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Salmon Bay Natural Area Pre-Restoration Monitoring 2004

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Key Words

Shoreline restoration, Puget Sound, benthic invertebrates, intertidal zone, shoreline modifications, overwater structure, juvenile salmon, Salmon Bay, Chinook salmon, snorkel surveys

Executive Summary

The Salmon Bay Natural Area (SBNA) is a planned restoration project which will protect and enhance the last largely undeveloped, wooded shoreline on Seattle's Salmon Bay. This is an important location in the migration of endangered populations of juvenile Chinook salmon, since it is directly downstream from the Hiram M. Chittenden Locks. The overall objectives for restoring the shoreline habitat are to improve riparian and upland vegetation, remove the existing overwater structure and associated rip-rap, and enhance intertidal habitat in order to improve rearing opportunities for juvenile salmonids.

Fieldwork was conducted during Spring and Summer 2004 at the overwater site and an adjacent reference site, sampling benthic invertebrates, terrestrial insects, fish (via snorkel surveys), and sediment grain size. The overwater site consisted of a recreational house with a deck and an attached floating dock, while the reference site was a stretch of adjacent beach. Two different tidal levels were included in the sampling design, pertaining to the high tidal elevation of the overwater structure at +8 Mean Lower Low Water (MLLW) and the low tidal elevation of the floating dock at +1 MLLW.

All measurements of total invertebrate densities showed significantly higher numbers at the reference site as compared to the overwater site. This includes benthic macroinvertebrates, harpacticoid copepods, and terrestrial insects, all important juvenile salmonid prey items. The reference site also had a greater number of taxa with significantly higher densities. Taxa richness of benthic invertebrates was not limited by the overwater structure, as number of taxa were similar at the two sites and even greater at the low tidal elevation overwater structure site for benthic macroinvertebrates. Taxa richness of insects was much higher at the reference site.

Differences in the benthic invertebrate communities are probably due to shading by the overwater structure and compacting of the benthos by the floating dock at low tides when the dock rests directly on the substrate. Sediment grain size seemingly has a minimal effect, as the overwater site had only slightly coarser sediments. It is clear from

insect sampling that the overwater structure blocks the production and input of riparian resources to the aquatic zone.

Fish densities were not that significantly different between the two sites. Although overall densities were higher at the reference site than the overwater site at high tidal elevations, the only significant taxa difference was greater numbers of shiner perch at the reference site for both tidal levels. These shiner perch were often observed to be associated with coarse woody debris in the water column. Although juvenile Chinook salmon densities were relatively greater at the reference site, these differences were not significant. However, the only salmonid observed at high tidal elevations at the overwater site were large cutthroat trout, a potential predator on other juvenile salmonids, especially chum. The overwater structure appears to also affect salmonid movements, as juvenile salmonids were never observed underneath either the overwater structure or the floating dock.

The current study represents a solid baseline for comparison with future post-restoration monitoring. We recommend utilizing the same sampling techniques for post-restoration monitoring, with an ideal timeline of 1, 2, 3, 5, and 8 years post-restoration. Possible directions for expansion of monitoring include another year of pre-restoration fish surveys, and the addition of fish-diet sampling post-restoration. Utilization of all of these techniques during both pre- and post-restoration will allow us to adequately assess the success of the SBNA restoration effort.

Introduction

Ocean-type juvenile Chinook salmon (*Oncorhynchus tshawytscha*) in the Pacific Northwest utilize estuarine and nearshore habitats early in their outmigration and rearing period (Simenstad et al. 1982). In Puget Sound, different habitat types along the shoreline can affect Chinook and other fish abundance, distribution, and behavior patterns (Toft et al. 2003). This is also true for invertebrates, which are an important salmon prey component (Sobocinski 2003, Toft et al. 2003, Toft 2005, Brennan et al. 2004). Because of the importance of shorelines to salmon and their prey, measuring the affects of specific shoreline types on fish and invertebrates can provide useful information about how to improve degraded shorelines. This will help in designing appropriate restoration of Puget Sound nearshore habitats and ultimately increase the shoreline's ecological function.

In this study, we examine the Salmon Bay Natural Area (SBNA), which will protect and enhance the last wooded shoreline on Seattle's Salmon Bay. This is an important location in the migration of endangered populations of Chinook, since it is directly downstream from the fish passage ladder at the Hiram M. Chittenden Locks, which links the Lake Washington Ship Canal to Puget Sound. It is important to attempt to restore this area towards more natural shoreline conditions, given the effects of shoreline conditions on refuge and rearing abilities of juvenile salmonids and the current state of the Salmon Bay area having approximately 75% of the shoreline retained with artificial structures (Fig. 1; Toft et al. 2003). For these reasons, the community group Groundswell NW, the Cascade Land Conservancy, and the City of Seattle have worked together to acquire five shoreline parcels. The parcels will undergo restoration and installation of public outreach facilities with interpretive signage, to provide habitat for salmon and ecological information for people in an urban context.

The main goals of the project include: (1) protecting, enhancing, and restoring estuarine shoreline habitat in Seattle's Salmon Bay Waterway for salmonid species, and (2) educating the public about the importance of restoring habitat for salmon and other aquatic resources in urbanized areas. This report focuses on monitoring the before-restoration biological attributes related to juvenile salmonid utilization of the site.

The overall objectives of the habitat restoration at the SBNA site are to restore and maintain native riparian vegetation in order to enhance juvenile salmonid food production and refuge functions, and restore intertidal habitat to improve rearing opportunities for juvenile salmonids. Riparian and intertidal habitat restoration and enhancement is scheduled to occur in 2006, and will consist of removal of riprap, cement blocks, and overwater structures, as well as planting of native riparian vegetation.

Based on current understanding of nearshore aquatic systems, it is believed that certain linkages between shoreline habitat and juvenile salmon will be improved by the restoration. Riparian vegetation provides habitat and detritus as a food supply for invertebrates, which are in turn preyed upon by juvenile fish, and also provides refuge from predators. Fine substrates provide invertebrate prey habitat while not providing hiding/ambush opportunities for predatory fish. Shorelines with retaining structures can cause coarsening of sediments, due to increased wave energy (Sobocinski 2003). It is also thought that removing overwater structures will be beneficial to juvenile salmon because they prevent light penetration to the substrate (Simenstad et al. 1999) reducing primary productivity and some types of invertebrate production, may provide refuge habitat for larger fish that could prey on juvenile salmon (Tabor et al. 2004), may affect movement patterns of juvenile salmon if they avoid dark areas underneath structures, and cause habitat disturbance when floating structures rest on the substrate during low tides.

Based on these relationships, we monitored the following biological attributes at the site before habitat restoration and enhancement: (1) invertebrate assemblages, (2) juvenile salmonid and other fish assemblages, and (3) sediment grain size. Data from this monitoring will serve as a baseline for comparison after overwater structures and shoreline armoring are removed and riparian habitat is enhanced.

