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Baseline Characterization and Monitoring of the OSU Mobile Ocean Test Berth Site

Benthic Habitat Characteristics and Organisms on the Central Oregon Coast

Prepared by
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On behalf of Oregon Wave Energy Trust

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Baseline Characterization and Monitoring of Oregon State University's Ocean Test Facility Site

Principle Investigator: Sarah Henkel in collaboration with Lorenzo Ciannelli and Jack Barth

This project was carried out collaboratively by Oregon State University (OSU) scientists and involved participation by Oregon Department of Fisheries and Wildlife and NOAA Northwest Fisheries Science Center scientists. The goal of this project was baseline characterization via observations and sample collection of the habitat and biological assemblages present at the future site of the Northwest National Marine Renewable Energy Center Ocean Test Facility near Newport, OR. Specifically, CTD casts, box core and beam trawl collections, and video observations were conducted at the site from spring 2010 to fall 2011. These collections and observations help characterize the baseline variability in habitat and species characteristics across seasons over two years. Below we summarize overall findings. In the following document we report on the spatial and temporal variability of the habitat features and biological assemblages. Finally, we review our participation to date in disseminating these results and outline plans for post-installation monitoring of the Test Facility site.

OVERALL FINDINGS

- Two distinct sediment types were found in the area proposed for the Oregon State University Northwest National Marine Renewable Energy Center Ocean Test Facility near Newport, OR: silty sand at approximately 30 m, and potentially shallower, and nearly pure sand at 40 m and deeper.
- Distinct infaunal invertebrate assemblages were found in the silty sand that were different from the deeper, sand stations.
- Distinct infaunal invertebrates assemblages were found north and south of Yaquina Head at the deeper stations.
- Fish species present in the area varied with season: flatfish dominated the summer catch, poacher abundances increased in the fall, and smelt abundances were high in winter.
- Mysid shrimp and *Crangon* shrimp were highly abundant and likely form the basis of the food web in this nearshore zone as opposed to the krill-supported food web further offshore.
- Videographic observations are challenging in this sedimentary habitat; however, it is a more effective tool for sampling large invertebrate species such as crabs, sea stars, and sea pens than the trawl.

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BACKGROUND

Through the United States Department of Energy (USDOE)-funded Northwest National Marine Renewable Energy Center (NNMREC), Oregon State University (OSU) is designing an Ocean Test Facility to serve as the nation's first integrated marine energy testing facility. Although NNMREC has funding to design and build the first test platform, conduct associated engineering research, and monitor for potential environmental effects post-installation, funding had not been obtained for the field observations and analyses necessary for baseline environmental characterization at the site. Chapter 5 of the Oregon Territorial Sea Plan (TSP) requires offshore energy facility applicants to provide a resource inventory and effects evaluation regarding possible impacts on marine resources, use of the territorial sea, and coastal communities. Baseline 'before installation' sampling to the Ocean Test Facility site to characterize the habitat and biological resources in the area may facilitate and expedite industry use of the testing facility and provide a potential model for site characterization and monitoring to be used by industry partners. An important OSU contribution to the advancement of wave energy in Oregon is to inform the development of industry-wide standard environmental characterization and monitoring protocols. This project leverages previous baseline studies conducted by OWET (Ortega-Ortiz and Mate 2008; Özkan-Haller et al. 2009; Terrill et al. 2010) and ongoing work that NNMREC is conducting with other federal agencies. Knowledge gained about ocean conditions, biological species assemblages, and bird, whale, and crab migration patterns along the Oregon coast based on this Ocean Test Facility site characterization, other projects funded by OWET, industry (e.g. those for the OPT Settlement Agreement), and other studies conducted by OSU in conjunction with state and federal agencies will lead to a more comprehensive understanding of key features of the Oregon territorial sea. Information leaned from this project can be used to inform the permitting process for offshore renewable energy by providing baseline information on the dynamics of Oregon living marine resources, allowing potential developers to focus on site-specific evaluation needs.

INTRODUCTION

The Ocean Test Facility Site

The Ocean Test Facility will be located to the northwest of Yaquina Head off Newport, Oregon, in approximately 50 m water. The footprint of the testing area will be no more than 1 square mile. At the time of the proposal for this project, the exact deployment location was not yet known. However, a general area for evaluation had been determined in consultation with local fishermen. This evaluation area was 2 miles wide by 3 miles long, spanned Yaquina Head, and encompassed depths of 30 to 50 meters. The bottom type is unconsolidated sediment, which is preferred for installation of anchors for the testing platform and commercial buoys under test.

Sedimentary (soft bottom) habitat is the predominant habitat on the continental shelf and slope throughout the Pacific Northwest. Although these sandy or muddy habitats are sometimes considered an ocean 'desert', they are dynamic and full of life. Organisms living in and on the sediment have to contend with significant changes to their habitat as a result of wave action and ocean currents, making them generally resilient to disturbance. This habitat encompasses two main community types: infaunal (living in the sediment) and epifaunal (living on top of the sediment). Infaunal invertebrates modify the sediment and structure the habitat, making them key species despite their individual small sizes. Since sediment grain size often determines which animals can live in the sediment, changes to sediment movement due to ocean energy extraction or alterations of flow and sediment scour around large device arrays and associated anchors may affect the distribution of infaunal soft-bottom organisms.

Typically waves have strong influences on bottom currents at depths of 50 m and less (Largier et al. 2008); thus, the reduction of wave energy inshore of the installation could affect bottom currents and sediment distribution. Furthermore, the effects of the reduction in wave energy or scour around anchors may go beyond the spatial extent of an installation. Sand adjacent to an artificial reef installed in La Jolla, California, at 13 m water depth was scoured to a depth of 20 to 40 cm as far as 15 m from the reef (Davis et al. 1982). Grain size analysis of sediment collected along a transect from Oil Platform "Eva" off Huntington Beach, California, in 18 m water depth indicated coarse sand to 20 m from the platform with very fine sand beyond (Wolfson et al. 1979). Studies of offshore platforms in the Mediterranean indicated that benthic infaunal assemblages varied with distance from the platform, but the spatial extents of these differences varied with depth of the platform (90 m versus 30 m; Terlizzi et al. 2008) and over time (Manoukian 2010). In some cases, the project footprint surrounded by a buffer of 3 km may be considered the "impact area" (Vanerman and Stienen 2009).

While sedimentary habitats from the territorial sea to the edges of offshore rocky banks in the Pacific Northwest are most likely to be developed for offshore renewable energy, this portion of the seafloor is the least characterized. Many studies have been conducted in southern California (Fauchald and Jones 1977, 1979, SAIC 1986, Hyland et al. 1991, Allen et al. 2007), but studies from well-characterized southern California sites are not necessarily transferrable to this region.

Sampling Sedimentary Habitat and Species

In order to collect baseline information about sediment dynamics that may occur in the vicinity of wave energy capture installation, seasonal and inter-annual dynamics in the composition and distribution of the local sediment should be determined so that potential effects can be evaluated in the context of natural variability. Techniques that traditionally have been used to study and classify the benthic environment include sediment-profile cameras, side-scan sonar, sediment grabs and cores, acoustic sub-bottom profiling, and acoustic backscatter (Rhoads, Muromoto, and Ward 1994). Side-scan sonar, sub-bottom profiling, and acoustic back-scatter provide continuous broad areal maps of the bottom sediment types while sediment-profile cameras and sediment sampling devices provide descriptions of the benthic environment and sediment characteristics at points on the seafloor. Grabs and cores collect sediment that can be used for a variety of tests to determine sediment characteristics including grain size, density, porosity, redox, and total organic carbon. Effects monitoring methods would be similar baseline sampling protocols. However, broad areal surveys of the actual project area likely will not be possible post-installation due to the presence of the devices. Sediment collection and grain size analysis varying distances and directions from the project location will indicate whether the project has had an effect on sediment dynamics.

To evaluate potential effects on benthic invertebrates and fishes in the project area, information about their distribution, habitat associations, and food habits should be collected, and the degree of temporal and spatial variability in species or assemblages of interest needs to be characterized before project-related changes can be evaluated. Fishes and invertebrates may be observed using different visual survey methods or collected using trawls or grabs. These three methods are briefly reviewed below:

Visual Surveys: Epibenthic fish and invertebrate presence, density, size, and temporal distribution can be ascertained using visual survey methods (Somerton & Glendhill 2005). Specific methods include SCUBA or diver-operated video transects (Martin and Lowe 2010), towed video transects using sled-mounted cameras (Sheenan et al. 2010), manned-submersibles (Yoklavich & O'Connell 2008) and ROV transects (Pacunski et al. 2008).

