OCS Study
BOEM 2020-008

Cross-Shelf Habitat Suitability Modeling for Benthic Macrofauna

US Department of the Interior
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ABOUT THE COVER

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List of Abbreviations and Acronyms

BOEM	Bureau of Ocean Energy Management
cm	centimeter
CMECS	Coastal and Marine Ecological Classification Standard
CTD	Conductivity, Temperature, Depth
DO	Dissolved Oxygen
DOI	US Department of the Interior
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
EMAP	Environmental Monitoring and Assessment Program
EPA	US Environmental Protection Agency
EUNIS	European Nature Information System
FRAM	Fisheries Resource Analysis and Monitoring
GIS	Geographic Information System
GPS	Global Positioning System
GS	Grain Size
µm	micrometer
m	meter
mm	millimeter
MDS	multidimensional scaling
MLML	Moss Landing Marine Laboratories
MRE	Marine Renewable Energy
NCCOS	National Centers for Coastal Ocean Science
NETS	North Energy Test Site
NMFS	National Marine Fisheries Service
NNMREC	Northwest National Marine Renewable Energy Center
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
OCNMS	Olympic Coast National Marine Sanctuary
OCS	Outer Continental Shelf
ODFW	Oregon Department of Fish and Wildlife
ODMDS	Ocean Dredged Material Disposal Site
ONR	Office of Naval Research
OSU	Oregon State University
PMEC	Pacific Marine Energy Center
PNW	Pacific Northwest
SETS	South Energy Test Site
ROV	Remotely Operated Vehicle
SCCWRP	Southern California Coastal Water Resources Project
SETS	South Energy Test Site
SGH	Surficial Geologic Habitat
TN	Total Nitrogen
TOC	Total Organic Carbon
USGS	United States Geological Survey

1 Executive Summary

There is increasing interest in offshore wind development, which is likely to be sited in deeper waters (i.e., the continental slope) on the US west coast as compared to wind installations in northern Europe and the US east coast or to proposed wave energy deployments. While many environmental interactions of marine renewable energy (MRE) deployments have been considered, a certain effect will be localized changes to the seabed, potentially affecting benthic invertebrates living in or on the seafloor. Previous work sponsored by the Bureau of Ocean Energy Management (BOEM) and conducted by Oregon State University (OSU) characterized seafloor habitats for benthic invertebrates on the inner to mid shelf (30 to 130 meters [m] deep). Deeper waters are less studied, and habitat suitability models are not developed for macrofauna (e.g., infauna) of the outer continental shelf and slope. Thus, for this study we sampled deeper waters (60 to 525 m) to expand the domain of the habitat characterization and of the individual species models. Improved models have the potential to inform regional spatial planning processes for future consideration of MRE projects and the necessary consultations associated with leasing (e.g., on Essential Fish Habitat [EFH]). Improved habitat suitability models could also improve site assessments needed for National Environmental Policy Act analysis and may reduce site survey requirements for lease holders.

The two primary outputs for this study are (1) cross-shelf habitat characterizations where benthic habitats are classified based on biological species groupings or assemblage distributions and (2) habitat suitability models for a subset of the macrofauna. The cross-shelf habitat characterization was conducted for the same latitudinal range as the prior BOEM study and includes data from both projects as well as other OSU collected samples for a depth range of 20 to 525 m deep. Outputs focused on linking spatial variability in macrofauna assemblages with measured environmental parameters. The habitat suitability models were developed using the entire US west coast for the latitudinal range by including datasets from additional sources. To determine which macrofauna would be selected for habitat suitability modeling coast-wide, we determined which species were characteristic of the habitats classified and choose those with ranges throughout the study region. Additionally, we included species that comprise a wide range of tolerance/sensitivity to pollution. Finally, all seven of the species modeled previously were included in the final list of 44 species for which we conducted habitat suitability modeling. This study was a joint effort with the National Centers for Coastal Ocean Science (NCCOS). NCCOS took environmental and biological data from this study and built habitat suitability models. NCCOS will issue a separate BOEM report under Interagency Agreement Number M16PG00014.

Significant differences in macrofauna species assemblages were found across depth and in different sediment types. Depth was the primary structuring variable (i.e., macrofauna species assemblages first separated by depth) with sediment parameters (percent fines, grain size, and total organic carbon) secondary and nearly as statistically important. The depth break of ~90 m was the first major environmental variable that correlated with major differences among assemblages among our stations, which is not a classically described depth break for shelf fauna. Beyond the 90-m break point, we detected secondary changes in assemblage composition at 43 m and 200 m. Within each of these depth zones on the shelf, we detected significant differences in assemblages related to different sediment grain sizes. Below the 200-m break – a depth traditionally delineating the continental shelf and slope – subsequent depth breaks were detected at 221 m and 445 m. Knowing how macrofaunal communities respond to changes in grain size and depth can inform future site surveys and led us to develop tools for mapping macrofauna based primarily on these physical factors.

This study provides BOEM with information on seafloor habitats and invertebrate communities in consideration of Outer Continental Shelf (OCS) renewable energy development. Overall, the information derived from this study has greatly contributed to the greater body of knowledge regarding seafloor habitats and invertebrate communities in the Pacific Northwest (PNW).

2 Introduction to the Study

The seafloor is an important resource as habitat for commercial fisheries and supports the trophic base for many ecologically important and regulated marine species. The vast majority of benthic habitats in waters past the photic zone consist of unconsolidated sediments where macrofaunal (infaunal) and epifaunal invertebrate species play an important role in serving as trophic links between water column and benthic primary productivity and higher trophic levels (Snelgrove et al. 1998; Kędra et al. 2015). A benthic habitat type is defined as, "a particular environment which can be distinguished by its abiotic characteristics and associated biological assemblage, operating at particular, but dynamic spatial and temporal scales in a recognizable geographic area (ICES 2006)." These invertebrates are a key part of defining unconsolidated sediment habitats because species represent long-term environmental conditions (Elliot 1994), both responding to and affecting local sedimentary processes (Gray 1974, Rhoads 1974, Aller and Aller 1998), benthic boundary layer flow (Friedrichs and Graf 2009), and biochemical cycling (Josefson and Rasmussen 2000; Laverock et al. 2014). Macrofauna-based assessment indices have been developed to quantify these responses and are a primary biological tool utilized worldwide to evaluate the overall condition or health of benthic habitats in a variety of regulatory or disturbance assessment contexts (e.g., waste water discharge, dredge disposal) around the world (Gillett et al. 2015; Diaz et al. 2004).