Material and Methods

Sampling was conducted using standard methodologies that have been used extensively in the region, in four different categories: (1) benthic invertebrates, (2) terrestrial insects, (3) juvenile salmon, and (4) sediment grain size (Simenstad et al. 1991; Sobocinski 2003, Toft et al. 2003). All sampling compared habitats both at the overwater structure and an adjacent less disturbed reference area, immediately east of the structure (Fig. 2). The study design included a sample size of seven for all invertebrate samples, and three for sediment grain size samples. Fieldwork was conducted during six sampling events (4/22, 5/24, 6/7, 6/14, 6/21, 7/6/2004), spanning the juvenile salmonid outmigration period of chum and Chinook.

The overwater structure and attached floating dock were located at two different tidal levels (approximately +1 MLLW for the floating dock and +8 for the overwater structure; Fig. 3). Therefore, the study design included sampling both underneath the floating dock and underneath the overwater structure, with comparable sampling at the adjacent reference site. The floating dock contacted the substrate at low tides, adding a physical disturbance effect.

Benthic Invertebrates

Benthic macroinvertebrates were sampled using a 0.0024 m^2 core taken to a depth of 10 cm; meiofauna were sampled using a 0.0002 m^2 core (Fig. 4). The cores were fixed in 10% buffered formalin in the field and dyed with rose-bengal to aid in taxa identification, and preserved in 70% isopropanol in the laboratory. Samples were separated into macrofauna and meiofauna fractions based on sieve sizes of 0.5 mm and 0.106 mm, respectively. Macrofauna were processed at both tidal levels (overwater structure and floating dock), while meiofauna were processed only for the lower tidal level (meiofauna prey taxa are rare at higher tidal elevations; Simenstad et al. 1991). Macrofauna characterize the larger taxa that are typically consumed by juvenile Chinook salmon (the main focus of the sampling design), while harpacticoid copepods in the meiofauna are consumed primarily by juvenile chum salmon (predominantly at lower tidal levels; Brennan et al. 2004, Simenstad et al. in review).

Terrestrial Insects

Fallout traps were used to determine insect contribution from the riparian zone to shallow water habitat. These traps consisted of 55 x 38 cm plastic bins, filled with approximately 4 cm of water with a small amount of dishwashing soap added to reduce surface tension. Traps were placed along the front of the overwater structure and at the base of the riparian zone in the adjacent reference site (Figs. 5, 6). The traps were deployed for 3 days, after which insects were collected and preserved in 70% isopropanol. Density and assemblage structure of insects in the fallout trap samples will allow estimates of (1) insect compositions at the overwater structure versus the reference site, and (2) baseline numbers of juvenile salmon prey and other insect types at the site before habitat restoration and enhancement.

Juvenile Salmon

Presence and behavior of juvenile salmonids and other fish were monitored using snorkel surveys. Transects were conducted around the edges of the overwater structure (30-m) and around the floating dock (37-m), as well as at the adjacent reference site. Snorkel surveys were centered around high slack tide to assure proximity to shoreline habitats. Successful transects depended on horizontal secchi-disk measurements exceeding 2.5-m for sufficient visibility.

Numbers of fish were standardized by transect length and water visibility (number/[transect length x horizontal secchi depth]). Additional data that was collected during snorkeling transects included:

- Fish identification and number
- Approximate fish length (2.5-cm increments)
- Water column position of fish (surface, mid-water, bottom)
- Fish behavior (unaffected, swimming away, fleeing, feeding, not moving, schooling, hiding)
- Specific location and movement if next to an overwater structure
- Water depths
- Distance from shore

Sediment Sizes

Sediment grain-size samples were collected using the same core as for the benthic macroinvertebrates. Samples were collected at both tidal levels and overwater/reference sites during one sampling event in June. Samples were frozen and processed in the laboratory. They were first mechanically shaken through nested #10, #18, #35, #60, #120, and #230 sieves, and then oven dried at 60°C and weighed (Fig. 7).

Data Analysis

Data was entered into Microsoft Excel, and densities analyzed with univariate ANOVA tests (alpha = 0.05) using the statistical program S-Plus. Densities of benthic macroinvertebrates were also analyzed with multivariate nonmetric multidimensional scaling (NMDS) ordination using the statistical program PC-ORD (McCune and Grace 2002), as these samples covered both tidal stages and sites.

Results

Benthic Macroinvertebrates

The high elevation reference site had significantly greater total average densities than the high elevation overwater structure site (Fig. 8). The high elevation reference site also had greater densities of the amphipod *Corophium insidiosum*, non-*Corophium* amphipods (specifically *Eogammarus confervicolus*), insect larvae (Chironomidae larvae), Nematoda, Oligochaeta, Tanaidacea (*Sinelobus stanfordii*), and the polychaete worms Phyllodocidae and Spionidae. The high elevation overwater structure site had significantly greater densities of Turbellaria and the polychaete worm *Manayunkia aestuarina*. Taxa richness (numbers of species present) was about equal (Tables 1, 2).

The low elevation reference site had significantly greater total average densities than the low elevation overwater structure site (Fig. 8). The low elevation reference site additionally had greater densities of *Corophium* amphipods (specifically *C. acherusicum*, *C. insidiosum*, *C. salmonis*, and juvenile *Corophium*), non-*Corophium* amphipods (*Eogammarus confervicolus* and Ampithoe), insect larvae (Chironomidae larvae), Oligochaeta, Tanaidacea (*Sinelobus stanfordii*), Anthozoa, Turbellaria, and the polychaete worm Phyllodocidae. The low elevation overwater structure site had significantly greater densities of *Corophium spinicorne*, *Gnorimosphaeroma* spp. isopods, and the polychaete worm Nerillidae. Cumaceans (*Cumella vulgaris*) were relatively abundant, but at similar densities. Taxa richness was higher at the low elevation overwater structure site (Tables 1, 2).

Multivariate analysis of the log-transformed data using NMDS ordination further illustrated the differences between the reference and overwater sites, as well as tidal elevations (Fig. 9). The final stress for a 2-dimensional solution was 15.3, with a instability of 0.00353 ("quite satisfactory" according to the guidelines of McCune and Grace 2002). Together, both axes explained 89% of the variation, 44.3% by axis 1 and 44.7% by axis 2. Both high and low sites of reference and overwater grouped separately, with low elevations more separate than high elevations. The two tidal elevations also grouped differently from each other.

<u>Benthic Meiofauna (Harpacticoid Copepods)</u>

The low elevation reference site had significantly greater total average densities than the low elevation overwater structure site (Fig. 10). The low elevation reference site also had greater densities of *Harpacticus* sp. A, *Harpacticus* spp., *Heterolaophonte longisetigera*, *Heteroloaphonte discophora*, *Huntemannia jadensis*, *Mesochra* sp., *Nitokra* sp., *Parastenhelia spinosa*, and *Amphiascus* sp. The low elevation overwater structure site had greater densities of *Amphiascus minutus* and Ectinosomatidae. Taxa richness was exactly the same at the two sites (Tables 1, 3).

<u>Terrestrial Insects</u>

All significant differences were for higher densities at the reference site (Fig. 11). The high elevation reference site had greater overall densities, as well as for Coleoptera, Diptera, Hemiptera, Homoptera, Hymenoptera, insect larvae, Psocoptera, Microcoryphia, Araneae (spiders), terrestrial isopods, Thysanoptera, Acarina, and Collembola. Taxa richness was much higher at the reference site (Tables 1, 4).