Bottom Trawls: Bottom trawling using beam trawls or otter/shrimp trawls can be effective to inventory epibenthic fish and invertebrates. The 2 m beam trawl is routinely employed for the collection of epifaunal samples from a variety of sediment types and is designed to sample at and just above the surface of the seabed. It performs reliably on soft and coarse sediment; although whether or not quantities of individuals are sampled reliably with this equipment is still under debate (Callaway et al. 2003). Its small size makes it easy to deploy and usually results in the collection of a manageable sample size (Ware & Kenny 2011). For each tow, an average towing speed of 1.5 knots should be maintained for 5 to 10 minutes, usually depending on the density of organisms.

Grabs: Box corers, van Veen, Ponar, and other types of grabs can be used for sampling infaunal organisms. The U.S. Environmental Protection Agency (EPA) initiated the Environmental Monitoring and Assessment Program (EMAP) in 1990 to develop, test, and validate environmental monitoring methods for sampling benthic macrofaunal invertebrates (U.S. EPA 1990). Originally the EMAP protocol required 3 to 5 replicate samples per station (a number commonly seen in the literature). However, studies have shown that a single sample per station is sufficient (Summers et al. 1992; Macauley et al. 1993); thus the EMAP protocol has been modified and now replicates are optional (U.S. EPA 2001). Analysis of the cost-effectiveness of benthic sampling conducted through the EMAP program found that using a smaller sampler (0.01 m^2 versus 0.1 m^2) and a larger mesh size (1.0 mm versus 0.5 mm) is the least costly and was effective at describing taxonomic composition and abundance. To maximize cost efficiency and minimize small scale end point variability in future comparative studies, they recommend taking one 0.1 m^2 benthic macrofaunal sample at each station (which may be subsampled if desired) and sieving through 1 mm mesh (Ferraro et al. 2006). Box corers and van Veen grabs are two commonly used 0.1m^2 collection devices. Beukema (1974) tested the efficiency in sampling macrofaunal benthos of the 0.2 m^2 van Veen grab compared with a Reineck 0.06 m^2 box sampler. Densities obtained from the grabs equaled those from the box corer only in the species living exclusively in the top 5 cm of the sediment; thus the box corer was more effective at sampling deeper dwelling organisms.

The broadest spatial study of benthic infaunal communities on the US west coast was conduced by the Environmental Protection Agency (EPA). The EPA National Coastal Assessment (NCA; the coastal component of the nationwide Environmental Monitoring and Assessment Program – EMAP) has traditionally assessed embayments and estuaries; however, one west-coast shelf assessment was conducted in 2003. Sampling for the west-coast shelf assessment was conducted in 20 to 126 m water depth using a 0.1 m^2 van Veen grab, and organisms were sieved through 1 mm mesh. (Nelson et al. 2008). However, few samples (7 of 50) were actually taken in the Oregon Territorial Sea and analysis of distinct biological communities within regions and the habitat features driving differences were not pursued. Similarly, the National Marine Fisheries Service routinely samples the groundfish community via fisheries independent trawl surveys conducted by the Fishery Resource Analysis and Monitoring Division. However, depth strata are shallow (55-182 m), middle (183-549 m), and deep (550-1,280 m), so they also are not sampling in the depth ranges where the Ocean Test Facility will be installed (30 – 50 m). Thus, these surveys could not serve as adequate baseline for characterizing the habitat and organisms found at the test berth site. The US Army Corps of Engineers has sampled the Yaquina Bay dredge disposal sites periodically from 1986 to 2000 using a box corer and again in 2008 using a 0.1 m^2 Young modified Van Veen grab sampler and Otter trawl. Future work will including comparing our results to the findings of these surveys. However, the dredge stations have inadequate temporal replication for the questions addressed by our project.

METHODS

Site selection

Because the location of the future test site was not known prior to the start of sampling, sample stations were established on a regular grid. This was done to ensure that, post-installation, there would be sampling stations at regular, increasing distances away from the installation site. In May 2010, preliminary visual surveys of the bottom type were made using a 'flying camera sled'. These surveys confirmed the presence of a small reef directly off Yaquina Head in 40 m water. The surveys also confirmed the absence of hard bottom to the NW of Yaquina Head in 50-60 m water. Thus to evenly distribute the sampling and avoid hard bottom areas, twelve stations were established with two transects north of Yaquina Head, two transects south of the head, and stations at approximately 30, 40, and 50 m on each of the four transects: a-e (Figure 1).

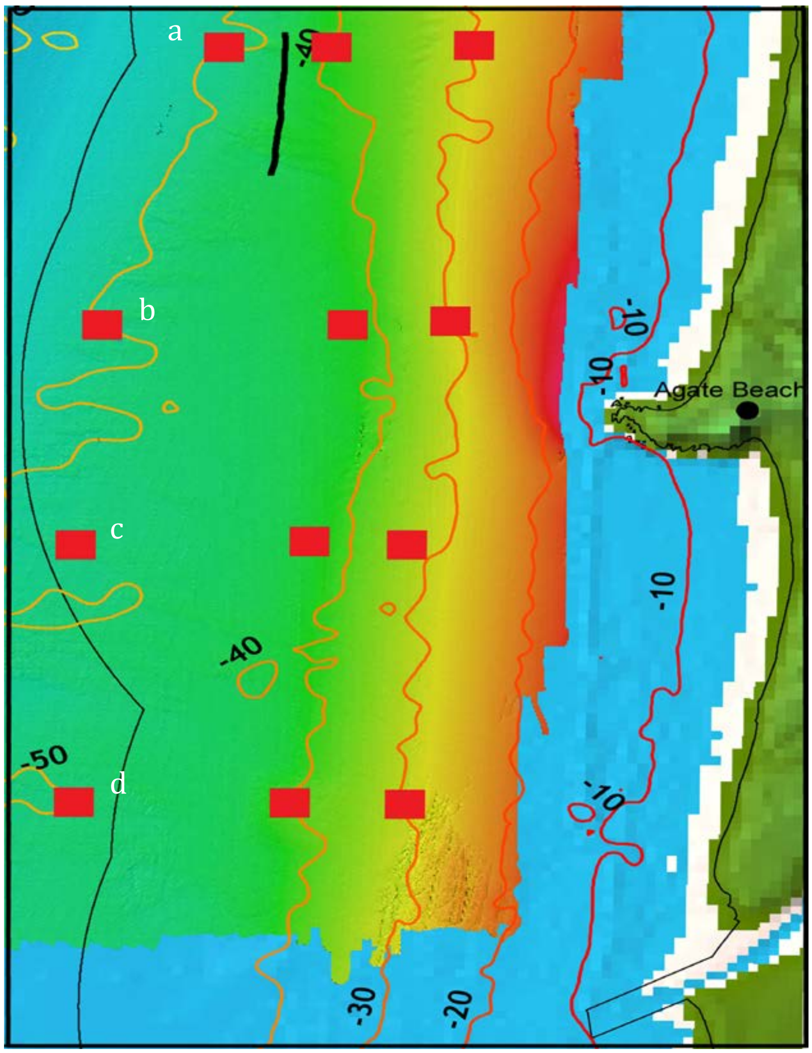

Figure 1: Twelve sampling stations off Newport, Oregon, near the future OSU Ocean Test facility. Transects are labeled a – d, north to south.

Box Coring

Infaunal invertebrates and sediment for grain size and total organic carbon samples were collected using a modified Gray-O'Hare 0.1 m^2 box core (Figure 2). Two grabs were taken at each of the 12 stations. These two grabs were not used as replicates for each station but rather were used to investigate fine scale spatial variability in the samples. Upon landing the box corer on the boat, a sub-sample of sediment was taken from the undisturbed top layer of the collected sample. The contents of the core were emptied from the corer, and second sub-sample of sediment was taken from the middle of the sample. The remaining sediment was sieved onboard through a 1.0 mm screen in order to collect all organisms greater than 1 mm. Collected organisms were preserved in 5 % buffered formalin. A total of seven box core sampling trips were made from June 2010 to October 2011 (Table 1).

