
	Goniadidae	Goniada sp.																										0.02%
		Goniadidae																										0.75%
	Hesionidae	Hesionidae, juv.											0.02%	0.89%			0.25%	0.09%	0.15%				0.05%			0.60%	0.37%	0.06%
		Micropodarke dubia																									0.05%	
	Nereidae	Neanthes limnicola									0.20%	0.15%								0.06%	0.02%	0.03%	0.02%				0.05%	
		Nereidae		0.08%	0.02%	0.04%		0.03%	0.11%		0.94%	0.44%	0.65%	0.06%	0.18%		0.06%			0.74%	1.78%	0.14%	1.34%	0.20%	0.47%	0.34%	2.32%	0.19%
		Nereis vexillosa											0.03%	0.06%						0.06%	0.04%	0.10%	0.02%					
		Platynereis bicanaliculata				0.01%	0.06%																0.12%				0.05%	0.03%
	Opheliidae	Armandia brevis												0.35%										0.07%		0.09%	0.19%	1.63%
	Orbiniidae	Orbiniidae																										0.47%
		Scoloplos sp.																										0.03%
	Oweniidae	Oweniidae, juv.																									13.29%	0.02%
	Phyllodocidae	Eteone californica				0.03%			0.06%								0.12%						0.03%					0.09%
		Eteone sp.																						0.03%			0.14%	0.02%
		Eulalia sp.																					0.02%				0.09%	
		Phyllodoce longipes																						0.03%				
		Phyllodoce sp.																								0.17%		
		Phyllodocidae											0.02%	0.12%			0.06%	0.27%						0.03%			0.14%	0.06%
	Pisionidae	Pisionidae																0.54%										
	Polychaete, unk.	Glycerid/goniadid																										0.14%

			+12								+8									+5								
			South Ref				South Rest			North SW	South Ref				South Rest				North SW	South Ref				South Rest				North SW
Main Taxa Grouping	Secondary Taxa Grouping	Taxa	2004	2006	2008	2010	2006	2008	2010	2010	2004	2006	2008	2010	2004	2006	2008	2010	2010	2004	2006	2008	2010	2004	2006	2008	2010	2010
		Polychaete				0.03%								0.18%	0.53%				0.15%	0.11%			0.06%	0.75%		0.09%	0.14%	0.13%
	Polynoidae	Harmothoinae, juv																										0.03%
		Malmgreniella macginitiei												0.06%														
		Polynoidae												0.12%													0.51%	0.09%
	Sabellidae	Sabellidae																						0.03%				
	Spionidae	Boccardia sp.												0.06%														
		Dipolydora brachycephala																										0.14%
		Prionospio lighti												0.06%														0.11%
		Pseudopolydora kempi																						0.31%				
		Pygospio elegans															0.12%						0.03%				0.05%	0.02%
		Pygospio sp.															0.06%											
		Rhynchospio gluteae																0.09%	0.15%								0.28%	0.44%
		Scolelepis sp.																										0.03%
		Spionidae												0.06%	0.18%		0.25%		0.30%	0.06%	0.02%		0.08%	0.10%	0.28%	0.09%	0.32%	0.23%
	Syllidae	Syllidae																	0.30%					0.03%			0.23%	0.02%
		Syllis elongata																								0.09%		
Terrestrial amphipod/isopod	Terrestrial Amphipod	Megalorchestia pugettensis	0.39%	5.19%	0.97%	0.02%	2.87%	0.22%	0.02%	30.47%		0.29%				0.62%	0.06%											
		Talitridae spp.				0.19%			0.02%																			
		Talitridae, juv.	55.75%	19.72%	67.18%	69.09%	31.52%	58.77%	36.92%	22.90%	0.40%	0.91%	0.26%	4.26%		0.56%	1.35%	1.54%	0.45%		0.02%	0.03%	0.12%				0.19%	0.05%
		Traskorchestia georgiana	7.06%	0.49%	2.44%	7.86%	2.87%	2.62%	7.39%											0.06%								
		Traskorchestia traskiana	12.17%	0.83%	5.78%	8.14%	15.67%	7.65%	11.67%		0.05%	0.56%	0.07%	0.18%		0.37%		0.09%		0.06%								
	Terrestrial Isopod	Detonella papillicornis	0.41%			0.13%		0.16%	0.27%																			
		Oniscoidea, juv.					0.81%	0.03%	0.02%							0.06%												