<u>Juvenile Salmon and Other Fishes</u>

Snorkel surveys were done mainly on morning high tides (average time 7:09), except the survey on a week with afternoon high tides (17:18). Average high tide was +9.3 MLLW. Average water salinities and temperature were 18.6 ppt/14.5 °C at the surface, and 24.3 ppt/13.3 °C bottom.

Forty-eight snorkel transects were conducted; twelve at each site, two per sampling date. Fish identifications sometimes had to be lumped into general categories, due to complications arising from water turbidity and short time of viewing. The high elevation reference site had significantly greater total average densities and greater densities of shiner perch than the high elevation overwater structure site (Fig. 12). The low elevation reference site had greater densities of shiner perch than the low elevation overwater structure site. High sand lance densities at the low elevation overwater structure site were due to the presence of two large schools, and were not significantly different than at the low elevation reference site. Although salmon densities were greatest at the low elevation reference site (Fig. 13), densities were not significantly different.

Average salmon forklength estimates (cm) were Chinook 11.25, Chinook/coho 15, coho 17.5, chum 8.75, juvenile salmonid unknown 5, cutthroat trout 25, and adult sockeye 90. Salmonid behaviors were similar between sites, typically either swimming away, schooling, or unaffected (Table 5). Water column positions of salmonids were also similar between sites, with most observations being in the middle of the water column (Table 5). Exceptions were observations at the bottom for one sighting of coho and cutthroat trout at the high elevation reference site, two sightings of cutthroat trout at the bottom at the high elevation overwater structure site, and one sighting of chum at the surface at the low elevation overwater structure site.

The majority of fish observed were not located underneath the overwater structure (high elevation) or the floating dock (low elevation; Fig. 14), typically being at least a meter away from the edge (Table 6). The only species observed underneath a structure were sculpin, dungeness crab, shiner perch, and stickleback. The four sand lance sightings were all at the upstream edge of the overwater structure and dock (towards the reference site).

Sediment Sizes

Sediment grain sizes were fairly similar between overwater and reference, with overwater having slightly coarser sediments than reference (Fig. 15). Sediment sizes were coarser at high elevations than at low elevations.

Discussion

The Salmon Bay Natural Area resides within an important location for the rearing of juvenile salmonids leaving Lake Washington and migrating toward Puget Sound. Although it is a small site, it is directly downstream from the Chittenden Locks where juvenile salmon are first exposed to marine water. This transition zone where salmon physiologically adapt to salt water is truncated and highly modified compared to a natural estuary. Although the ship canal and locks complex is an artificial construction, it should benefit juvenile salmon to create relatively natural habitat and the functions that accompany it.

All measurements of total invertebrate densities showed greater numbers at the reference site as compared to the overwater site. This includes benthic macroinvertebrates, harpacticoid copepods, and terrestrial insects, all of which contain important juvenile salmonid prey items. Total densities of fish were greater at the high intertidal reference site but not at the low intertidal, perhaps indicating a more significant influence of the overwater structure on fish populations at higher tidal levels.

Benthic invertebrates did not appear to be limited in the number of taxa able to occupy the overwater and reference habitats, as taxa richness was similar between these two sites for benthic macroinvertebrates and harpacticoid copepods, being even greater for benthic macroinvertebrates at the low elevation overwater structure site. However, the reference site had a greater number of taxa with significantly higher densities. This is probably due to shading caused by the overwater structure and shading and compacting of the benthos caused by the floating dock at low tides, as illustrated by lower densities and differing groupings in multivariate analysis. Sediment grain size probably had minimal effects on the invertebrate assemblages, as the overwater site had only slightly coarser sediments than the reference site.

Lower taxa richness and densities of terrestrial insects suggest that the overwater structure blocks the production and input of riparian salmonid prey resources to the aquatic zone. Although insects (especially Diptera) were observed to be attracted to the lights associated with the overwater structure, none of these insects had significantly greater densities than at the reference site. It is also possible that the attraction of the lights high above the water keeps insects from the water surface, where they could be available as fish prey.

Fish densities showed minimal differences between the two sites. Although overall densities were greater at the high elevation reference site as compared to the high elevation overwater structure site, the only specific taxa difference was greater numbers of shiner perch at the reference site for both tidal levels. Shiner perch were often observed in association with coarse woody debris in the water column.

Although snorkel observations of juvenile Chinook salmon were greater at the reference site, these differences were not significant. However, the only salmonid observed at the high elevation overwater structure site were large cutthroat trout (25 cm average forklength), a potential predator on other juvenile salmonids, especially chum (Jauquet 2002, Brennan et al. 2004). Other fish at the high elevation overwater structure site were mostly small sculpin, crabs, and sticklebacks that are not known to prey on juvenile salmonids. The overwater structures appear to also affect salmonid movements, as juvenile salmonids were never observed underneath either the overwater structure or the floating dock, nor were sand lance and herring. Sculpin, dungeness crab, shiner perch, and stickleback were the only fish that were sighted underneath an overwater structure.

A study conducted in 2001 utilized the SBNA reference site (Simenstad et al., in review), including beach seine and juvenile salmonid diet sampling. It was found that juvenile salmon in Shilshole Bay fed extensively on freshwater zooplankton (mostly the cladocerans *Daphnia* spp.) exported from Lake Washington and the Ship Canal. These allochthonous sources of pelagic organisms that are entrained in the freshwater surface lens from discharge at the Locks are not typical prey items for juvenile salmon in estuaries and nearshore waters of Puget Sound (Brennan et al. 2004). So, although we found that typical juvenile salmonid prey items were much more abundant at the SBNA reference site as compared to the overwater site, they may not be highly utilized in this area at times when easily obtainable *Daphnia* are abundant. However, as found in our study, a complicating factor could also be lower abundances and availability of typical estuarine prey items due to shoreline modifications, causing a decrease in the amount of estuarine prey that is available as a resource. Additionally, fish caught in a beach seine could have been feeding in a larger geographic area than just the site they were caught at, especially apparent in such a “truncated” estuary where they could have even been feeding in freshwater habitats above the Locks.

Prey items from the 2001 study besides freshwater zooplankton were illustrative of more typical estuarine prey items (Simenstad et al., in review), including harpacticoid copepods in the diets of juvenile chum, decapod larvae in the diets of hatchery Chinook, as well as nereid worms. Wild Chinook did prey some on insects, mostly Diptera, Psocoptera, Aphididae, and Formicidae. Again, in a typical estuary we would expect less feeding purely on planktonic organisms (especially from freshwater sources) and more influence of benthic/epibenthic (Nereid worms) and terrestrial riparian sources (insects;

Toft et al. 2003; Brennan et al. 2004). Juvenile salmonid habitat can be enhanced by increasing both the production and availability of these estuarine prey resources.