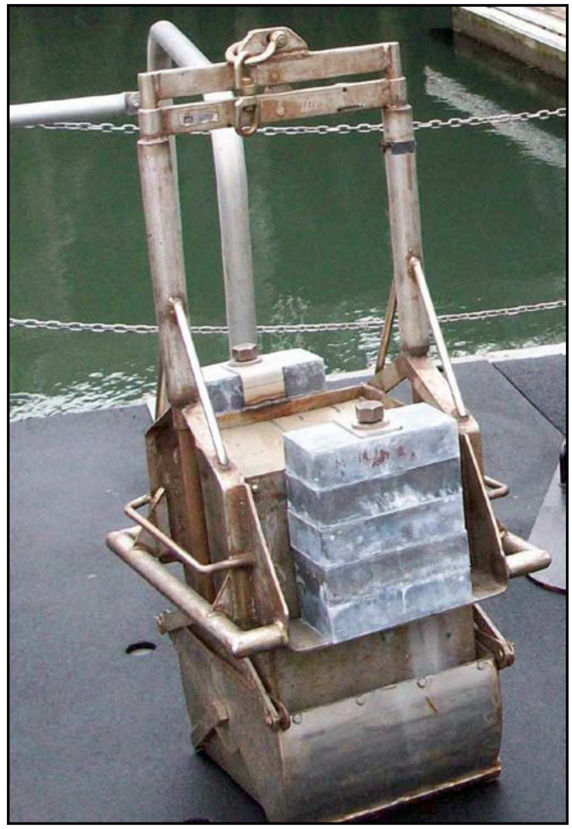

Figure 2: Modified Gray O'Hare box corer used for sampling infaunal invertebrates.

Upon return to the laboratory, rose Bengal was added to the samples in buffered formalin to stain the organisms. After 48 h samples were transferred to 70 % ethanol. Benthic infauna were sorted into major taxonomic groups laboratory staff. All groups except crustaceans and polychaetes were identified by laboratory staff using a stereomicroscope and, when necessary, a compound scope. Contracted 'taxonomic experts' identified crustaceans and polychaetes. We used the same individuals contracted for 2003 EPA National Coastal Assessment project to ensure consistency in identification and to facilitate comparison with those surveys.

Grain sizes of the sediment were analyzed for samples from all visits using a Beckman Coulter Laser Diffraction Particle Size Analyzer (LD-PSA) to determine percent sand and percent silt/clay. After determining there was no significant difference in the grain size of the surface versus mid-core samples, only the surface samples were analyzed using the LD-PSA. Samples from the first year (June 2010 to April 2011) were analyzed for percent total organic carbon. Due to the low values for TOC and lack of temporal variability, we did not continue these measurements for the second summer/fall sampling in 2011.

Trawling

For collection of epifaunal invertebrates and fishes, a beam trawl was used. The beam trawl is 2 meters wide by 70 centimeters high with a 3-millimeter (mm) mesh liner the entire length of the net and a tickler chain (Figure 3). Tows were conducted for 10 minutes (except in summer 2011 when large numbers of ctenophores forced us to reduce the tow time to 5 minutes), and a constant speed of ~1.5 knots was attempted. A meter wheel on the sled of the trawl provided actual measures of the distance the trawl was on the bottom. For the trawl surveys, only 9 stations were sampled on each visit. Those stations along the southern-most transect lie at the edge of a reef. It was deemed too risky for the net and the reef organisms to sample those stations. A total of eight beam trawl sampling trips were made from June 2010 to October 2011 (Table 1). Upon bringing the collection on board, fish and small epifaunal invertebrates were sorted into major groups and promptly euthanized and frozen. Larger invertebrates such as crabs and sea stars as well as elasmobranchs such as skates were identified, sexed if appropriate, measured, and released. Upon return to the laboratory, fish and collected invertebrates were sorted by species and counted. All fish lengths and weights were measured.

Figure 3: Beam trawl used for capturing juvenile groundfish and epibenthic invertebrates.

Videography

In May 2010, preliminary videographic surveys were made using a 'flying' camera sled. This device had no mechanism to keep it a standard distance above the bottom, so frequently the sled hit the bottom (stirring up sediment and making the images unusable) or it was flying too high to be able to see the bottom. This was determined to be suitable for habitat classification but not organism identification. Thus, it was helpful in choosing permanent station locations that were not on rocky substrate but it was not used for subsequent organism analysis.

In August 2010, and February, May, June, and October of 2011 *in situ* videographic surveys using a DCV video camera were conducted in conjunction with normal trawling activity. The camera was mounted in the center of the trawl's cross beam (Figure 3) such that all organisms stirred up by tickler chain, or encountered in the tow path were be seen before entering the net. The trawl was also equipped with lights and a pair of lasers mounted 10 cm apart, positioned at the center of the camera's view, for use as a scaler. Due to the mobility and structure of some benthic organisms, it is believed that not all individuals encountered during a tow were captured; therefore, videos were analyzed to determine the percentage of encountered individuals captured by the trawl. Benthic macroinvertebrates, including crab (>3 cm carapace width), sea pens, and sea stars, have been analyzed.

In situ video footage was converted from DCV to digital, inspected and edited. Upon inspection, if a video was found to have a high degree of sediment re-suspension that obscured the bottom habitat, or if particles affixed to the camera lens caused the video to blur, the video was not analyzed. In total, 39 individual tow videos were collected, of which 22 were analyzed. Start time, end time, and total bottom time were noted, with start time classified as the point at which the beam trawl made and kept consistent bottom contact and stop time the point at which the trawl left the bottom for the final time. Intervals where the beam trawl was not in contact with the bottom were noted and subtracted from the total bottom time. The total number of crab, sea pens, and sea stars encountered during the tow were noted.

In October 2011 we evaluated a third type of videography system. We used a drop camera designed by the Oregon Department of Fish and Wildlife. This camera is designed to be dropped to the bottom and left for a period of time to observe fish in the vicinity. This has been used very effectively on rocky reefs; however, the amount of sediment disturbance caused by the 'drop' resulted in unfavorable videography conditions. Thus it was determined that this was not an effective survey device for the sedimentary habitat.

Water column sampling

At each station-visit vertical water-column profiles of conductivity (proxy for salinity), temperature, dissolved oxygen, and depth were obtained with a Sea-Bird Electronics unit.

Table 1: Sampling visits and gear types.

	Box Core	Trawl	Video
Mav 2010			✔
June 2010	✔	✔	
August 2010	✔	✔	✔
October 2010	✔	✔	
February 2011		✔	✔
April/May 2011	✔	✔	✔
June 2011	✔	✔	✔
August 2011	✔	✔	
October 2011	✔	✔	✔

Flatfish Body and Feeding Condition

English sole, Butter sole, Pacific sanddab, and Speckled sanddab ≥ 90 millimeters were used for feeding analysis. Body condition (which indicates overall growth and relatively long-term feeding history) of the selected flatfish was determined using two methods: Fulton's K-value [$K = 100 (W/L^3)$ where W is the body mass and L is the total length] and residuals. Fulton's K-value is a morphometric index using weight and length of a fish, assuming heavier fish for a given length are healthier fish, as an indication for its condition. Residual analysis provides a comparison of each individual fish to the species data, revealing the variation of condition within each species (Ogle n.d.). After weighing and measuring the fish, their guts were removed and the contents weighed for stomach fullness. Stomach fullness (%Fullness = Ws/Wt*100, where Ws is the weight of stomach contents and Wt is the weight of the fish) indicates the recent feeding success of a fish. Guts in this study were defined as the stomach and the intestine.

Data Analysis

Environmental Variability: To investigate the physical variability among sampling stations, principal components analysis (PCA) was conducted on the 'environmental' variables associated with each station: water depth, temperature, dissolved oxygen, salinity, and % silt/clay. PCA is one of the most commonly used multivariate statistical techniques used to reveal patterns in data, especially among objects (e.g. stations) that cannot be found by analyzing each variable separately (Quinn & Keough 2002). Biplots were generated with axes representing the dominant principal components (reduced variables), points representing the stations, and vectors, representing the physical variables, drawn from the origin. The direction of the vector indicates that the value of the variable increases in that direction and the length of the vector indicates the rate of increase – long vectors are more gradual increases, short vectors are faster increases (Quinn & Keough 2002). Two-way ANOVAs also were used to investigate differences in individual physical characteristics across the site and over time.

Flatfish Condition: After using Fulton's K-value to measure condition of fishes, residuals to measure variation in fishes' condition, and percent fullness to indicate feeding success, two-way ANOVAs were used for balanced data sets. Those data sets that were not balanced were analyzed using General Linear Model analyses. A one-way ANOVA was used for Pacific sanddab data at the 50 m depth across the seasons because it had so little data coverage over 30 and 40 m depths.

Box Core and Trawl Assemblages: For species assemblage analyses (conducted separately for box core invertebrates, trawl invertebrates, and trawl fishes), taxa for which there was just one individual collected for the entire dataset were removed so as not to skew the data based on rare species. Shannon–Weaver diversity (H) and Pielou's evenness (J) were calculated for each sample. Indices were compared using two-way ANOVAs with the factors depth and month. Data were then square root transformed for subsequent multivariate analyses.

Cluster analysis was conducted on the transformed density datasets for each 'assemblage' (infaunal invertebrates from box cores, epifaunal invertebrates from trawls, and fish from trawls) in order to produce groups of similar stations based on the species abundances. The SIMPROF routine was run in Primer 6 (Clarke 1993).