Despite the wide-use of assessment indices in water-quality based coastal regulation, the use of macrofauna to classify benthic habitats as a means to inform planning applications is not always possible nor done consistently (Reiss et al. 2015). In US Federal waters on the continental shelf, marine planning primarily addresses commercial fishing, conservation, and energy development. Laws and regulations specifically state the importance of benthic habitats. For example, the Magnuson-Stevens Fishery Conservation and Management Act regulates commercial ground fisheries and recognizes benthic habitat integration for fish species food and shelter through Habitats of Particular Concern and Essential Fish Habitat designations. Conservation of marine resources in the National Marine Sanctuaries on the US west coast covers 13,000 square miles of the seafloor. Macrofauna-focused analysis could assist with conservation (Bremner 2008) and inform spatial planning for groundfisheries (Thrush and Dayton 2002) and fish farming (Tomassetti and Porrello 2005).The Outer Continental Shelf Lands Act states the need to characterize and monitor benthic habitats in areas potentially impacted by energy development. Deep-sea coral distributions currently are utilized to delineate habitats of concern or warrant protection as these organisms are themselves fragile and characterize emergent bottom structure of limited extent and thus are consequently of increased concern. However, the much more extensive soft sediments are not themselves uniform, and also harbor areas which should be of concern. Prior to oil and gas leasing offshore southern and central California, extensive macrofauna data was collected (Hyland et al. 1991; Lissner 1989) but not utilized for planning purposes. In contrast, research has been conducted in the Alaskan arctic to link macrofauna data with higher trophic species (Kędra et al. 2015) and has informed energy policy in the Beaufort and Chukchi Seas.

Macrofauna assemblages represent the biological community most likely to be impacted by energy development. Further, the area of impact to benthic organisms could be larger than the direct footprint of development. 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 around large device arrays may affect the distribution of invertebrate species that are dependent on grain size, near-bottom sedimentation and particle loads (Etnoyer and Morgan 2003). In this study we conducted macrofauna community analysis and correlated it with environmental covariates as an approach for applied decision-making at the regional scale needed for planning applications of the US west coast seafloor.

A prior regional analysis (referenced as Benthic Habitat Characterization; BOEM-BHC, Henkel et al. 2014) was spatially comprehensive within the mid- to inner-continental shelf (30 to 130 m) that wave energy projects have targeted – the primary focus of offshore renewables at the time. In 2018, BOEM issued a Call for Information and Nominations for areas with water depths from 300 to 1,200 m (Fed Reg 2018). These deeper waters are less studied, and habitat suitability models have not been developed for macrofauna of the outer shelf and slope. Thus, we aimed to sample these deeper waters in order to expand the domain of the habitat characterization and habitat suitability models developed in the 2014 BHC project. Additionally, since the time of the BHC project, there has been greater interest in siting renewable energy projects offshore California. Thus, we aimed to expand the latitudinal range of the models as well by utilizing previously gathered data from various other survey programs in California as well as in Oregon. Evaluating and improving the spatial extent of habitat suitability models is necessary before they can be useful tools for siting and permitting.

The following chapters step through the study components. Chapter 3 describes box core surveys and subsequent analyses to describe macrofaunal invertebrate species assemblages and the classification of benthic habitat in the northern portion of the planning region. Chapter 4 describes the processes used for selecting species modeled for habitat suitability throughout the entire planning region from the California-Mexico border to Vancouver, Washington.

3 Cross-shelf Habitat Classification

3.1 Purpose

New technologies are in development to produce renewable energy (wave, wind, etc.) to reduce dependence on fossil fuels. The energetic continental shelf of the PNW is particularly appealing for marine renewable energy development and areas of the seafloor have the potential to be leased to developers for this purpose. An assessment of potential impacts on marine environments is needed, but the lack of baseline data on the characteristics, distribution, abundance and condition of seabed habitats limits our ability to predict how they might change. However, even before seabed habitat distribution, abundance and condition can be assessed, a better approach for classification of seabed habitats is necessary. In the rationale for Session G: Habitat Modelling and Mapping for better assessment and monitoring of our seas at the ICES Annual Science Conference in 2011, conveners stated, "empirical evidence shows this new categorisation [EUNIS] results in a poor match between modelled and observed biotopes; primarily because the boundaries between classes have not been defined because of any known effect on benthic community distribution". This knowledge gap also affects other aspects of marine spatial planning, including evaluation of potential impacts on biological resources such as fisheries and other higher trophic levels that may respond to the distribution of benthic communities rather than physical features.

Due to their living position and life history, macrobenthic fauna are both indicators of sediment characteristics and sensitive to changes to sediment conditions; thus, they are the biological community most likely to be impacted by seafloor development. Not only do they serve as a food source for higher trophic levels, they also are a link between toxicants in the sediments and bioaccumulation in tissues of fishes, marine mammals, birds, and humans. Thus, benthic macrofauna have long been used as indicators of both habitat and environmental status and trends. Planning for both offshore renewable energy and fisheries management is ongoing across the shelf and slope-shelf transition zone in the PNW, driving the need for better understanding of the distributions of habitats as it relates to these critical, low trophic level species.

In southern California, where there are extensive long-term macrobenthic fauna-based regional monitoring programs in place across the continental shelf and slope (Schiff et al. 2016), depth has been considered to be the primary variable structuring macrofaunal invertebrate species distributions with other factors such as dissolved oxygen, grain size, and total organic carbon being secondary (SAIC 1986, Lissner 1989, Hyland et al. 1991, Bergen et al. 2001, Gillett et al. 2017). Henkel and Politano (2017) focused on the mid-continental shelf (50 to 110 m) macrofauna of the PNW and defined important breaks in sediment characteristics that resulted in different macrofaunal assemblages within that depth range in the region. Across a broader latitudinal (US west coast) range and slighter greater depth expanse (30 – 130 m), Henkel and Nelson (2018) similarly found within-region differences based on low percentages of fine sediment along with latitudinal breaks in species assemblages, potentially related to temperature and/or upwelling. However, because of the relatively limited depth range in both studies, we were not able to determine if/where significant depth breaks in macrofaunal assemblages occur across the entirety of the shelf and slope, if those breaks are consistent with those observed in Southern California, or if the sediment classifications defined in the previous studies apply across the broader geographic scope of the outer shelf and slope of the PNW.

The purpose of this study was to understand how macrofauna are distributed in relation to physical factors across the shelf and the upper slope (~20 to 525 m) from Mendocino, California, to Grays Harbor, Washington. The objective was to classify sedimentary benthic habitats as defined by the macrofaunal organisms. We specifically sought to determine (1) where significant depth-related breaks in species assemblages occurred; (2) what sediment differences correlate with different species assemblages; and (3) if regional differences were detectable in this sampled range. The results of this effort will more accurately characterize a large seafloor expanse and assess the impacts of marine renewable energy development.

3.2 Methods

3.2.1 Study Area

The study area ranged from Fort Bragg, California (39.5 °N) to Grays Harbor, Washington (47.0 °N) on the west coast seafloor of the continental United States. From 2010 to 2012 a total of 242 samples were collected from nine distinct sites in this range; within each site, sample stations were randomly determined using Generalized Random Tessellation Stratified methods (GTRS; Stevens and Olsen 2004) as described in Henkel and Politano (2017). In early summers 2014 and 2015, we collected 77 samples from 60 to 500 m deep along regularly spaced (0.5 degrees latitude) offshore transects from Brookings to the Columbia River, Oregon. An additional site near Newport, Oregon, was sampled in June of 2015, within which 17 stations were arranged on a regular grid. In summer 2016, we sampled 68 additional stations from Coos Bay to Tillamook, Oregon, from 64 to 525 m deep. Thus, a total of 404 samples ranging from 18 to 525 m deep were available for analysis (Figure 1; Table of all station locations in the Appendix).