The current study represents a baseline for comparison with future post-restoration monitoring. If the opportunity exists, incorporating another year of pre-restoration fish monitoring with snorkel surveys would be beneficial, because fish abundances and distributions are patchy when measured on a scale as small as the SBNA site. We recommend utilizing the same sampling techniques for post-restoration monitoring, with an ideal timeline of 1, 2, 3, 5, and 8 years post-restoration to adequately assess progression of site functions. It would also be helpful to incorporate some fish-diet sampling after restoration is complete, to look for evidence that post-restoration changes in abundance and availability of insects and invertebrates produced at the site are reflected in salmon diets.

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Figure 1. Historic photo of Salmon Bay.

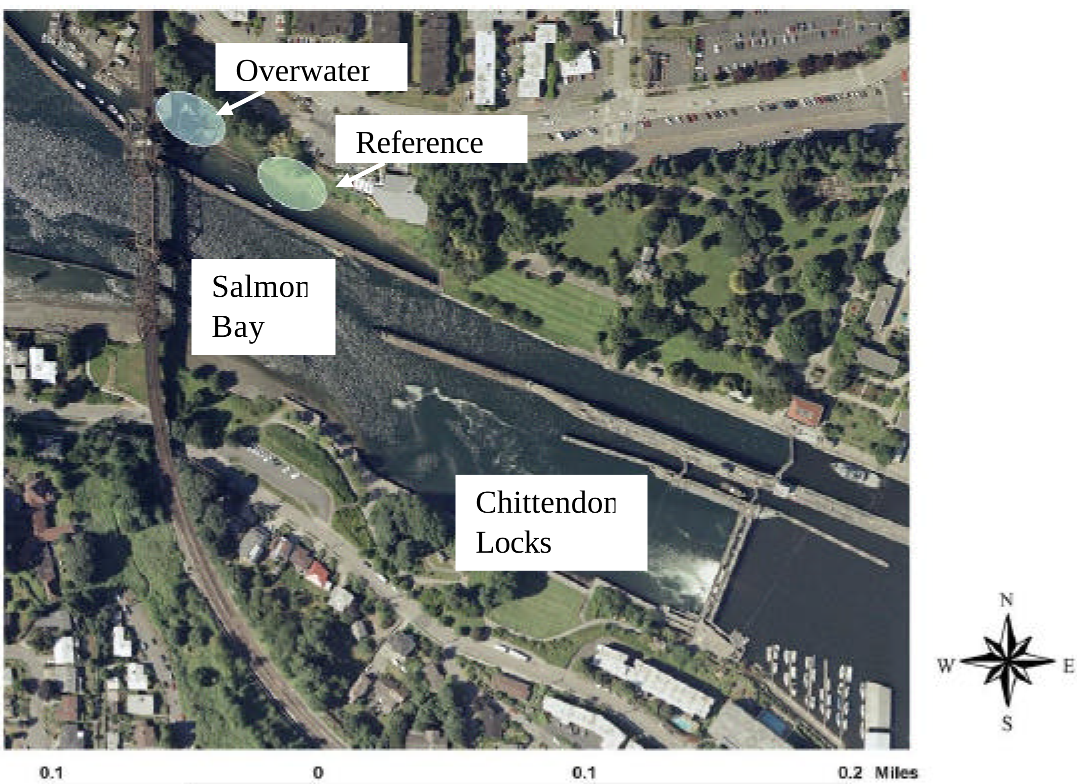

Figure 2. Location of the overwater and reference sites.

Figure 3. The Salmon Bay Natural Area study site at low tide, showing the overwater structure and floating dock.

Figure 4. Benthic cores at the floating dock were taken underneath a middle section.

Figure 5. Insect traps at the overwater structure.

Figure 6. Insect traps at the reference site.

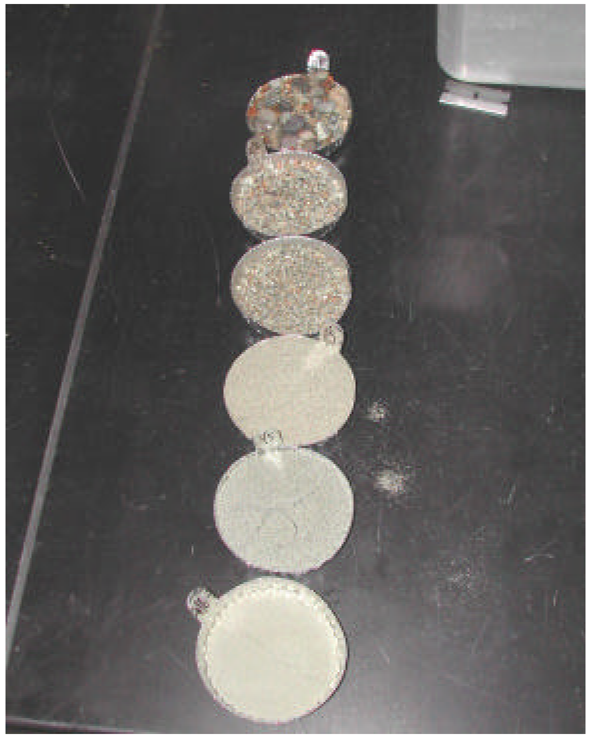

Figure 7. A sediment sample fractionated into different grain sizes.

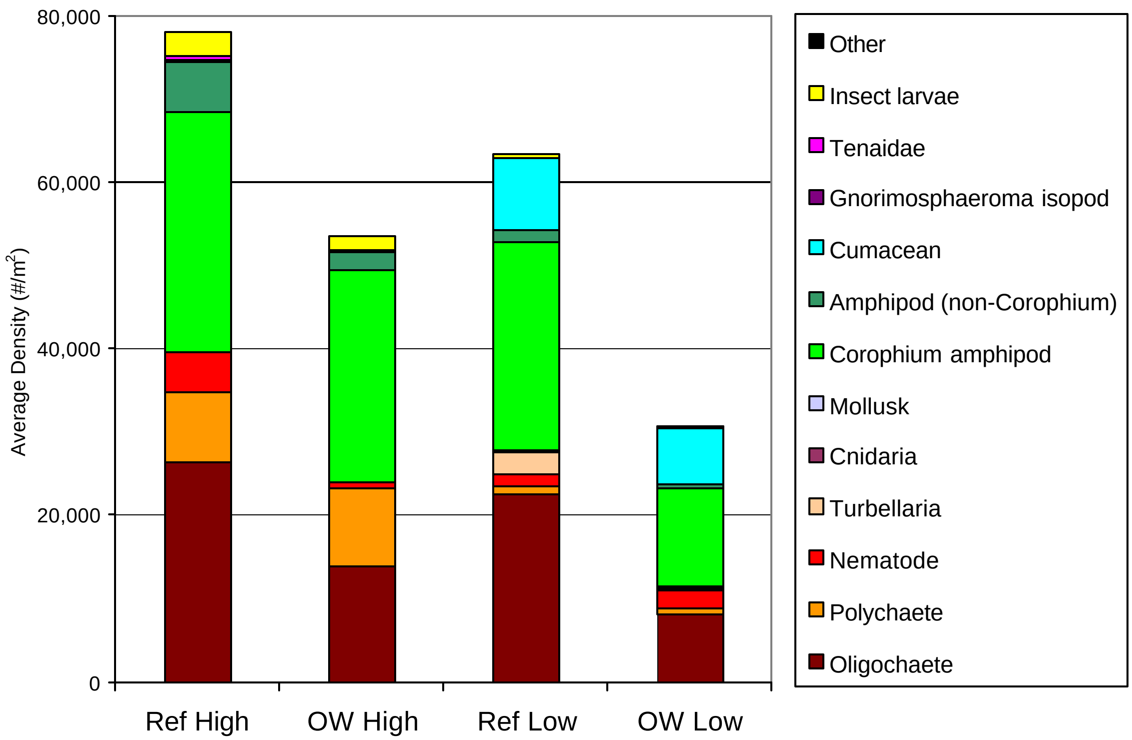

Figure 8. Total average densities of benthic macroinvertebrates. Ref and OW refer to Reference and Overwater sites, respectively. High and Low are tidal elevations.