This routine conducts a series of permutation tests to determine if clusters in the dendrogram have statistically significant structure. Samples within a cluster that could not be significantly differentiated are considered to be a genuine group. The SIMPER procedure in Primer was then used to identify the species contributing most to similarities within clusters and differences between clusters.

Multidimensional Scaling (MDS) was used to analyze the transformed density data to examine species composition and proportions across stations. MDS is an ordination technique where a small number of axes are selected prior to analysis and data are fitted to those dimensions, but no axes are hidden from variation (Holland 2008). Data were analyzed using the MDS function in Primer 6 (Clarke 1993). Data are displayed in MDS plots such that samples that form a genuine cluster, as determined using the SIMPROF routine, have the same symbol on the plot. Following MDS analysis of the organism data, the BEST function in Primer was used. The BEST function is based on the BIO-ENV procedure, which uses all the available environmental variables to find the combination that corresponds best to the patterns in the biological data. In order to fully investigate the relationship among all physical variables and species distributions, for analysis of the trawl catches, sediment data from box core grabs from corresponding months were used.

Video Analysis: Comparisons of video and catch data were made using encounter/capture rates and estimates of percent captured. Encounter/capture rates were calculated for each tow by dividing the total number of individuals for each species by the total bottom time rounded to the nearest minute. For videos, this metric provides a measure of how often a species was encountered by the trawl; while for the catch data, it is an estimate of how often a species is captured by the net. Mean encounter/capture rates were also calculated for each species and compared using one-tailed t-tests. Estimates of percent captured for both individual tows and species were made by dividing the number of individuals caught by the number encountered in the video.

RESULTS

Box Coring

Physical Characteristics

The median grain size of the sampling stations over the course of the study ranged from 188 µm to 462 µm. Smaller median grain sizes were found at the 30 m stations while larger grain sizes were found at the 40 and 50 m stations (Figure 4). Specifically, all the grabs from the 30 m stations contained at least 0.83 % silt/clay (defined as grains 62.5 µm or smaller). Most (77 %) of the grabs from the 40 and 50 m stations were 0 % silt/clay. Two-way ANOVA of median grain size with the factors depth and month indicated that while depth was highly significant ($p < 0.001$), month was not ($p = 0.975$). Percent total organic carbon (TOC) in the collected sediment ranged from 0.018 % to 0.087 % and was inversely related to grain size. The best fit between the variables was an exponential relationship with an R^2 value of 0.49. TOC also varied significantly by depth ($p < 0.001$) but not by month ($p = 0.813$).

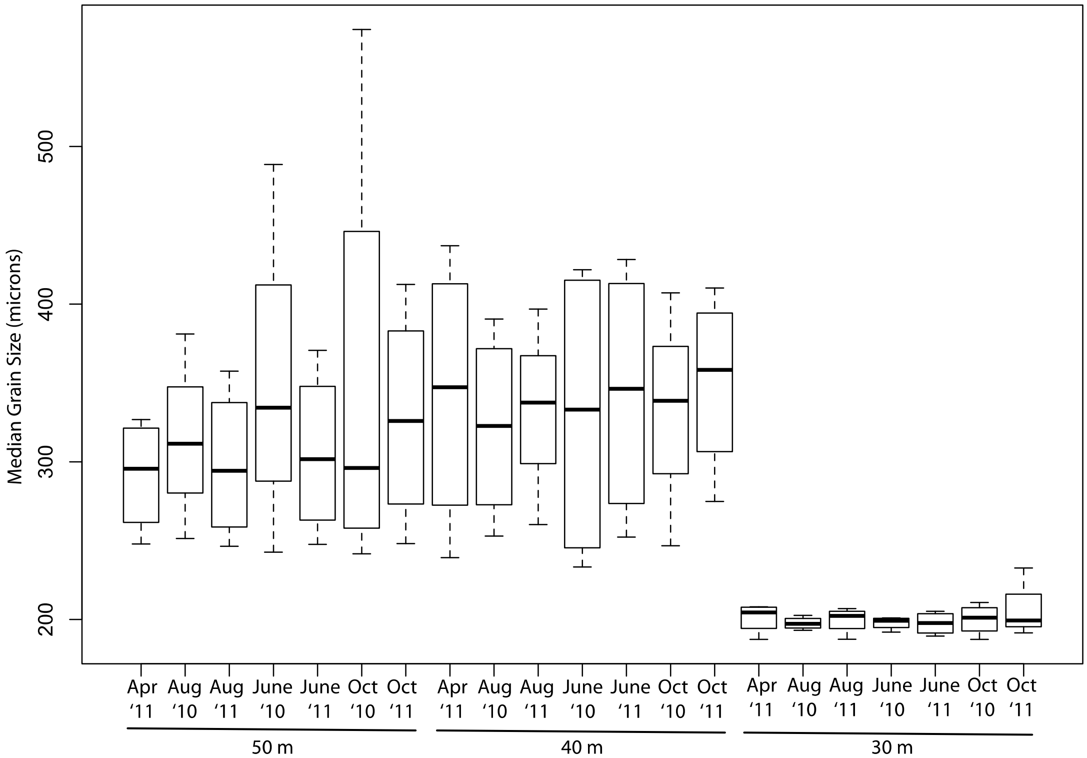

Figure 4: Median Grain Size of sediment samples collected from all box cores, grouped by station depth and month of collection.

Bottom water property values at the site all varied significantly with station depth, month, and the interaction of depth and month. However, these water property values did not all vary in the same way. Temperatures ranged from 7.08 °C in August 2010 to 14.73 °C in October 2011. The August 2011 water temperatures were not significantly different than those measured in June 2011 and August 2010 while all other sampling events had significantly different water temperatures. Dissolved oxygen values ranged from a low of 1.14 ml/L in August 2011 to a high of 6.38 ml/L in April 2011. June 2011 DO values were not significantly different than June 2010 and August 2011. October 2011 and April 2011 were statistically indistinguishable while all other sampling events had significantly different DO levels.

Analysis of the variation in physical attributes of the box core stations using Principle Components indicated that the first axis accounted for 99.3% of the variation. Component 1 aligned with the Median Grain Size vector, plotted as a long vector, indicating this variable changed gradually (Figure 5). The Depth vector integrated Components 1 and 2 and was short, indicating this value changed rapidly. Together Components 1 & 2 explained 99.8% of the variance in physical characteristics of the samples.

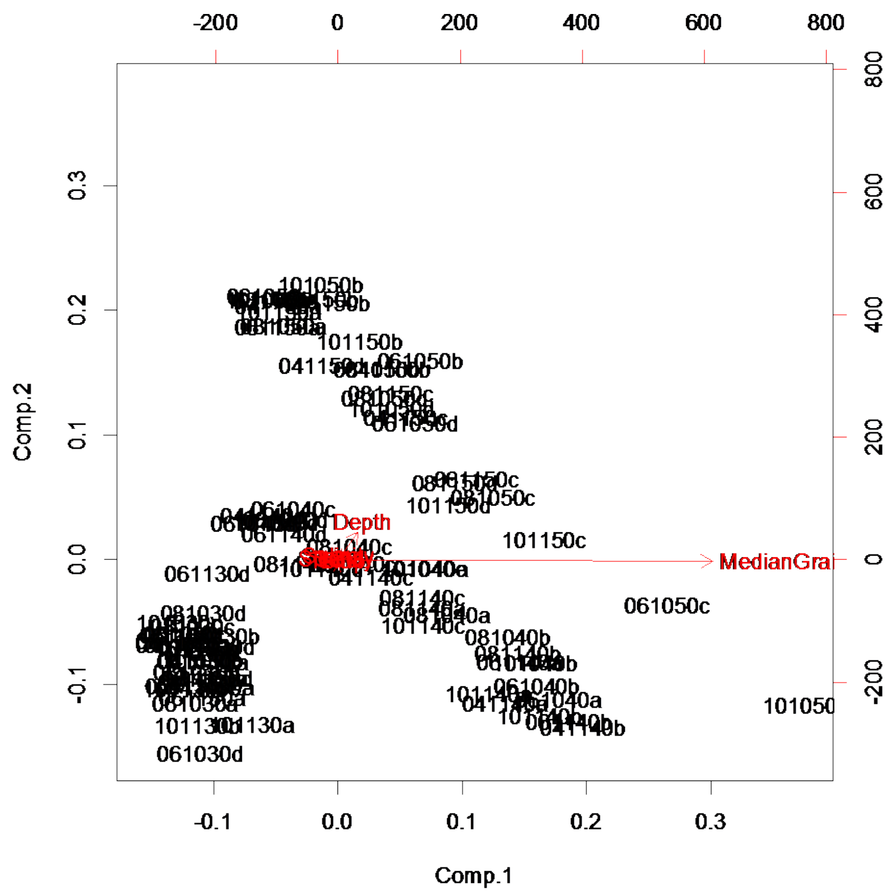

Figure 5: Principle Components Analysis of physical attributes of box core samples.