3.2.2 Sample Collection and Processing

At each station, samples were collected with a modified Grey-O'Hara 0.1 m^2 box core. One box core sample was taken at each station. Only samples with a penetration depth of at least 5 centimeters (cm) and no slumping or other evidence of disturbance (i.e., by washing) were accepted for processing. Approximately 80 milliliters (mL) of sediment were collected from the undisturbed surface layer for grain size analysis. Any organisms noticed in the sediment subsample were removed and placed in the organism sample at the time of collection (occasionally a specimen was detected when conducting the sediment analysis). The remainder of the collected core was sieved onboard through a 1.0 millimeter (mm) mesh screen, and all collected organisms (both infauna living in the sediment and small epifauna which may have been on the surface – hereafter collectively called macrofauna) were preserved in a mixture of 10% buffered formalin and seawater. At most stations (primarily excluding the 2014 and 2015 offshore sampling) vertical water-column profiles of conductivity, temperature, dissolved oxygen, pH, and fluorescence were obtained with a Sea-Bird Electronics CTD (conductivity, temperature, depth) unit equipped with additional sensors. Depth was recorded from the vessels' echosounder at the time the box corer hit the bottom.

Upon return to the laboratory, organisms were transferred to 70% ethanol then sorted into major taxonomic groups by OSU staff. Crustaceans, polychaetes, other worm-like creatures, and a portion of the molluscs were sent to contracted taxonomic experts. OSU laboratory staff identified other molluscs, echinoderms, and any remaining taxa.

Sediment from the top of the core was analyzed using a Beckman Coulter Laser Diffraction Particle Size Analyzer (LD-PSA) to determine mean and median grain size and percent fines (silt/clay; portion less than 62.5 micrometer [μm]; Wentworth 1922). In most cases, sand (62.5 μm to 2 mm) was the balance of the sample. Where grain sizes larger than 2 mm (maximum size for the LD-PSA) were encountered, these samples were fractioned and the percent gravel (that fraction greater than 2 mm) was determined by weight. The balance of the fraction was then analyzed by the LD-PSA to determine % sand and silt/clay and grain size (the mean/median grain sizes are thus not representative of the full composition of the sediment). Approximately one quarter (n = 110) of the sediment samples were analyzed for percent total organic carbon (TOC) and total nitrogen (TN) using an NA1500 Elemental Analyzer operated by staff in the College of Earth, Ocean, and Atmospheric Sciences at OSU.

3.2.3 Statistical Analysis

A variety of multivariate analyses were undertaken using PRIMER 6th Edition (Clarke and Gorley 2006). Abundance data were 4th root transformed to reduce the influence of highly abundant species without giving as much weight to rare species as would the more severe log(x+1) (Clarke and Warwick 2001). A Bray-Curtis similarity matrix was created for the 404 samples and a multidimensional scaling (MDS) plot was created. As Henkel and Politano (2017) determined that stations containing gravel and those with less than 1% fines hosted significantly different assemblages, and Henkel and Nelson (2018) detected a significant difference in assemblages at a break of 5% fines, we first coded the MDS with sediment classes representing these and other breaks in percent fines (Figure 2). As expected, the gravel-containing stations were rather separate from the rest of the stations. These stations represent a unique habitat type with its own assemblage of organisms (characterized mostly by polychaetes; Henkel and Politano 2017); however their inclusion in this analysis would make other differences within gravel-free sediment difficult to resolve; thus, we removed all 11 stations that contained gravel. Additionally, we removed from the dataset any taxon that had only a single observation. A new resemblance matrix was created using the remaining 393 samples. We used the similarity matrix to create a dendrogram by agglomerative cluster analysis with group-average linking and the Similarity Profiles (SIMPROF) procedure to identify significant clusters based only similarities in macrofaunal abundance. Using a SIMPROF significance threshold of 1%, the dendrogram included 76 multi-station clusters and 15 individual samples as outliers (Figure 3). These outliers were removed from the remainder of the analysis for a final dataset of 378 samples.

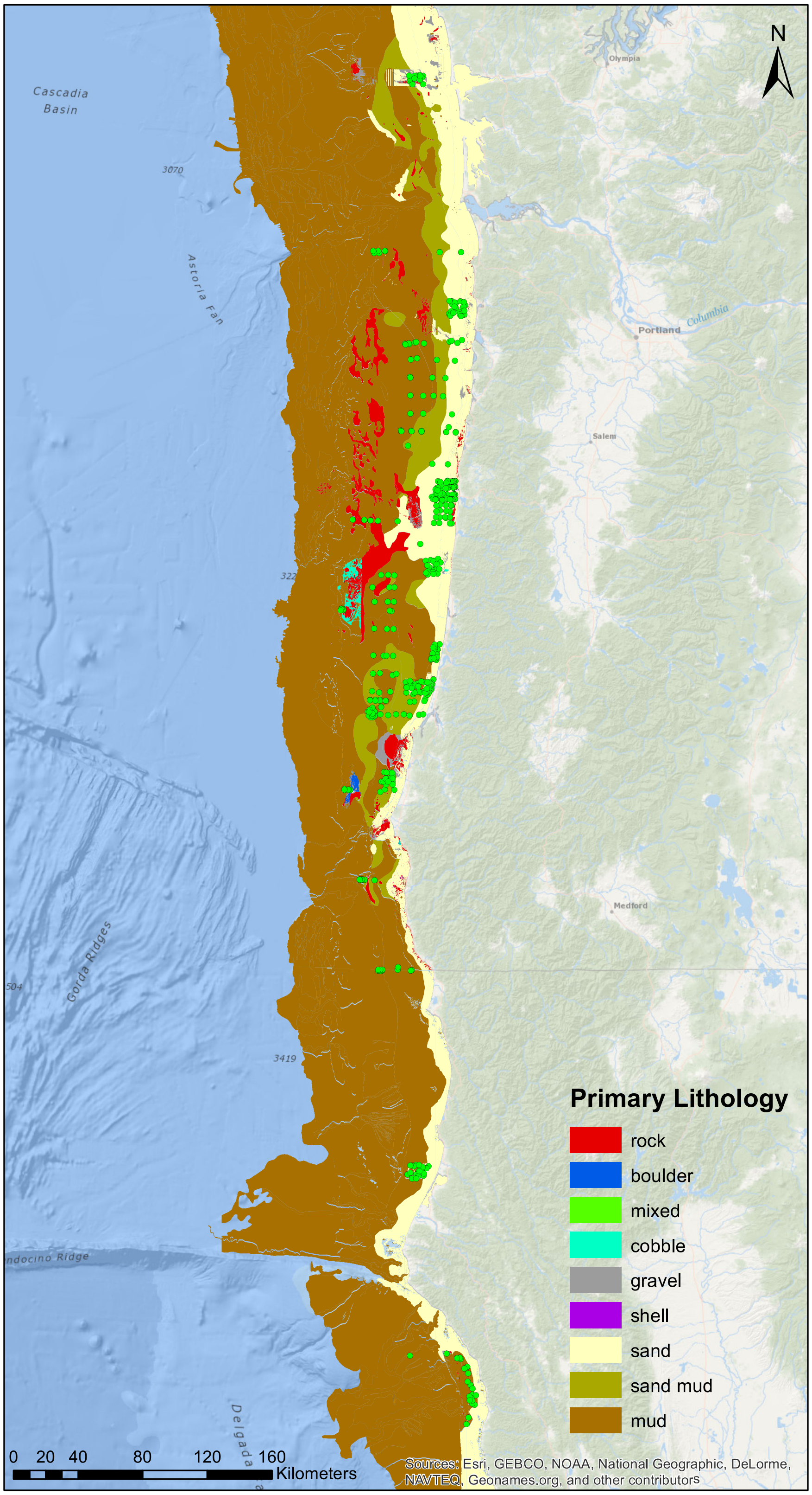

Figure 1. Macrofaunal grab samples (n = 404) gathered for habitat classification.
The base map is the primary lithology as described in the BOEM-BHC project (Goldfinger et al. 2014).