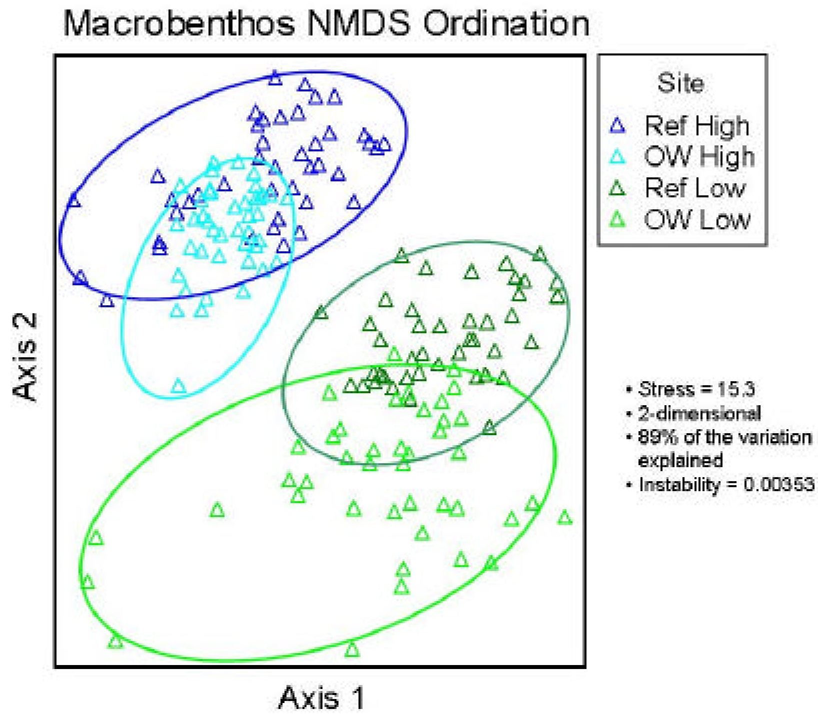

Figure 9. Multivariate analysis of the benthic macroinvertebrate data, using nonmetric multidimensional scaling. Each triangle represents an individual sample.

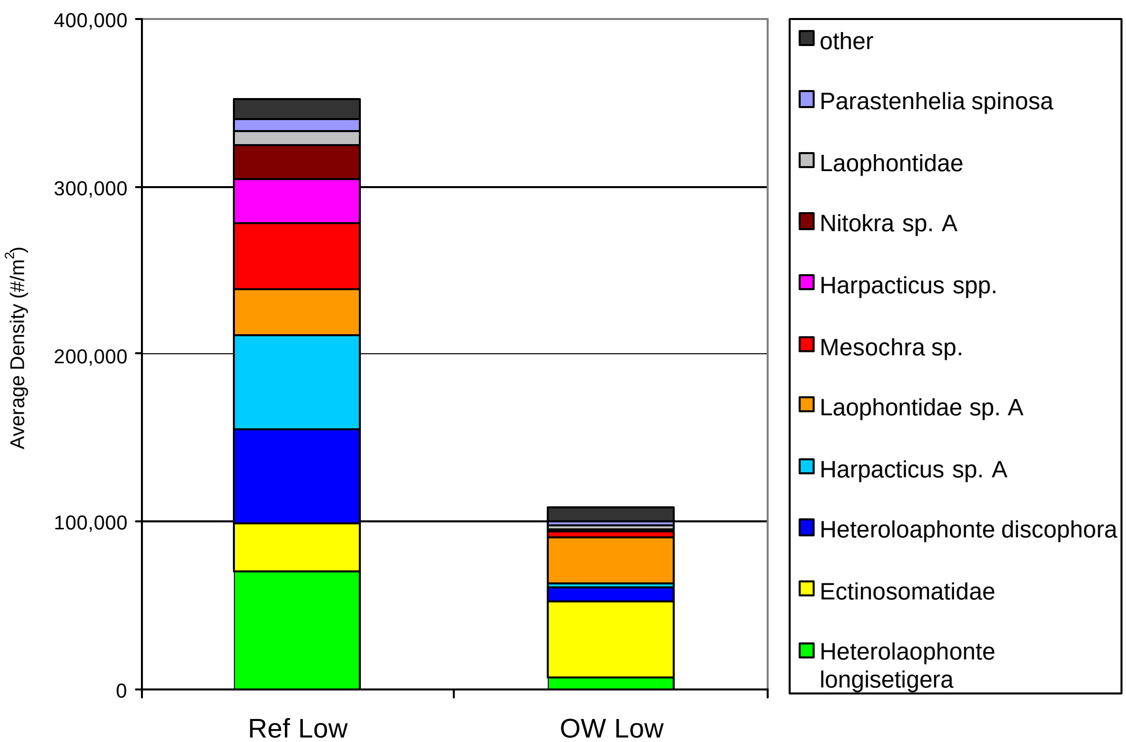

Figure 10. Total average densities of harpacticoid copepods from meiofauna samples.