Infaunal Invertebrates

The diversity of infaunal invertebrates at the sampled stations varied significantly with station depth ($p = 0.001$) but not with month ($p = 0.443$). The 30 m stations had significantly higher diversity than 40 and 50 m, but 40 and 50 m stations were not different from one another. The same patterns held true for significant differences in evenness by depth ($p < 0.001$) but not month ($p = 0.887$).

Analysis of infaunal invertebrates based on the density of collected species indicated that similar communities formed primarily based on station depth (Figure 6). All the 30 m stations and occasionally the southern-most 40 m stations clustered together and could not be significantly differentiated at the 5% level (Group f). The remaining southern 40 m stations were indistinguishable (Group g), and clustered with the 30 m group with 42.4 % similarity. The northern 40 m stations clustered with the southern 50 m stations (Group a). The two northern-most 50 m stations clustered significantly and exclusively with themselves (Groups b and c). One singleton (Group e, station 30d from October 2011) demonstrates how the assemblage varied when the box corer landed adjacent to the reef rather than at the intended sampling location. The BEST function indicated that the highest resemblance between the ordination of the stations based on the biological variables and the ordination of the stations based on the environmental variables was achieved when just two of the environmental variables were used: depth and median grain size. This resulted in a correlation of 0.697. This procedure was bootstrapped 499 times with a resultant significance level of 0.02.

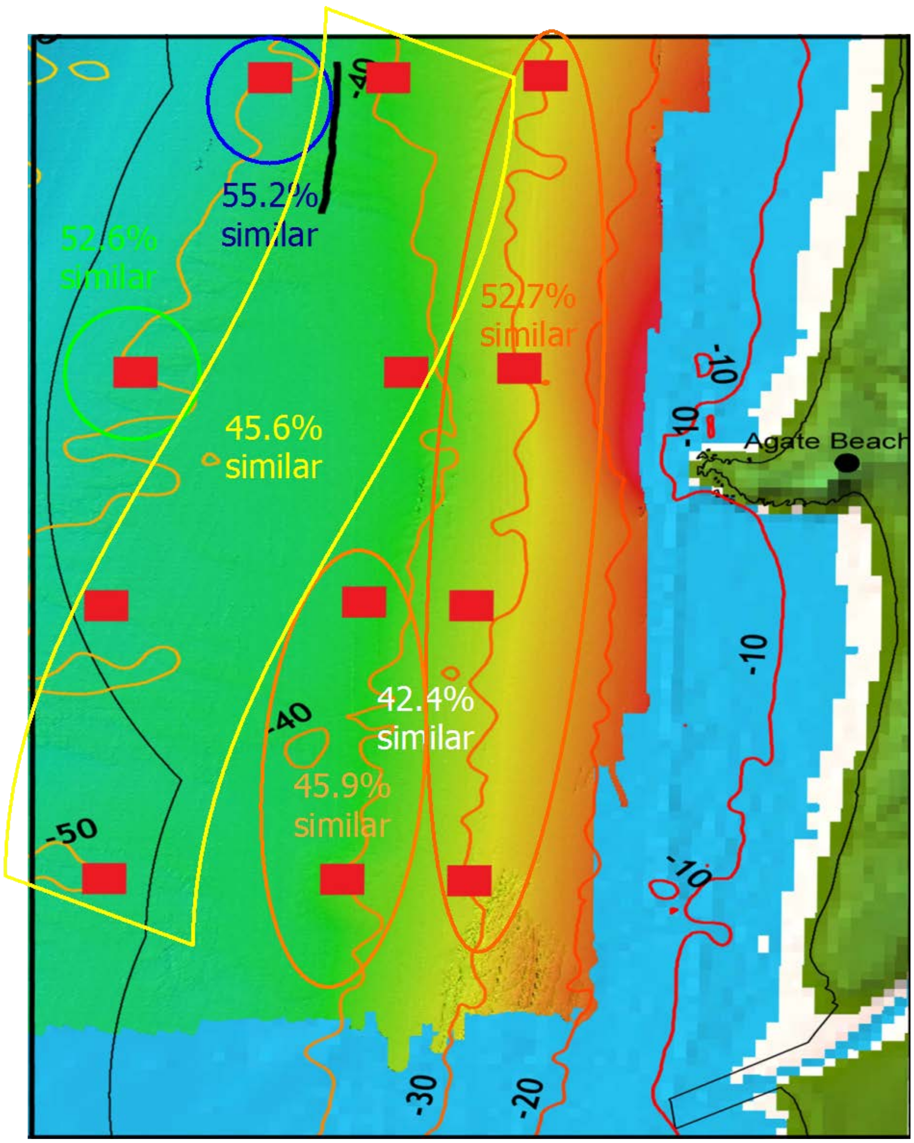

Figure 6: Similarity among box core stations based on infaunal invertebrate assemblages.

Trawling

Physical characteristics

As with the box core sampling trips, bottom water property values at the site all varied significantly with station depth and month as well as the interaction of depth and month. However, because the trawl trips were taken at different times during the month than the box core trips, the similarities and differences among months did not hold the same patterns. For the water temperature, only February and October 2011 were indistinguishable; all other sampling visits had different average water temperatures. Temperatures ranged from a low of 7.21 °C in August 2010 to a high of 11.88 °C in October 2010. Dissolved oxygen values ranged from a low of 1.08 ml/L in August 2010 to a high of 5.43 ml/L in February 2011. October 2010, February 2011, and October 2011 all had statistically indistinguishable dissolved oxygen values. May and June 2011 were similar as were June 2010 and August 2011.

Analysis of the variation in the water quality attributes (no sediment samples were taken on the trawl trips) of the trawl sampling visits using Principle Components indicated that the first axis accounted for 95.7 % of the variation. Component 1 aligned with the Depth vector, plotted as a long vector, indicating this variable changed gradually (Figure 7). The Temperature and Dissolved Oxygen vectors nearly aligned with Component 2 (which accounted for 4.0 % of the variation) and were short, indicating these values changed rapidly. Together Components 1 & 2 explained 99.8% of the variance in the samples.

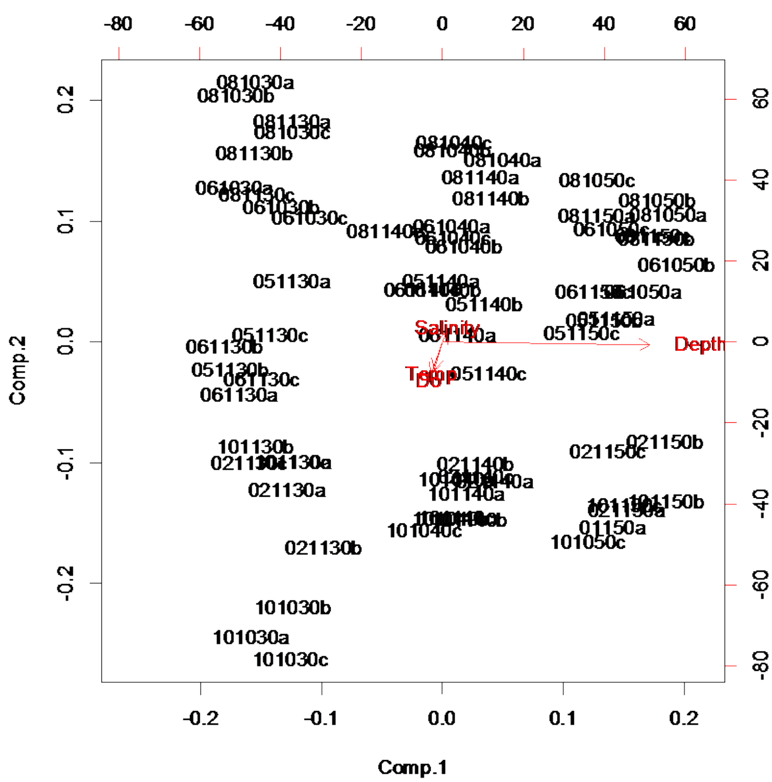

Figure 7: Principle Components analysis of water properties of tow stations

Collected fish

Speckled sanddab (*Citharichthys stigmaeus*), butter sole (*Isopsetta isolepis*), English sole (*Parophrys vetulus*), Pacific sanddab (*Citharichthys sordidus*), and juvenile smelt were the 5 most abundant species (in order) captured during trawling efforts (Table 2). These 5 species represented 86% of the total catch by number. The diversity of fish (calculated using the Shannon-Wiener index) collected via beam trawl at the sampled stations varied significantly with the month of collection ($p < 0.001$) but not with station depth ($p = 0.225$). Generally, there were no significant differences in fish diversity observed among the summer months, but October 2010 and October 2011 were significantly different from June 2010, June 2011, and August 2010. The February 2011 collections did not have different diversity values than either the October collections or the summer collections. Similar patterns held true for significant differences in evenness by month ($p = 0.007$) but not depth ($p = 0.929$); however in evenness October was different only from June.