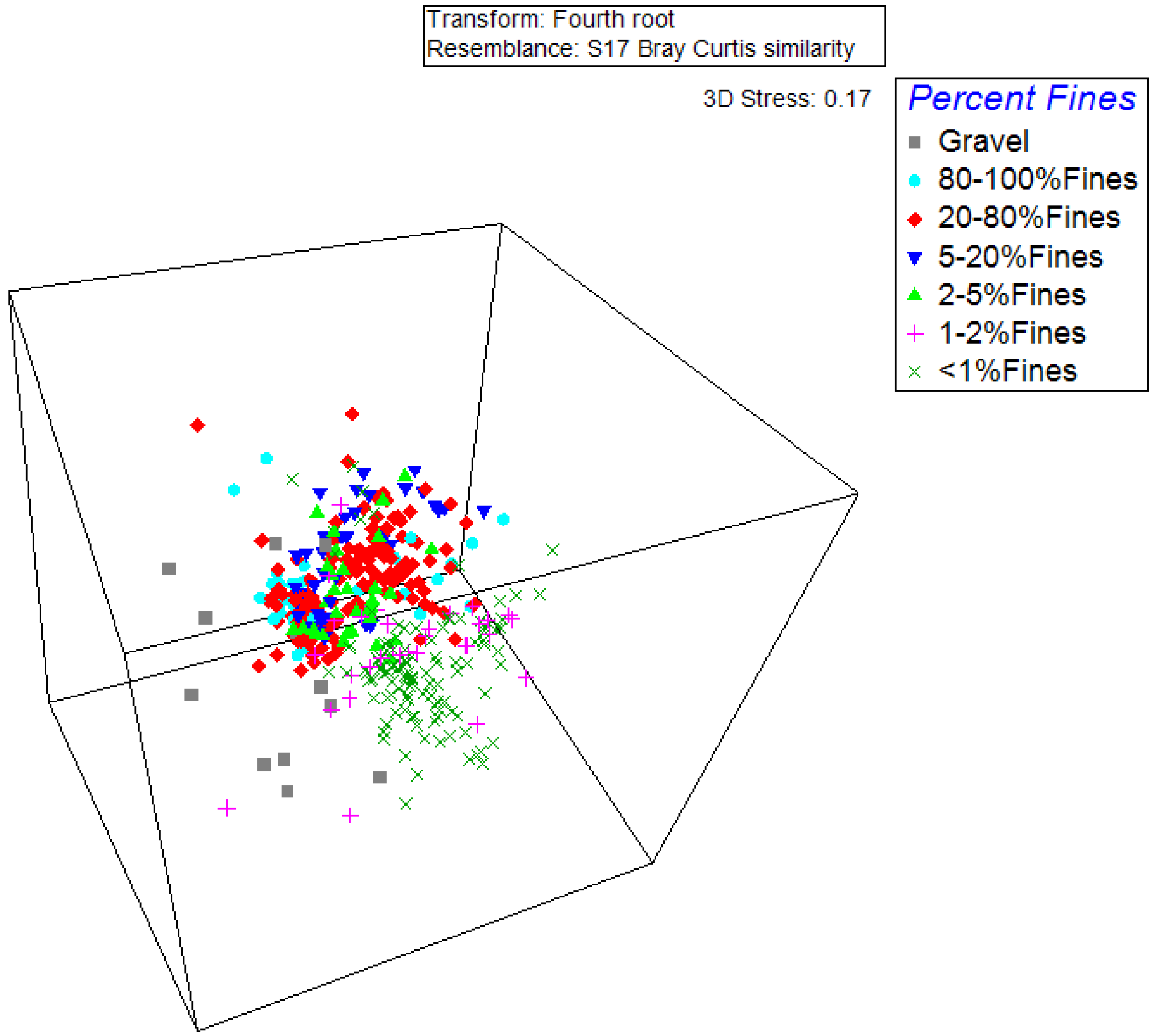

Figure 2. Three-dimensional nMDS plot of all 404 stations.
Gravel stations are grey boxes on the left side of the plot.