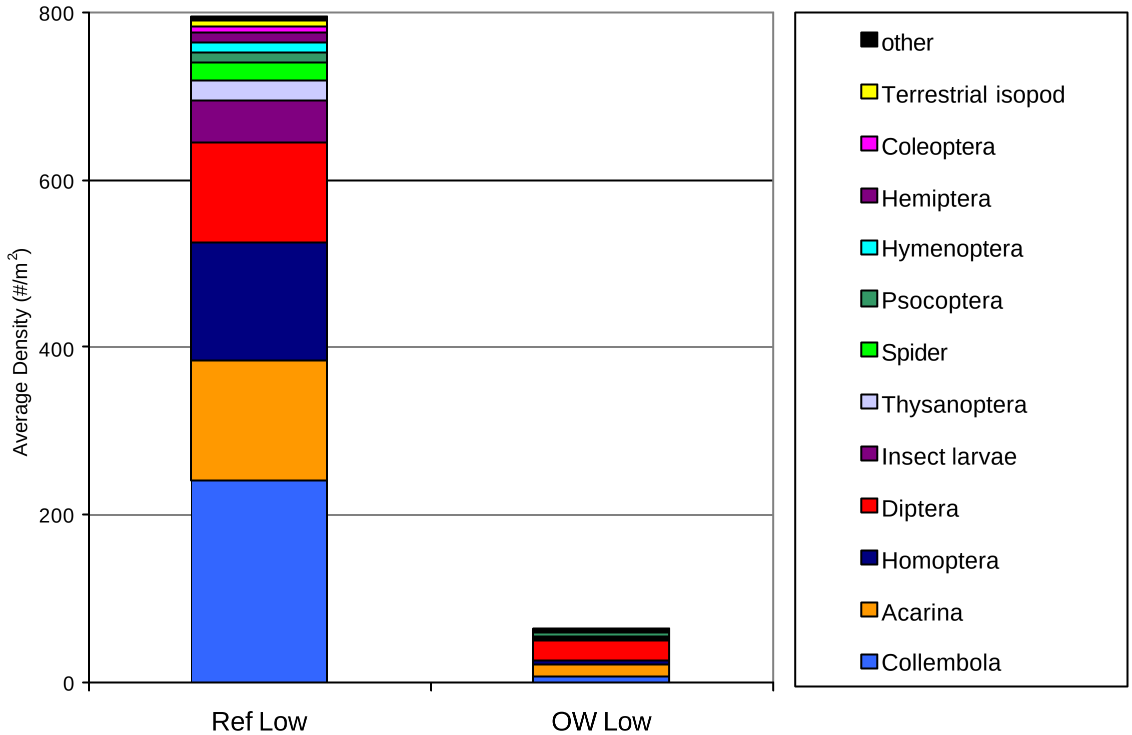

Figure 11. Total average densities of insects and other taxa from fall-out traps.

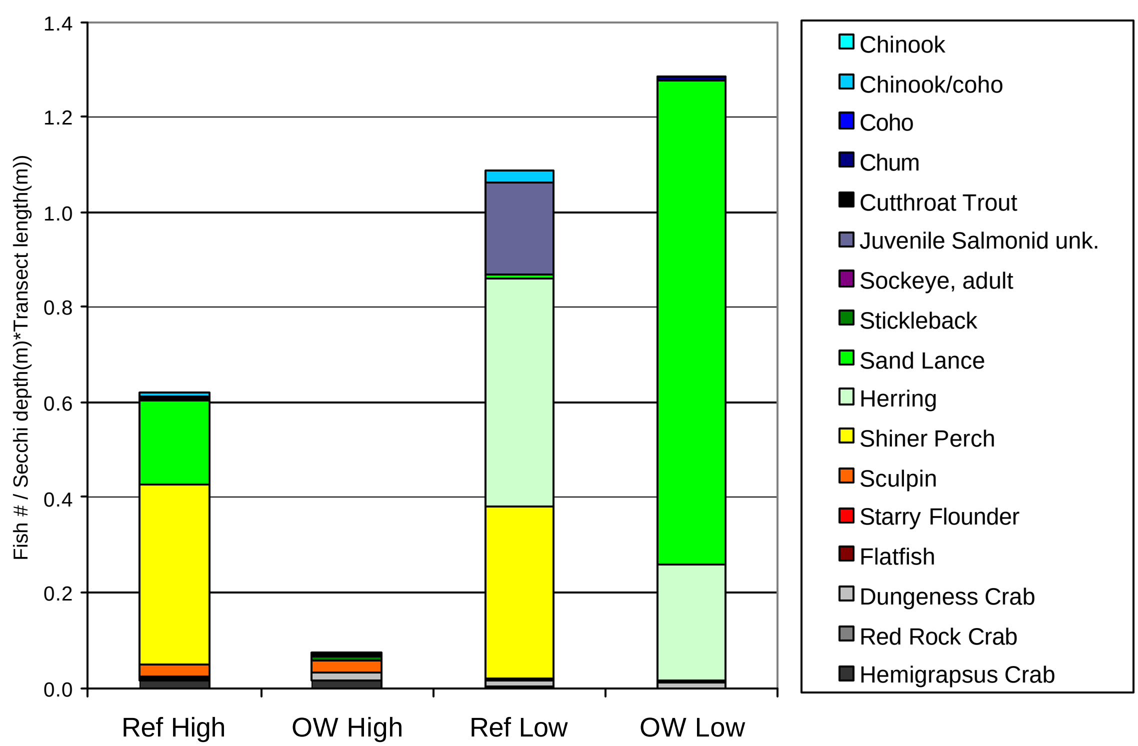

Figure 12. Total average densities of fish and crabs from snorkel transects.

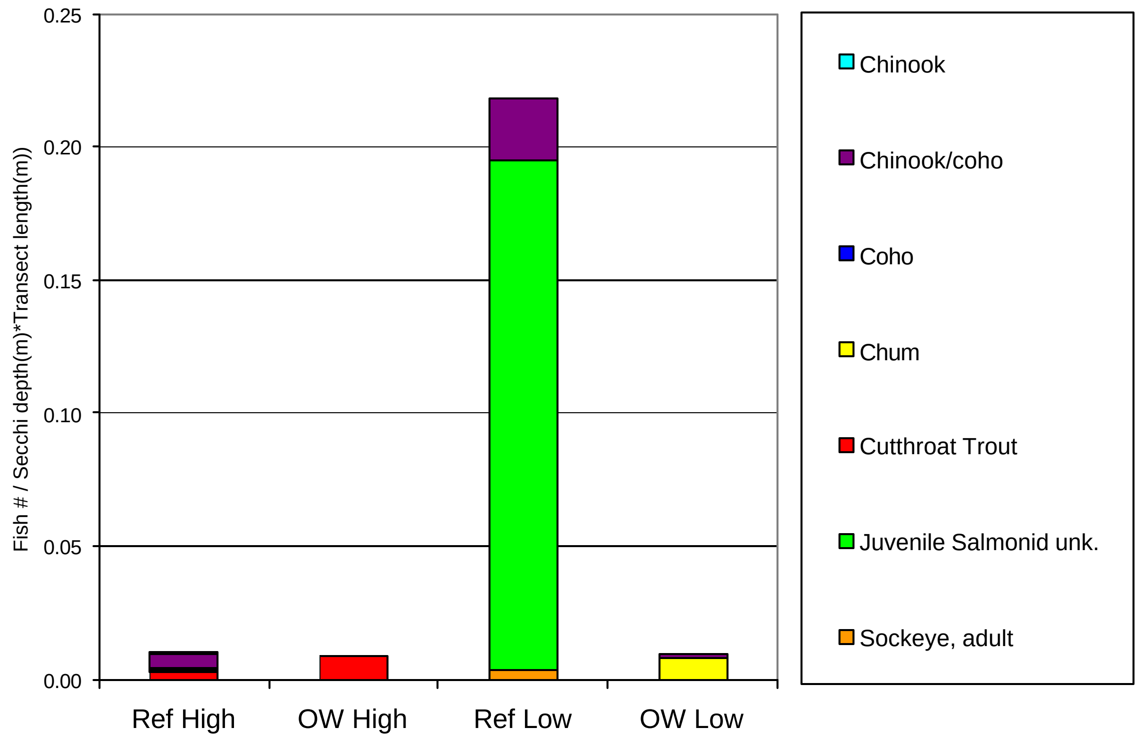

Figure 13. Total average densities of salmonids from snorkel transects.