Similar groups of fish were found in similar seasons (Figure 8). Summer collections formed tight clusters with most June 2011 samples in Group b (high densities of flatfish dominated by butter sole) and most other summer samples in Group c (high densities of flatfish dominated by specked sanddab). These two summer groups were 43.88 % similar to each other. Fall (Group a) and fall and winter (Group d) collections were different from summer and less similar within groups as well. In October, we collected the highest abundance of poachers, and in February we collected most of the juvenile smelt. The greatest resemblance between the ordination of the stations based on the biological variables and the ordination based on the environmental variables (sediment and water characteristics as well as 'month') was achieved when month, temperature, and salinity were used in the analysis. This resulted in a rho value (correlation) of 0.430. This procedure was bootstrapped 499 times with a resultant significance level of 0.02.

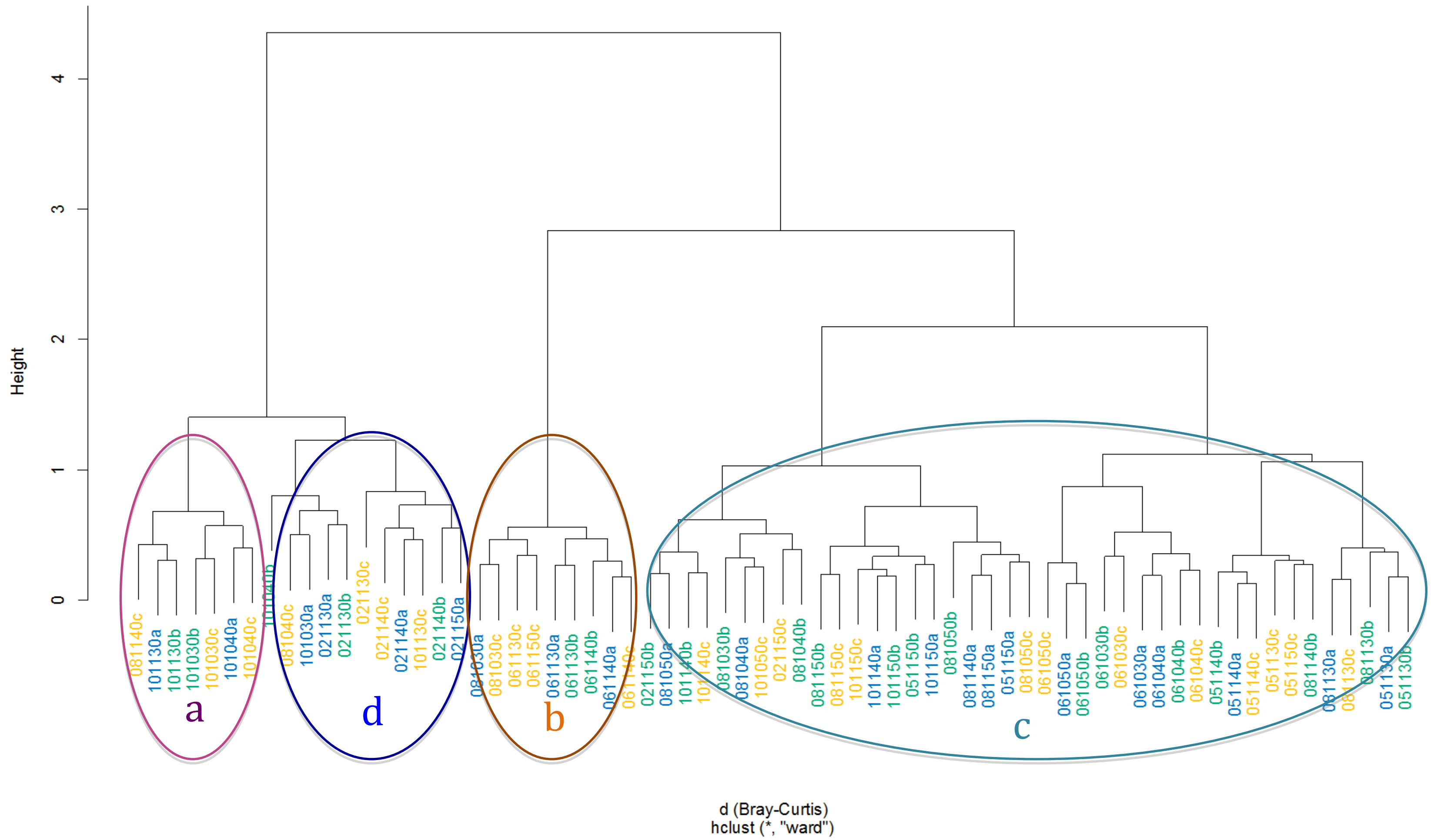

Figure 8: Cluster dendrogram of similarity in fish assemblages among trawls. Significant clusters (circled) were determined using Bray Curtis similarity. Colors represent transect lines north (blue) to south (gold).

Table 2: The number of individuals per species and percent of total captured via trawl during all visits to all stations for fish (68 tows) and year 1 for invertebrates (42 tows). The most abundant groups of invertebrates collected in the trawl, mysid shrimp, *Crangon* shrimp, and olive snails, are bolded.

Fish Species	Total #	% of Total
speckled sanddab	1555	35.8
butter sole	803	18.5
English sole	539	12.4
sanddab sp.	379	8.7
Pacific sanddab	239	5.5
juvenile smelt	238	5.3
sand sole	135	3.0
warty poacher	104	2.3
Pacific staghorn	61	1.4
pricklebreast poacher	56	1.3
unknown fish	32	0.7
Pacific sandlance	29	0.7
black rockfish	29	0.7
Pacific tomcod	26	0.6
rex sole	23	0.5
snailfish sp.	23	0.5
rainbow smelt	20	0.5
ribbon snailfish	13	0.3
roughback sculpin	12	0.3
big skate	10	0.2
showy snailfish	9	0.2
tubenose poacher	9	0.2
sole sp.	7	0.2
bay pipefish	6	0.1
canary rockfish	4	0.1
alligator poacher	3	0.1
petrale sole	3	0.1
pygmy poacher	3	0.1
northern anchovy	2	<0.1
rockfish sp.	2	<0.1
blackfin poacher	1	<0.1
buffalo scuplin	1	<0.1
red Irish lord	1	<0.1
spotted ratfish	1	<0.1
Icelinus sp.	1	<0.1
lemon sole	1	<0.1
white surfperch	1	<0.1
spiny dogfish	1	<0.1
unknown poacher	1	<0.1

Invertebrate Species	Total #	% of Total
Neomysis kadiakensis	51810	35.5
Callianax pycna	25610	17.5
Crangon stylirostris	23849	16.3
Neomysis rayii	21584	14.8
Crangon alaskensis	10182	7.0
Callianax biplicata	4108	2.8
Pagurus sp.	2697	1.8
Cumacea sp.	2143	1.5
Amphipoda sp.	701	0.5
Crangon franciscorum	622	0.4
P. nephrophthalma	357	0.2
Astyris aurantiaca	329	0.2
Tellina nuculoides	281	0.2
Archaeomysis grebnitzkii	234	0.2
Isopoda sp.	200	0.1
Crab megalopae	164	0.1
Dendraster excentricus	155	0.1
Armina californica	139	0.1
M. magister adult & juvenile	112	0.1
"Other" Shrimp	112	0.1
Crangon holmsei	110	0.1
Caesia fossata	107	0.1
Gemma gemma	101	0.1
Polychaete worms	90	0.1
Non-polychaete worms	78	0.1
Pisaster brevispinus	26	<0.1
Paracaudina chilensis	16	<0.1
Alienacanthomysis macropsis	12	<0.1
Ptilosarcus gurneyi	11	<0.1
Cylichna attonsa	11	<0.1
Cephalopoda sp.	9	<0.1
Luidia foliolata	6	<0.1
Macoma carlottensis	6	<0.1
Axinopsida serricata	4	<0.1
Oenopota fidicula	4	<0.1
Siliqua patula	3	<0.1
Pycnopodia helianthoides	2	<0.1
Amphiodia urtica	2	<0.1
Tellina bodegensis	2	<0.1
Gastropteron pacificum	1	<0.1
Odostomia sp.	1	<0.1
Insecta sp.	1	<0.1

Flatfish condition

Flatfish body condition and feeding condition were analyzed over the first full year of sampling (June 2010 to May 2011; Table 3). Butter sole and speckled sanddab were the only fish abundant enough to run the full two-way ANOVA model to analyze both depth and month as factors. Butter sole generally had larger K-values (were in better condition) during fall and winter months than in summer months. While depth was not found to be a significant factor, it appeared the condition of the fish collected at 30 m was generally higher than those collected from 40 m and 50 m. The variability in condition of fish collected from 40 m and 50 m data was more similar, with lower residual values in the summer months and higher residual values in the winter and fall months. A highly significant relationship was found for Speckled sanddab residuals over season, across depth and the interaction between depth and date. This significance is likely an artifact as the data were heavily influenced by one large (295 mm, 265.94 g) outlier that made up the single specimen for October sampling at 40 m. English sole and Pacific sanddab were found in all months only at 50 m, so the results of one-way ANOVA with the factor month are presented. For English sole Fulton's K condition was significantly different across months with October being different than the August, May and June, but not February. English sole condition as measured using residuals also varied across months with August being significantly different than February, May, and June. Gut fullness did not vary across seasons for English sole. For Pacific sanddab month was a significant factor for Fulton's K condition but not for residuals or gut fullness.