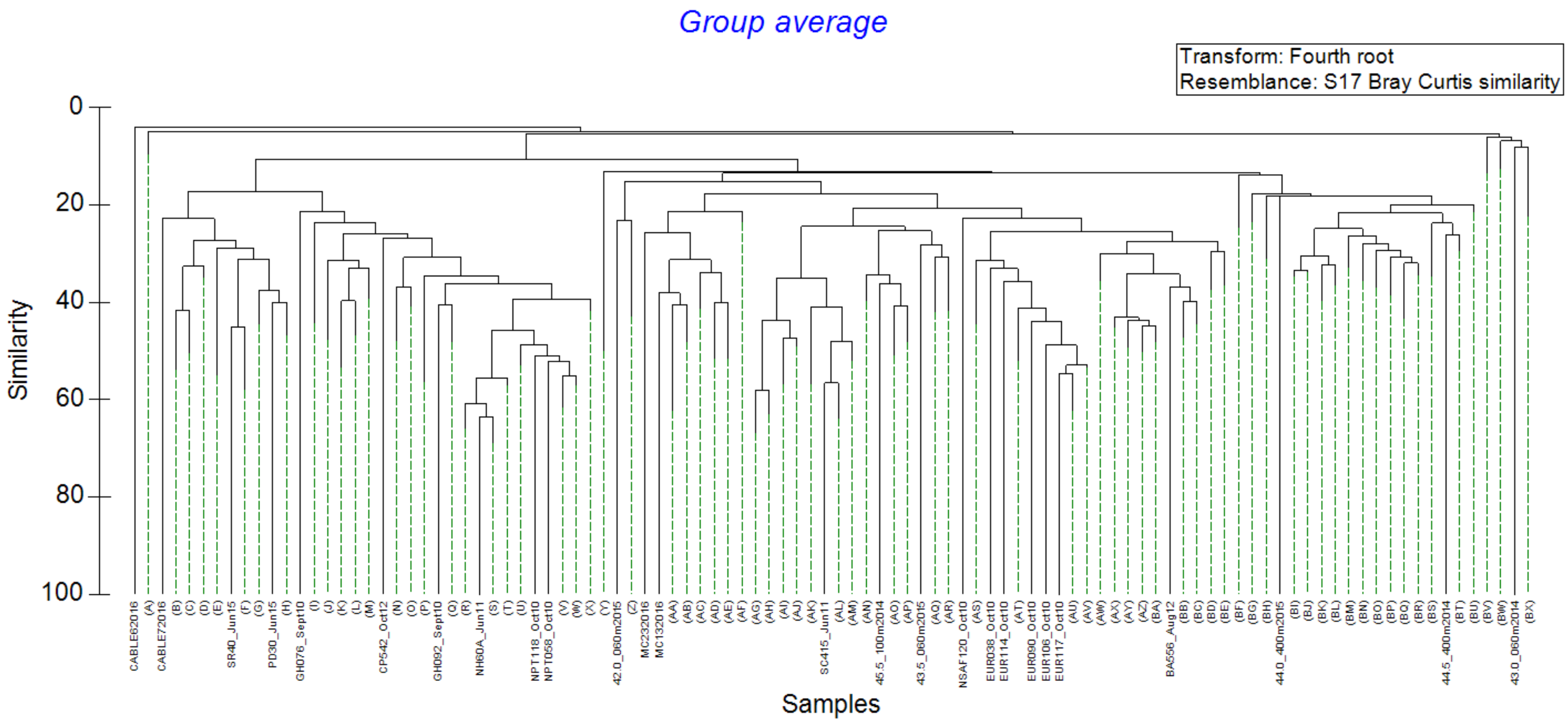

Figure 3. Dendrogram developed using the 393 stations (gravel-containing stations removed prior) showing the multi-station clusters (groups indicated with letters in parentheses) and the singletons.
Significance evaluated at the 1% level found 76 distinct groups and 15 singletons, which were removed for final analysis.

A final resemblance matrix of the 378 stations was created for the entire suite of taxa, and individual matrices were created for polychaetes, molluscs, crustaceans, and echinoderms. These resemblance matrices were then compared between all pairs of sub-groups, and sub-groups were compared to the matrix based on all taxa using the RELATE procedure in PRIMER to determine if patterns were similar for the different subgroups and which subgroup was most similar to the matrix generated with all taxa.

The final set of 378 stations were plotted on 2-D and 3-D MDS planes and potential physical correlates to MDS axes were assessed. Here we included all station and sample data [Latitude, Depth, sediment fraction less than 62.5 µm (Fines%), Mean Grain Size, Median Grain Size, total organic carbon (TOC), total nitrogen (TN), and bottom values from CTD casts (Temperature, DO, Salinity, Fluorescence, Turbidity, Beam Transmission, and pH)]. We also included upwelling indices from NOAA's Pacific Fisheries Environmental Laboratory (https://www.pfeg.noaa.gov/products/PFELData/upwell/monthly/upindex.mon) for the month of sampling (UpwellingMon), the previous month (UpwellingPrev), and the average for the year (UpwellingYear) for the latitudinal zone of each of the stations. Those parameters with greater than $R = 0.4$ to any MDS axis were plotted on the included 2-D plot.

To determine which measured environmental factors "best" described the distribution of macrofaunal invertebrates across the study region, the BIO-ENV (BEST) procedure was used to find the subset of environmental variables (summarized as pairwise normalized Euclidean distance) with the strongest Spearman rank correlations to the macrofauna observed among the samples (summarized as pairwise Bray Curtis similarities). The BEST procedure requires a complete inventory of biological and environmental data at all stations in the two similarity matrices for analysis; thus, only Latitude, Longitude, Depth, Fines%, Mean Grain Size, Median Grain Size, UpwellingMon, UpwellingPrev, and UpwellingYear could be considered in the analysis of all stations. We additionally conducted a BEST analysis using only the stations ($n = 249$) for which we had the majority of the environmental data (16 variables; Table 1). In both cases environmental data were normalized prior to running the procedure.

Table 1. The 16 environmental variables for which we had data for most (249) stations.
Variables in italics are those for which we had data for all (378 stations).

Station Data	Sediment Data	CTD Data	Indices
Latitude	*Fines%*	Temperature	*UpwellingMon*
Longitude	*MeanGS*	Dissolved Oxygen	*UpwellingPrev*
Depth	*MedianGS*	Salinity	*UpwellingYear*
	TOC	Fluorescence	
	TN	pH	

The variables determined to be highly correlating with the species assemblage patterns were then used as the starting point to classify the stations in the LINKTREE procedure in PRIMER 6. The LINKTREE procedure is a form of constrained cluster analysis involving a divisive partition of the biotic community samples into ever smaller groups, but in which each division has an 'explanation' in terms of a threshold on one of the environmental variables (Clarke et al. 2008). We constrained the minimum group size to be two stations (so as not to have singletons) and used the SIMPROF procedure (using the Bray-Curtis similarity index) to finalize the tree when there were no significant differences ($p < 0.01$) among the remaining stations. Within a resulting LINKTREE, each branch of the tree corresponds to a group of samples with similar macrofaunal composition (based on taxon and abundance); each split maximizes the Analysis of Similarity (ANOSIM) R statistic between macrofaunal groups and reports the threshold value of the environmental variable associated with that division (Clarke et al. 2008). If a threshold in more than one environmental variable corresponds to a break between groups of stations in the LINKTREE, threshold values for both variables are reported. We wanted to explore which combination of physical variables yielded the most parsimonious LINKTREE (i.e., the fewest number of splits). Thus, we created LINKTREEs using each of the physical parameters individually, in pairs, in trios, in groups of four, and with all the potential predictors.

Additionally, abundance, areal taxa richness, and Shannon-Weiner diversity were calculated from the 378 stations (samples) and plotted against depth to summarize how macrofaunal abundance and diversity changed across the shelf and the upper slope and the significance of that relationship was tested using linear regression. Abundance equals the number of all animals per station, areal (sample) richness is the number of taxa per box core (0.1 m^2 area of seafloor), and numerical richness is the number of taxa per number of individuals at a station. Shannon's diversity index (H' diversity) weights the geometric mean of the proportional abundances of the taxon groups.

3.3 Results

The final dataset for analysis of 378 stations ranged from 18.2 m deep to 525 m deep and from 39.5° to 47° N. Actual penetration depth of the box corer averaged 21.3 cm with a median of 23.75 cm for an average total core volume of over 2000 cm^2.

The highest correlations among environmental parameters were between percent fine sediment and mean and median grain size (-0.76/-0.77), as expected as they are different measures of the same component. The second highest correlations were between TOC/TN and percent fine sediment (0.84/0.81) followed by TOC/TN correlations with depth (0.78/0.79). Latitude correlated most strongly with upwelling (as we based the upwelling indices on the latitude of the stations) and secondarily with percent fines (-0.60). Correlates among all environmental variables are given in Figure A-1 in the Appendix.

Organism abundances ranged from 10 to 542 individuals per 0.1 m^2 grab, and sample richness ranged from 5 to 64 taxa per grab. In total, 757 taxa were identified and included for analysis, most to the species level. Seven of the top ten most abundant species in the entire dataset were bivalves with two polychaetes and the pea crab, *Pinnixa occidentalis* complex, making up the other three (see Tables A-2 through A-5 in the Appendix). Overall, both organism abundance and sample richness (per 0.1 m^2) declined significantly ($p < 0.001$) with depth; however, no significant response to depth was detected for Shannon's diversity index ($p = 0.753$) while numerical species richness (number of taxa per number of individuals per grab) significantly increased ($p < 0.001$) with depth (Figure 4). The resemblance matrix generated with the full suite of taxa was most similar to molluscs only with a Rho of 0.828 and secondarily similar to the polychaetes only with a Rho of 0.751. The resemblance matrices of the different groups compared amongst each other were not highly related (Table 2).