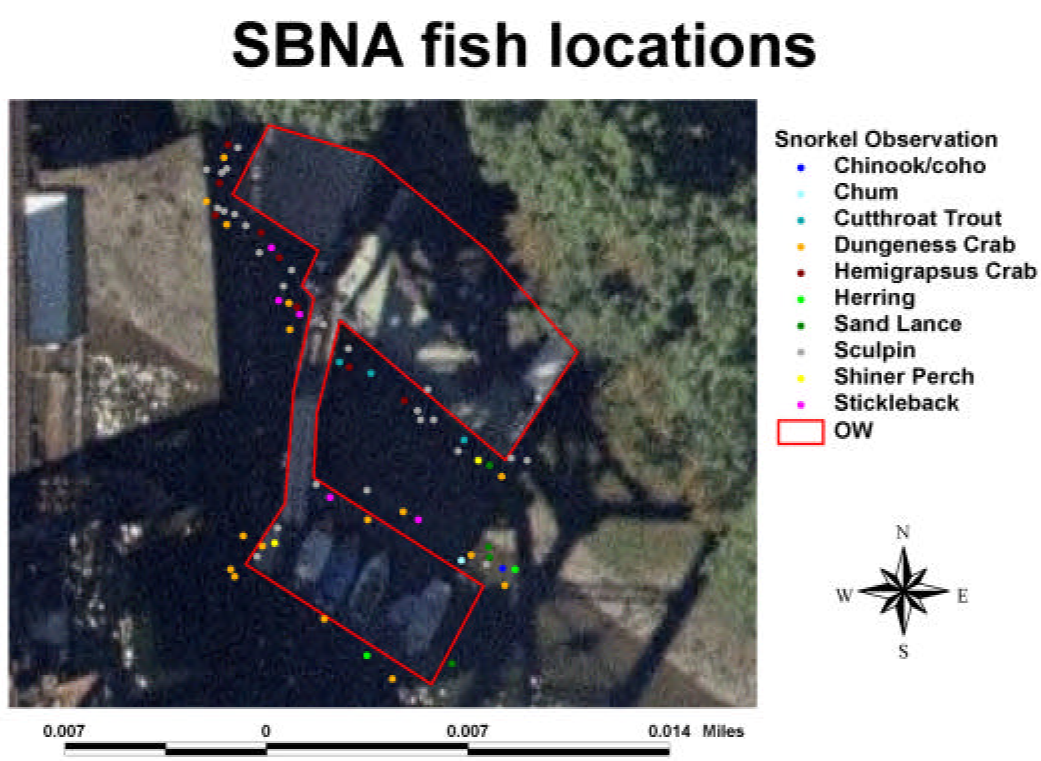

Figure 14. GIS Locations of fish observations from snorkel surveys around the overwater structure.

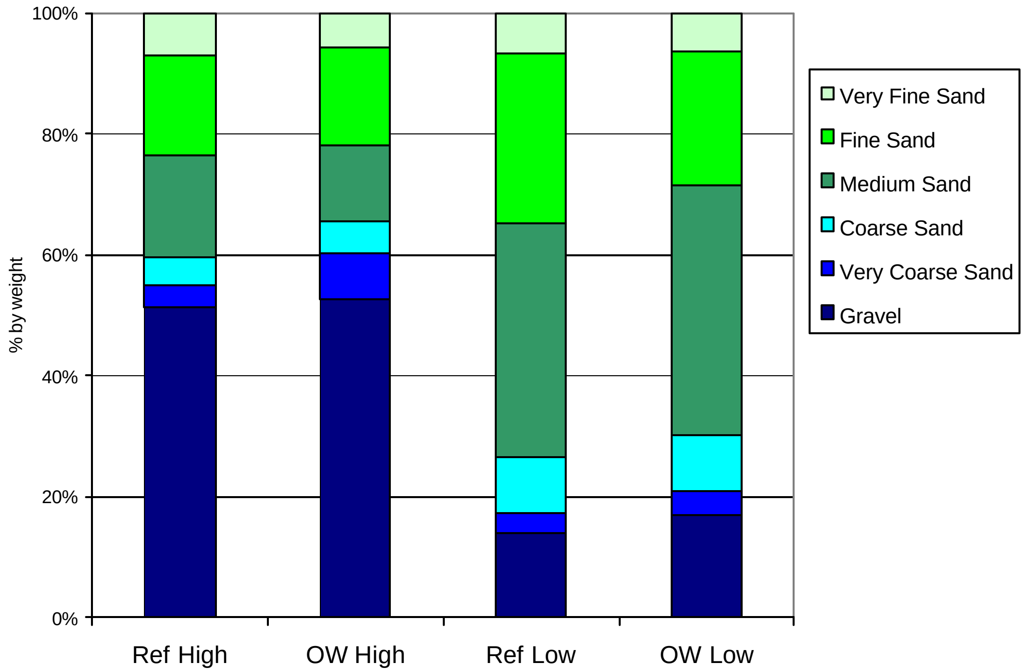

Figure 15. Average sediment grain-sizes.

Table 1. Taxa Richness of invertebrate samples.

Site	Benthic Macroinvertebrates	Harpacticoid Copepods (Meiofauna)	Terrestrial Insects
Ref High	26	–	70
OW High	25	–	48
Ref Low	28	30	–
OW Low	36	30	–

Table 2. Average densities of benthic macroinvertebrates (#/m^2).

Taxa Groupings	Taxa	Ref High	OW High	Ref Low	OW Low
Insect Larvae	Chironomidae larvae	2,917	1,657	407	20
	Chironomidae pupae	20	40	10	0
	Diptera larvae	0	30	0	0
	Dolichopodidae larvae	0	20	0	0
	Insect larvae	20	0	0	0
	Insect pupae	10	0	0	0
Tenaidae	*Sinelobus stanfordii*	556	50	99	20
Gnorimosphaeroma isopod	*Gnorimosphaeroma* juv.	0	0	0	179
	Gnorimosphaeroma oregonense	50	20	10	10
Cumacean	*Cumella vulgaris*	10	10	8,591	6,756
Amphipod (Non-Corophium)	Amphipod, juv.	367	308	30	119
	Ampithoe	327	40	179	0
	Eogammarus confervicolus	5,456	1,825	1,131	446
Corophium amphipod	*Corophium acherusicum*	0	0	79	10
	Corophium insidiosum	744	20	1,190	377
	Corophium salmonis	79	0	4,474	675
	Corophium spinicorne	11,319	9,435	119	694
	Corophium, juv.	16,667	15,952	19,246	10,040
Harpacticoid copepod	*Harpacticus* sp. A	734	1,161	0	0
	Dactylopusia	0	10	0	0
	Huntemannia jadensis	69	10	0	0
	Laophontidae	50	30	0	0
Mollusk	Clam, juv.	0	0	0	10
	Bivalve, juv.	0	0	0	10
	Mussel, juv.	0	10	0	0
	Macoma balthica	0	10	79	30
	Mya arenaria	0	0	10	10
Cnidaria	Anthozoa	0	0	109	10
	Hydroid	0	0	10	40
Turbellaria	Turbellaria	20	109	2,728	327
Nematode	Nematode	4,861	605	1,379	2,093
Polychaete	Capitellidae	0	0	198	218
	Goniadidae	0	0	30	60
	Glyceridae	0	0	40	10
	Manayunkia aestuarina	238	5,198	0	20
	Manayunkia speciosa	0	20	20	30
	Nereidae	30	0	50	40
	Nereidae, juv.	30	0	0	30
	Nerillidae	0	0	0	89
	Opheliidae	0	0	0	109
	Phyllodocidae	218	0	417	69
	Polychaete, juv.	0	0	0	10
	Polychaete, unk.	30	0	89	60
	Spionidae	7,798	4,216	60	20
Oligochaete	Oligochaete	26,300	13,849	22,510	8,016
other	*Cancer magister*, juv.	0	0	0	10
	Collembola - Isotomidae	0	0	0	10

Table 3. Average densities of meiofauna (#/m^2).