Table 3: Analysis of variation in body and feeding condition of select flatfish species across month (and depth & the interaction of month and depth when available). Bold values indicate significance.

	Fulton's K Condition			Residuals			Gut Fullness		
	Depth	Month	Inter.	Depth	Month	Inter.	Depth	Month	Inter.
Butter Sole	0.151	**0.001**	**0.074**	**< 0.001**	**0.004**	**0.042**	**0.022**	0.234	**0.003**
English Sole	n/a	**0.008**	n/a	n/a	**< 0.001**	n/a	n/a	0.263	n/a
Pacific Sanddab	n/a	**0.004**	n/a	n/a	**0.013**	n/a	n/a	0.864	n/a
Speckled Sanddab	0.304	0.637	0.525	***< 0.001***	***< 0.001***	***< 0.001***	0.705	0.779	0.730

Collected epifaunal invertebrates

Due to the time expense of sorting and identification, only the first year's (June 2010 to May 2011) epifaunal invertebrate collections are reported here. Mysid shrimp, *Crangon* shrimp, and olive snails (*Callianax* sp.) were the most abundant organisms, together making up 95 % of the invertebrates (by number) collected in the trawl (Table 2). The diversity of collected epifaunal invertebrates (using the Shannon-Wiener index) collected via beam trawl at the sampled stations varied significantly with the month of collection ($p = 0.001$) but not with station depth ($p = 0.227$). Generally, there were no significant differences in epifaunal invertebrate diversity observed among the summer and fall months, but February 2011 was significantly different from June, August, and October 2010. Similar patterns held true for significant differences in evenness by month ($p = 0.001$) but not depth ($p = 0.464$); where again February 2011 was significantly different from June, August, and October 2010.

Neither the cluster nor multidimensional scaling analyses resulted in discernable patterns in species assemblages. Multiple months and depths were found within significantly similar clusters of samples, and the pattern had a stress value of 0.21, which approaches the cut-off value of 0.3, greater than which for species abundance data indicate the configuration is no better than arbitrary (Clarke 1993). While the ordination pattern was weak, the BEST function indicated a correlation of 0.549 between the ordination of the stations based on the biological variables and the ordination of the stations based on the environmental variables was achieved when month and salinity were used in the analysis. This procedure was bootstrapped 499 times with a resultant significance level of 0.02.

Videography

Five macroinvertebrates could be distinguished in the trawl videos: three sea stars (*Pisaster brevispinus*, *Luidia foliolata*, and *Pycnopodia helianthoides*), one sea pen (*Ptilosarcus gurneyi)*, and Dungeness crab (*Metacarcinus magister*). *Ptilosarcus gurneyi* was the most abundant species seen in the videos with a total of 230 individuals, seen mostly at the 50 m stations. *Metacarcinus magister* was the most abundant species caught in the trawls, with a total of 15 individuals in those trawls for which we had usable video. No trend in *M. magister* distribution was evident across depths. One-tailed t-tests showed significant differences ($p < 0.05$; Table 4) in estimates of mean encounter and capture rates for all species except *Pycnopodia helianthoides* (likely due to small sample size). All species were more frequently encountered than captured.

Table 4: Encounter and capture rates for macroinvertebrate species observed via video mounted on the trawl net. Bold p-values indicate significance.

	Video		Trawl		
Species	Mean Encounter Rate (#/min)	SE	Mean Catch Rate (#/min)	SE	T-Test (p)
M. magister	0.12	0.031	0.041	0.014	**0.0046**
P. gurneyi	0.55	0.205	0.020	0.012	**0.0078**
P. brevispinus	0.22	0.052	0.036	0.011	**0.0002**
Luidia foliolata	0.049	0.016	0.013	0.005	**0.0070**
Pycnopodia	0.010	0.006	0.005	0.003	0.1643

Of the species analyzed, *Pycnopodia helianthoides* had the highest overall catch percentage at 50%; however this was based on very few individuals: 4 were observed and 2 were captured in the entire dataset. *Ptilosarcus gurneyi* had the lowest overall capture percentage at 4%. Overall capture rates for *Luidia foliolata* and *M. magister* were moderate, 26 % and 34% respectively.

DISCUSSION

Sediment and Infaunal Invertebrates

Strong patterns in sediment characteristic exist at this site. There is a very distinctive break in median grain size between the 30 m stations and the 40 & 50 m stations due to a larger amount of silt/clay present closer to shore. This pattern is static throughout most of the year; however, since we were not able to sample in winter we cannot confirm that this difference holds up in winter. Furthermore, this pattern is consistent across years as we observed it in 2010 and 2011 and backscatter data taken as part of the Oregon Territorial Sea mapping effort observed the sediment type break in 2009. These differences in median grain size and percent silt/clay with depth correspond to a difference in percent total organic carbon in the sediment as the amount of particle surface area available to adsorb a coating of organic carbon changes with grain size. Anthropogenic contaminants are also capable of elevating levels of TOC, which can pose a risk to benthic organisms. TOC values observed at this site (max. = 0.087 %) all fell far below the lower threshold (< 2 %) for biological significance, adopted from EPA National Coastal Condition Reports (e.g. U.S. EPA 2004). Thus, it does not appear that the benthic conditions at this site off Yaquina Head, Oregon, in depths greater than 30 m, are influenced by anthropogenic organic enrichment.

Differences among infaunal invertebrates assemblages were strongly associated with sediment grain size and depths. All the 30 m stations had a significantly indistinguishable assemblage of organisms, which matched the finding that there was a different sediment type (> 0.75 % silt/clay) in that zone. Thus, if effects of wave energy device installation and operation resulted in changes between a nearly sandy habitat and one with a small percentage of silt/clay, one would expect to observe a related shift in infaunal invertebrate species found in those areas. At the 40 m and 50 m stations, there was greater diversity in infaunal invertebrates assemblages among the depths and north and south of Yaquina Head. Thus, there likely are additional factors affecting the spatial distributions of infaunal invertebrates in sandy substrates at those depths. Future work may explore the ecology of specific species influential in determining distinct assemblages in order to pinpoint factors affecting their spatial distributions.

Because no seasonal differences were observed in either the sediment characteristics or the benthic invertebrates across seasons, site characterization and effects monitoring for these parameters may not have to be done with the sampling frequency used in this project. At a new site, quarterly (rather than bi-monthly) sampling may be enough to characterize a site. If a lack of seasonal variability is also observed at other locations, effects monitoring temporal intensity may be further reduced.

Fish

The major influence on species and abundances of fish in this habitat was season and the associated changes in the water properties (temperature and salinity) that correspond with different water masses. High densities of flatfish characterized the catch in summer, and speckled sanddab (*Citharichthys stigmaeus*), were usually the dominant species. However, in June 2011, there was a nearly 5-fold increase in the abundance of butter sole (*Isopsetta isolepis*), relative to other summer samples, while the abundance of speckled sanddab stayed the same. There are no physical factors that were abnormal in June 2011 relative to the other sampling periods: June 2011 had the median average temperature and DO and low but not the lowest salinity. Thus, further investigation into the life history strategies and behavior of butter sole will be required to fully understand the dynamics of this species. Although not statistically significant, there were observed differences in some flatfish species densities with depth. English sole and Pacific sanddab were usually absent from shallower stations and in low abundance at the 50 m stations. This suggests we were sampling at the edge of their depth distribution. If these species are of concern, future work should sample deeper to accurately characterize their abundances and distributions. These findings contrast with similar study conducted by Hogue and Carey (1982), where English sole were most abundant, followed by Speckled sanddab, Butter sole, and finally Sand sole; Pacific sanddab was not included in their study. Hogue and Carey sampled in shallower waters, from 9-30 m deep, so their high English sole abundances are surprising in comparison to our low abundances. Differences in relative species abundances could be due to different depth ranges or it could be due to a shift in species abundances over time; we will see, with continued sampling, if this pattern is consistent. In October, flatfish densities were significantly lower and we collected quite a few pricklebreast poachers (*Stellerina xyosterna*). In February rainbow smelt (*Osmerus mordax*) and other juvenile smelt were in high abundances. Because of these strong seasonal (and sometimes interannual) differences in species abundances, initial characterization of a site should be conducted for multiple seasons. Effects monitoring should also be conducted across seasons. Minimally, one should ensure that before and after effects monitoring is done in the same season across years, so that natural seasonal variation does not confound the observations and conclusions.