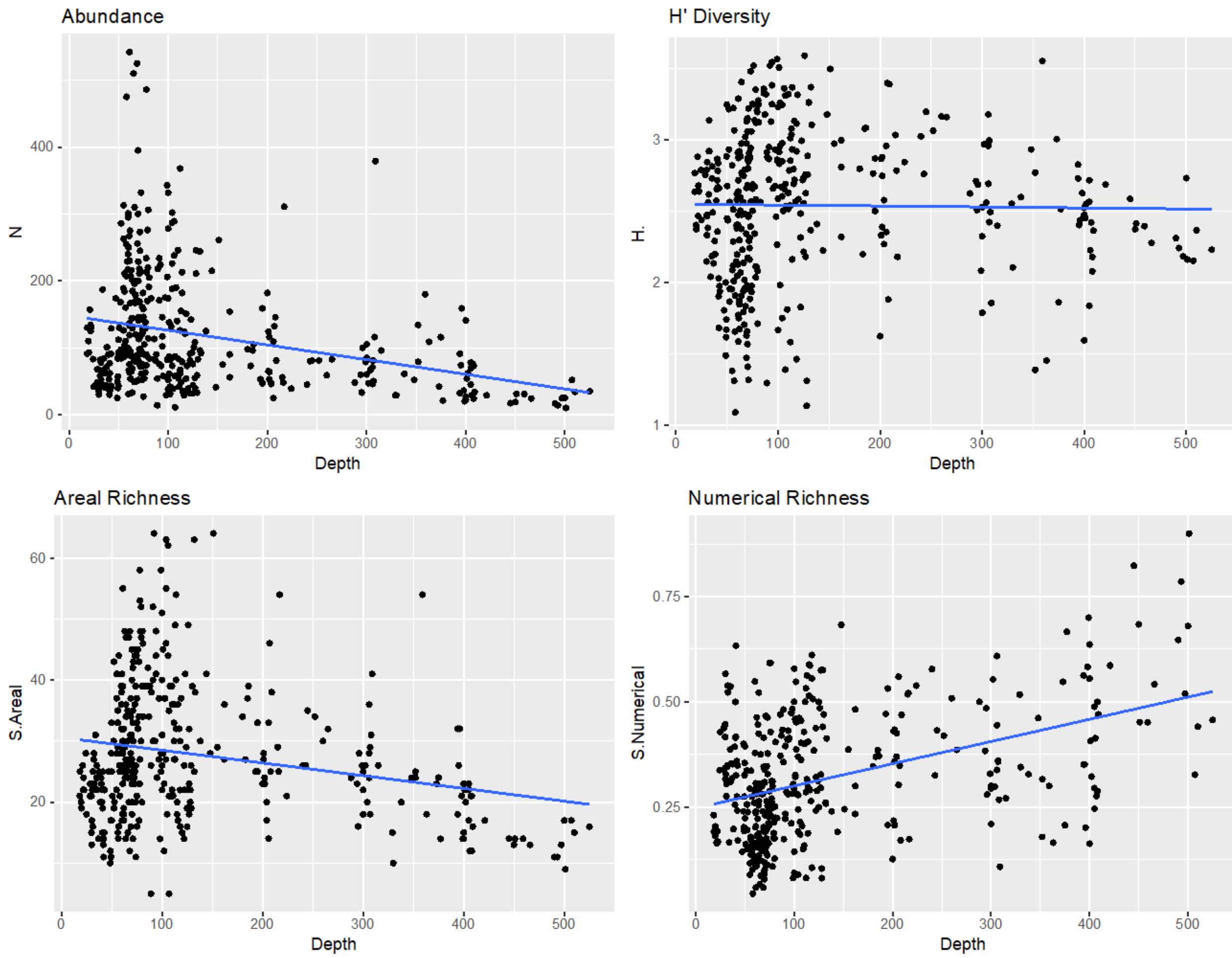

Figure 4. Response to depth for abundance (a), areal (sample) richness (b), H' diversity (c), and numerical richness (d).

Table 2. RELATE values for resemblance matrices generated from different suites of taxa.

Taxon Group	Taxon Group	RELATE Value
All taxa	Molluscs	0.828
All taxa	Polychaetes	0.751
All taxa	Crustaceans	0.461
All taxa	Echinoderms	0.377
Polychaetes	Molluscs	0.392
Polychaetes	Crustaceans	0.269
Polychaetes	Echinoderms	0.230
Molluscs	Crustaceans	0.304
Molluscs	Echinoderms	0.200
Crustaceans	Echinoderms	0.127

The MDS indicated a separation of assemblages with less than 2% fines, with 2-5% fines intermediate between those low silt containing stations and the remainder. Stations with >5% fines did not appear to further separate based on Folk (1974) defined breaks in silt content (Figure 5). Depth was the highest correlate with MDS1 (r = -0.725 for 2-D) with sediment grain size parameters the second highest correlate with MDS1. Stress was quite high for the 2-D MDS, and there were no correlates higher than 0.5 with the second MDS axis. Thus, the correlates to the 3-D MDS were determined and reported (Table 3). Depth and sediment grain size parameters remained the highest correlates of MDS1, followed by CTD parameters and the upwelling index for the previous month. Depth (again) and dissolved oxygen were the highest correlates of MDS2. All correlations of environmental variables with MDS3 were low.