Taxa	Ref Low	OW Low
Ameiridae	476	238
Amphiascoides sp.	119	595
Amphiascopsis cinctus	0	238
Amphiascus minutus	0	476
Amphiascus sp.	1,786	119
Dactylopusia crassipes	119	0
Dactylopusia vulgaris	0	119
Diacyclops thomasi	238	238
Diosaccus spinatus	119	0
Ectinosomatidae	29,286	46,548
Halicyclops sp.	119	0
Harpacticoida	952	1,071
Harpacticus sp. A	57,143	2,381
Harpacticus spp.	26,190	0
Heterolaophonte hamondi	0	476
Heterolaophonte longisetigera	69,881	6,071
Heteroloaphonte discophora	55,238	7,976
Huntemannia jadensis	3,690	357
Laophontidae	8,571	2,024
Laophontidae 2	238	119
Laophontidae 3	0	119
Laophontidae sp. A	27,262	27,143
Leimia vaga	238	714
Mesochra sp.	39,762	3,333
Nitokra sp.	952	238
Nitokra sp. A	19,643	2,024
Paradactylopodia sp.	119	238
Paralaophonte sp.	238	119
Parastenhelia hornelli	119	0
Parastenhelia spinosa	6,905	1,905
Pardactylopodia sp.	119	357
Pseudonychocamptus sp.	357	1,190
Schizopera knabeni	1,429	1,190
Tachidius triangularis	119	0
Tisbe sp.	952	357
Typhlamphiascus sp.	0	119

Table 4. Average densities of terrestrial insects (#/m^2).

Taxa Groupings	Taxa	Ref High	OW High
Terrestrial isopod	*Littorophiloscia richardsonae*	2.4	0
	Porcellio scaber	4.3	0
Coleoptera	Coleoptera	8.1	0.8
Hemiptera	Hemiptera	4.7	0.9
	Hemiptera nymph	5.4	1.1
Hymenoptera	Hymenoptera	9.8	0.9
	Formicidae	1.7	0.1
	Ichneumonidae	0.2	0
	Tenthredinidae	2.1	0
Psocoptera	Pscoptera	4.0	0.3
	Pscoptera nymph	6.5	2.2
	Pseudocaecillidae	1.4	0.2
	Psocidae	0.3	0
Spider	Araneae	21.6	1.6
Thysanoptera	Thysanoptera	6.9	3.2
	Thysanoptera nymph	16.2	0.2
Insect Larvae	Chironomidae larvae	4.1	0
	Coleoptera larvae	24.5	0.5
	Insect larvae	5.8	0
	Lepidoptera larvae	0.5	0
	Diptera larvae	16.5	0
Diptera	Anisopodidae	0.3	0
	Anthomyiidae	1.8	0
	Cecidomyiidae	48.2	2.8
	Ceratopogonidae	5.7	1.6
	Chironomidae	21.3	9.8
	Chloropidae	5.7	0.1
	Cicadellidae nymph	2.3	0
	Clusiidae	0	0.1
	Dixidae	0.3	0
	Dolichopodidae	0.7	0.7
	Empididae	0.5	0
	Ephydridae	0.2	0.1
	Heleomyzidae	0.1	0
	Lauxaniidae	1.0	0.1
	Muscidae	3.1	1.6
	Mycetophilidae	1.5	0.3
	Phoridae	5.8	0.8

* continued on next page

Table 4 cont. Average densities of terrestrial insects (#/m^2).

Taxa Groupings	Taxa	Ref High	OW High
Diptera cont.	Psychodidae	5.6	1.8
	Rhagionidae	0.2	0.1
	Sarcophagidae	0	0.2
	Scatopsidae	0.5	0.3
	Sciaridae	11.2	2.5
	Sphaeroceridae	0.1	0.1
	Tachinidae	1.0	0.7
	Tephritidae	0.1	0
	Tethinidae	0.1	0
	Therevidae	0.1	0.1
	Tipulidae	2.5	0.2
	Trixoscelididae	0.2	0
	Xylophagidae	0.1	0
Homoptera	Aphididae	19.7	2.2
	Aphid nymph	98.1	0.3
	Delphacidae	0.5	0
	Homoptera	1.7	1.0
	Homoptera nymph	13.8	0.5
	Cicadellidae	6.0	0.2
	Psyllidae	0.1	0.2
Acarina	Acarina	144.3	15.2
Collembola	Isotomidae	229.9	4.2
	Sminthuridae	10.3	0.9
other	Bristletail	1.9	0
	Lepidoptera	0.5	1.0
	Mollusc (slug)	0.7	0.1
	Neuroptera	0.1	0.3
	Larca granulata	0.1	0
	Pseudoscorpion	0.2	0
	Insect unknown	0.2	0
	Orthoptera	0.2	0
	Isoptera	0	0.1
	Zoraptera	0.2	0
	Odonata	0	0.1
	Plecoptera	0.1	0
	Siphonaptera	0.1	0
	Gastropod (snail)	0.1	0

Table 5. Water column position and behavior of salmonid observations.

Site	Fish Species	Water column position: Bottom	Water column position: Middle	Water column position: Surface	Behavior: Swimming Away	Behavior: Schooling	Behavior: Schooling, Fleeing	Behavior: Schooling, Swimming Away	Behavior: Unaffected
Ref High	Chinook		1						1
	Chinook/coho		3		3				
	Chum		1		1				
	Coho	1	1						2
	Cutthroat Trout	1	1		1				1
OW High	Cutthroat Trout	2	1		2				1
Ref Low	Chinook/coho		4		2	2			
	Sockeye, adult		1		1				
	Juvenile Salmonid, unk		1				1		
OW Low	Chinook/coho		1		1				
	Chum			1				1	

Table 6. Location of fish observations from the edge of overwater structures.

Site	Fish Species	Location of fish from structure (m): 0-1	Location of fish from structure (m): 0+1	Location of fish from structure (m): 1+
OW High (House)	Cutthroat Trout		1	2
	Dungeness Crab			6
	Hemigrapsus			8
	Sand Lance			1
	Sculpin	2		18
	Shiner Perch			1
	Stickleback			3
OW Low (Floating Dock)	Chinook/coho			1
	Chum		1	
	Dungeness Crab	3		7
	Herring		1	1
	Sand Lance		1	2
	Sculpin	3		2
	Shiner Perch	1		
	Stickleback	1		1