Patterns of fish condition generally were not associated with gut fullness. There were few significant differences in gut fullness, suggesting the ability to capture prey did not vary across seasons or with depth for most species. Only butter sole had significant differences in gut fullness with depth, and this did not correspond with a significant difference in Fulton's K condition with depth. Alternatively, month was a significant factor for fish condition (measured as both Fulton's K and based on residuals) for butter sole, English sole, and Pacific sanddab. Thus, the variation in condition must be associated with factors other than recent feeding success.

Epifaunal Invertebrates

Invertebrate assemblages collected via trawl seem to be driven by seasonal factors. While 'month' itself did not contribute significantly to the correlation between physical characteristics and species differences, temperature and salinity, which indicate different water masses, were influential. Part of the reason for a lack of clear patterns in this dataset as a whole may be that the organisms collected were both those that live in the surface layer of the sediment as well as those that live in the water column just above the sediment. Future work should separate these different assemblages and analyze them independently.

Videography

Trawl selectivity is often thought to be determined by the mesh size of the codend, as well as the behavioral response of the target organism (Rotherham et al., 2008; Yanase et al., 2009). However, many of the benthic invertebrates encountered by the beam trawl in this study are slow moving or sessile in nature making substantial avoidance behaviors unlikely. It is also unlikely that the mesh size of the codend played a role in capture as all of the individuals seen on the video measured well over the 3 mm mesh size, which lined the entire net. It is most likely then that the structure of the invertebrates themselves played the greatest role in their avoidance of capture. Sea pens, for example, were the most encountered organisms in the videos yet were the least captured; most likely due to their physical structure. The aboveground polyp of a sea pen is anchored in the sediment by a flexible, burrowing peduncle. When encountered by the trawl, the polyp often can be seen bending completely to the sea floor, allowing the tickler chain and net to pass over without being uprooted. Similar observations have been made with the sea whip, *Halipteris willemoesi*, a species of colonial cnidarian, which also uses a flexible peduncle to anchor to the seafloor (Troffe et al., 2005). The sea stars encountered, while often snagged by the tickler chain and dragged for up to several minutes, were not forced into the water column where they could be overtaken by the trailing net. These species likely escaped capture by passing through the gap between the footrope and the seafloor as has been seen in other studies also investigating the selectivity of beam trawls (Yanase et al. 2009). Of all the species encountered, *M. magister* is the only one capable of a rapid response to stimulus provided by the tickler chain making behavioral response a likely factor in capture. When hit by the tickler chain most of the crab seen attempt to escape by rising up from the sediment where they are buried thus allowing the chain to knock them into the water column where they can be captured by the sampling net.

Knowing gear selectivity and how it may influence invertebrate population estimates is crucial when attempting to evaluate the impact of wave energy development. While the fact that all of the invertebrates were more frequently encountered than captured means trawl data provides a conservative population estimate, accurate numbers are necessary to understand key features of this sandy bottom habitat and provide meaningful recommendations for future development. Monitoring programs may gain a more accurate understanding of the impacts of wave energy development if *in situ* videography is employed in conjunction with trawling activities.

DISSEMINATION OF RESULTS AND FUTURE PRODUCTS

Participation at OWET Ocean Renewable Energy Conferences

George Boehlert presented this work and our similar project, sponsored by BOEM, at the September 29-30, 2010, meeting presented by the Oregon Wave Energy Trust and EnergyOcean Pacific in Portland, Oregon. The session was entitled: BOEM Environmental Studies Program with Mary Elaine Helix, Bureau of Ocean Energy Management, Regulation and Enforcement (BOEM) and John Mason, Senior Associate, Environment International Ltd as the other panelists. This project, specifically, was also presented as a poster.

Sarah Henkel presented this work and a related protocols framework project, sponsored by BOEM and others, at the August 3-4, 2011, meeting presented by the Oregon Wave Energy Trust in Portland, Oregon. This session was entitled: Towards efficient and effective ocean renewable energy siting and permitting, Part One: Progress in Regional, Integrated, Ecosystem-Based Management. It was intended to showcase for developers, lobbyists, regulators and legislators recent progress towards making ocean renewable energy mandates and regional resource management play out in and efficient and effective way. Other panelists in part one were: Dr. Karen McLeod, Director of Science, Communication Partnership for Science and the Sea (COMPASS), Donna Schroeder, Marine Ecologist, Continental Shelf Region BOEM, and Phillip Levin, Program Manager – Ecosystem Science, Northwest Fisheries Science Center, Conservation Biology Division. This project was not presented as a poster as the 2011 meeting, but it will be presented at the 2012 meeting after project completion.

Sarah Henkel also presented this work at the following meetings and workshops:

Western Society of Naturalists: Vancouver, Washington – "Spatial and Temporal Patterns in the Distribution of Infaunal Invertebrates" November 11, 2012

Heceta Head Coastal Conference (Invited): Florence, Oregon – "Assessment of Benthic Habitats and Communities in Areas Targeted for Offshore Wave Energy Development" October 29, 2011

Research at the Intersection of Marine/Hydrokinetic Energy and the Environment, NSF-funded workshop: University of Minnesota, St. Anthony Falls Lab, *Invited speaker*: "Identifying Spatial and Temporal Patterns in Potentially Impacted Environmental Parameters" October 5-7, 2011

American Fisheries Society (Invited): Seattle, Washington – "Assessment of Benthic Habitats and Communities in Areas Targeted for Offshore Wave Energy Development" September 6, 2011

Advanced Marine Renewable Energy Instrumentation Experts Workshop: Golden, CO – *Invited Speaker*: "Surveying Benthic Habitats and Biological Communities in Areas Targeted for Offshore Wave Energy Development" April 7, 2011

Benthic Ecology Meeting: Mobile, Alabama – "Benthic Assemblages at Sites Proposed for Wave Energy Testing" March 18, 2011

Fishermen Involved in Natural Energy: Newport, OR – "Surveys of Soft-bottom Benthos off Yaquina Head, OR" November 16, 2010

Western Society of Naturalists (Poster): San Diego, CA – "Baseline survey of macroinfaunal invertebrate community at potential wave energy site off the Oregon coast" Co-author, presented by student Elizabeth Lopez, November 2010

Contributions to Environmental Characterization and Monitoring Methods

NNMREC will contribute, as appropriate, to guidance documents applicable to marine energy development. If requested by the state, NNMREC will prepare a short white paper that will detail the sampling efforts conducted by OSU, outlining the processes for conducting the sampling and analyzing the results. We are currently engaged in an effort at the federal level to provide a framework for developing protocols for evaluating a suite of potential environmental and ecological effects of offshore renewable energy. The project also will address how the protocols identified in that project relate to other national and international test facilities.

Recommendations for NNMREC Monitoring Plan

Following the deployment of the Ocean Tests Facility and associated wave energy devices NNMREC will conduct post-installation monitoring. The final requirements of the monitoring plan will be determined in association with federal, state and local agencies based on findings from this initial site characterization. In terms of invertebrate and sediment sampling, based on the findings of this project, we recommend decreasing the temporal intensity of the box core sampling. Furthermore, analysis of the duplicate grabs at each station indicates there are not significant differences in sediment characteristics or infaunal invertebrate assemblages at that small spatial scale. Thus, one grab per station is recommended, similar to the EPA NCA protocols. In terms of the trawling protocol, we generally recommend quarterly sampling to capture broad seasonal differences in the fish assemblages. However, due to some of the interesting patterns we have seen within the summer and between years, we hope to continue bi-monthly trawl sampling as a research pursuit. As NNMREC has plans to move to a full-scale test facility that may require deeper water in the future, we will pursue additional sampling outside of state waters (deeper than 50 m at Newport) to better characterize English sole and Pacific sanddab dynamics. The trawl-mounted video camera has been determined as the best method for observing large invertebrates and fish behavior.

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