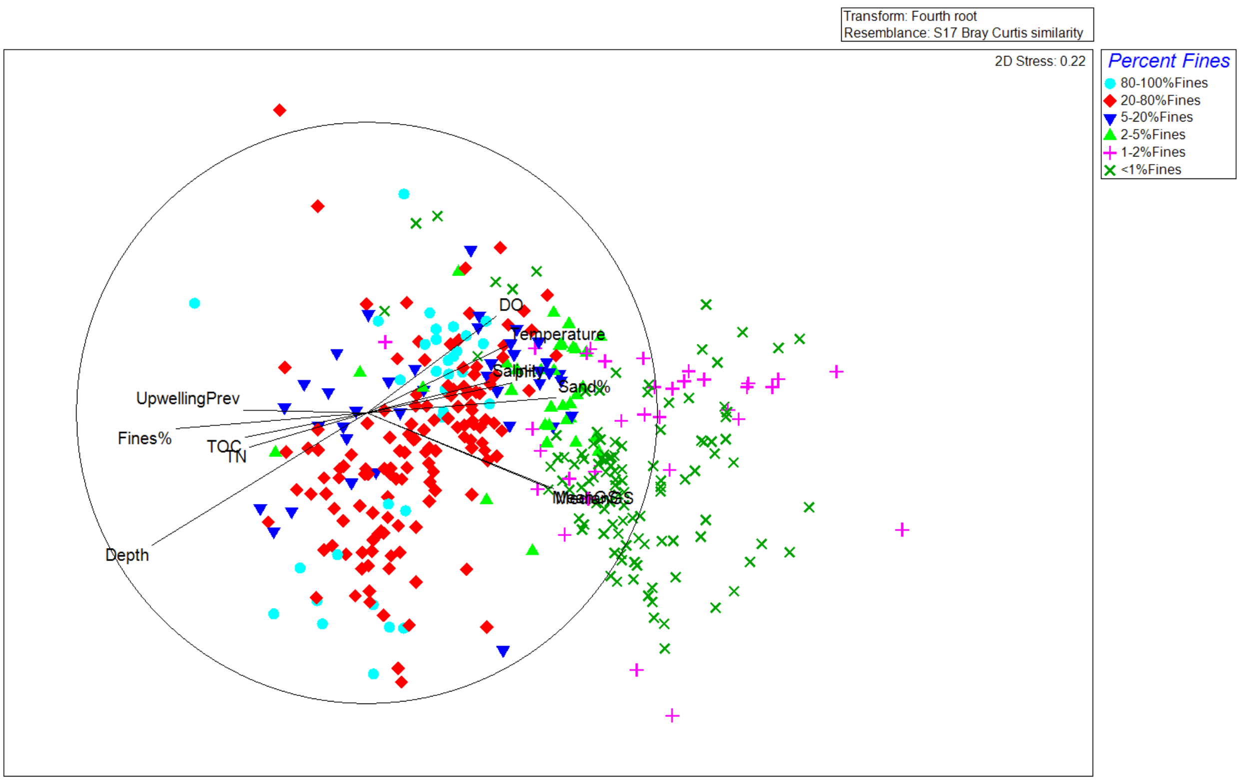

Figure 5. MDS of final 378 samples with vectors for environmental variables correlating at least 0.4 with MDS1 (listed in Table 3).
Stations are plotted according to the Folk (1974) percent fines classification with the addition of <1% and 1-2% fines based on the findings of Henkel and Politano (2017).

Table 3. Correlates with the 3-D MDS axes.
Variables were included in the table if they correlated >0.4 with any axis on the 3-D MDS plot. Bolded values on MDS1 are included on Figure 5.

	Depth	Fines%	Mean GS	Median GS	TOC	TN	Temp	DO	Salinity	pH	Upwell Prev
MDS1	**0.722**	**0.702**	**-0.684**	**-0.695**	**0.446**	**0.424**	**-0.468**	**-0.412**	**-0.414**	**-0.488**	**0.472**
MDS2	-0.502	-0.125	-0.221	-0.217	-0.111	-0.143	0.238	0.362	0.124	0.117	-0.028
MDS3	0.162	-0.268	0.055	0.035	-0.196	-0.177	-0.321	-0.176	-0.268	-0.283	-0.201

The BEST match between the biological data and the environmental data for which we had complete coverage used just two variables: depth and median grain size, with a rather high correlation ($r = 0.643$); however, we could not take any water column parameters or sediment TOC/TN into account in the full BEST analysis because we did not have data for all stations. Using just the stations ($n = 249$) for which we had the majority of environmental data (Table 1) the highest correlation used depth, mean grain size, median grain size, TOC, and fluorescence with $r = 0.655$ (using just depth and median grain size with the subset of stations resulted in $r = 0.637$). Despite being included in the BEST results, fluorescence's highest correlation with any MDS axis was just -0.283 with MDS1.

The initial LINKTREE run using only depth and median grain size resulted in 101 splits. Adding latitude resulted in a LINKTREE with 71 splits: the lowest number of splits with the fewest variables (see Table A-6 in the Appendix for all options) and only two more than using all the physical parameters, for a total of 72 distinct groupings of stations (Figure 6). Among the 71 splits, four minor splits (F, K, Q, AH) could be described by more than one of the three environmental variables. ANOSIM of these 72 groups had a global R of 0.892. We grouped the 72 termini of the LINKTREE into 12 major habitats based on a cut-off of 25% separation, plus one further major sediment split at B=18.6% (separating groups IV and V). We did not include splits with higher B% that resulted in < 5 stations on a terminus as we deemed those more outliers rather than separate habitats. Analyzing these 12 habitat types using ANOSIM resulted in a global R of 0.792.

The average values of the physical parameters that correlated with the MDS axes are given in Table 4 for each habitat group. Also shown are the average number of species and the average number of organisms per 0.1 m^2 box core grab. The individual average abundance per 0.1 m^2 box core and the cumulative percentage contribution to within group similarity of the top 12 "characteristic" species (those species whose abundances are highly contributing to the average similarity within a group as determined by SIMPER) of the 12 regional habitat groups determined by the LINKTREE analysis are shown in Table 5.

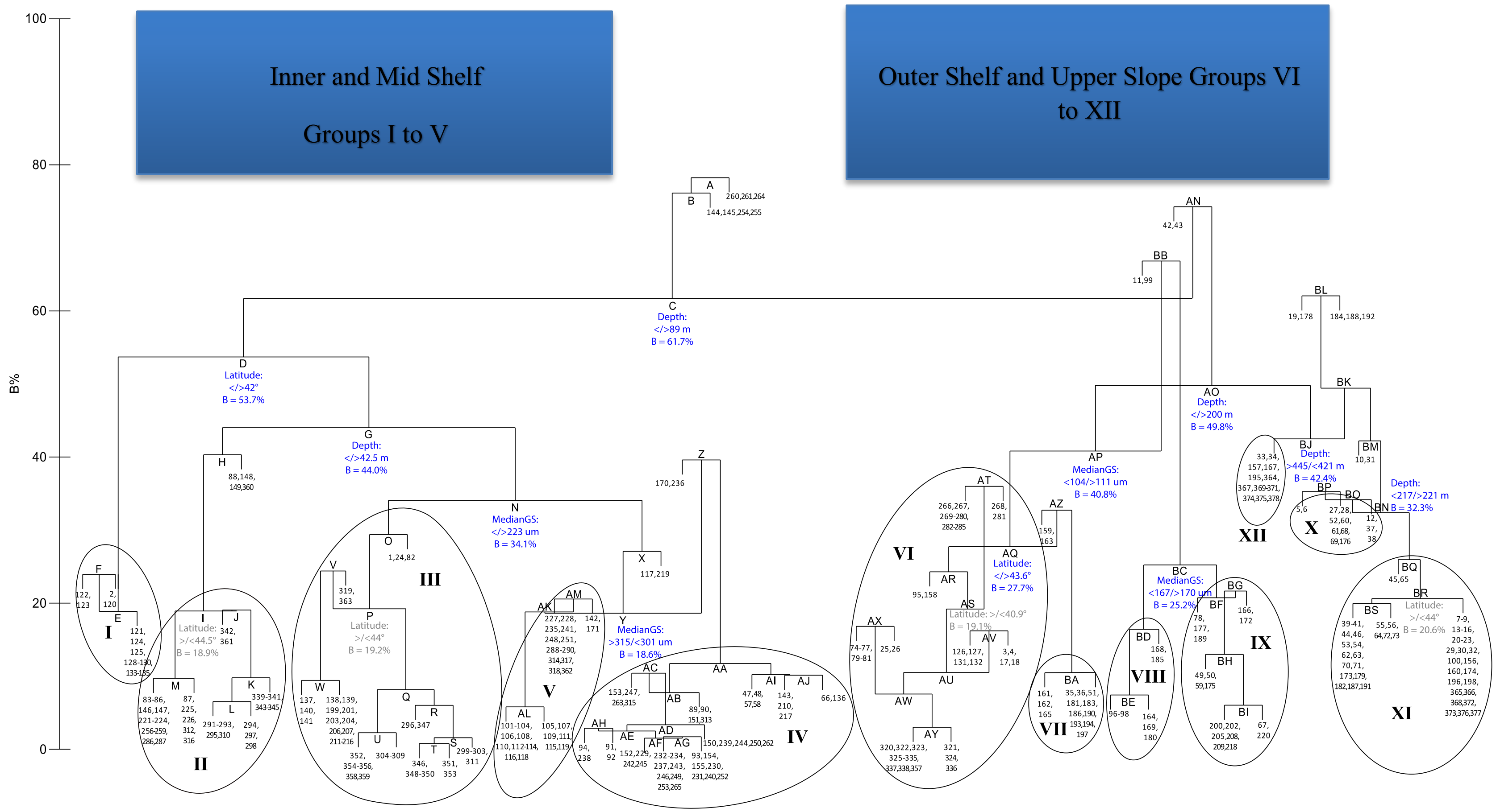

Figure 6. Final LINKTREE of 378 stations using depth, median grain size, and latitude to determine splits. Breaks that were used to determine the 12 regional-habitat groups are detailed in blue.

Table 4. Number of stations, average physical properties, sample richness, and organism abundance per grab for the stations that make up each of the 12 regional-habitat groups as well as the averages for the outliers in each depth division.

Supervised Group	N	Depth (m)	Fines %	Mean GS	Median GS	TOC	TN	Temp (°C)	DO (ml\L)	Salinity	pH	Avg. Rich	Avg. Abund.
I: Mid-Shelf Muddy NorCal	13	65.2	68.4	53.2	48.7	0.72%	0.07%	9.01	3.10	33.72	7.81	41.7	167.2
II: Inner Shelf (Clean Sand)	41	33.8	0.5	256.6	236.0	0.07%	0.01%	8.01	2.52	33.66	7.73	21.2	68.6
III: Mid Shelf <223 um	48	69.6	7.8	185.3	175.7	0.31%	0.03%	7.58	1.90	33.79	7.69	37.3	195.1
IV: Mid Shelf <301 um	46	63.7	0.4	286.8	251.4	0.08%	0.01%	7.71	1.69	33.76	7.67	26.3	179.6
V: Mid Shelf >315 um	33	63.9	0.4	459.6	430.1	0.07%	0.01%	7.79	1.68	33.78	7.73	20.8	94.1
VI: Outer Shelf <104 um North	15	161.5	50.0	72.4	68.2	1.38%	0.14%	7.28	1.78	33.82	7.71	30.9	103.9
VII: Outer Shelf <104 um South	59	114.9	63.2	55.4	48.3	0.91%	0.10%	8.31	2.02	33.68	7.72	27.7	111.0
VIII: Outer Shelf 111-167 um	8	122.3	9.3	152.5	145.9	0.59%	0.06%	7.49	1.83	33.88	7.72	47.4	184.4
IX: Outer Shelf >170 um	17	100.2	3.5	230.5	205.8	0.26%	0.03%	7.49	1.81	33.82	7.72	43.4	147.5
X: Slope Break	13	207.4	38.7	144.9	118.5	1.24%	0.14%	7.30	2.35	33.96	7.88	29.2	96.5
XI: Upper Slope	48	336.1	47.5	90.1	76.5	1.47%	0.16%	6.42	1.45	34.02	7.78	23.7	75.8
XII: Slope	13	484.2	80.9	39.0	28.4	1.62%	0.17%	5.28	0.69	34.13	7.66	13.6	25.7
Inner Shelf Outlier	4	19.0	0.55	197.6	193.3	n.d.	n.d.	7.84	2.13	33.67	7.70	21.3	106.0
Mid Shelf Outlier	7	70.2	0.8	508.6	479.4	0.12%	0.02&	7.63	1.35	33.83	7.65	17.9	60.1
Outer Shelf Outlier	4	124.5	16.6	325.3	272.2	n.d.	n.d.	7.68	2.31	33.87	7.72	15.0	48.3
Slope Outlier	9	354.1	65.6	96.7	73.2	2.46%	0.29%	6.56	1.51	34.03	7.81	22.2	57.2

Table 5. The top 12 characteristic species of the 12 regional habitat groups.
Species and percent characteristic (Cum. %) were determined using SIMPER. Average abundance per 0.1 m^2 box core in each group and the cumulative percentage contribution to within group similarity are listed.

I. Mid-Shelf Muddy NorCal	Avg. similarity: 41.15	
	Av. Abund	Cum.%
Axinopsida serricata	33.2	9.62
Ennucula tenuis	16.3	18.12
Ninoe gemmea	4.3	23.21
Ampelisca careyi	2.7	28.25
Magelona longicornis	1.5	32.69
Macoma spp	1.7	36.72
Sternaspis fossor	3.2	40.69
Acteocina spp	1.4	44.56
Euclymeninae spp	0.9	48.09
Turbonilla spp	0.8	51.62
Paraprionospio alata	0.8	55.12
Maldane sarsi	1.2	57.93

II. Inner Shelf Clean Sand	Avg. similarity: 30.60	
	Av. Abund	Cum.%
Callianax pycna	1.6	9.40
Carinoma mutabilis	1.0	17.88
Scoloplos acmeceps	0.7	24.60
Majoxiphalus major	0.6	30.58
Dendraster excentricus	0.3	35.74
Chaetozone bansei	0.3	40.41
Nephtys caecoides	0.2	44.91
Rhepoxynius vigitegus	0.4	48.96
Magelona sacculata	0.2	53.00
Eohaustorius sencillus	0.3	56.73
Rhepoxynius spp	0.2	60.42
Eohaustorius sawyeri	0.2	63.84

III. Mid Shelf <223 um	Avg. similarity: 31.78	
	Av. Abund	Cum.%
Axinopsida serricata	37.2	14.51
Ennucula tenuis	2.4	20.85
Pinnixa occidentalis complex	3.0	25.72
Acila castrensis	1.6	30.60
Amphiodia urtica	0.7	34.05
Onuphis iridescens	0.4	37.17
Kurtiella tumida	1.4	40.24
Scoletoma luti	0.5	42.91
Ampelisca careyi	0.3	45.56
Nephtys spp	0.2	48.07
Cylichna attonsa	0.2	50.56
Rhepoxynius spp	0.2	52.86

IV. Mid Shelf <301 um	Avg. similarity: 39.72	
	Av. Abund	Cum.%
Axinopsida serricata	32.6	15.01
Nutricola lordi	29.0	27.73
Cylichna attonsa	4.2	37.10
Magelona sacculata	1.2	42.57
Ampelisca careyi	1.0	47.88
Euphilomedes carcharodonta	0.9	52.26
Callianax baetica	0.8	56.53
Spiophanes norrisi	0.4	59.99
Onuphis iridescens	0.5	63.36
Alia gausapata	0.6	66.56
Glycinde armigera	0.3	69.69
Carinoma mutabilis	0.2	71.88

V. Mid Shelf >315 um	Avg. similarity: 35.22	
	Av. Abund	Cum.%
Nutricola lordi	10.0	14.78
Ophelia assimilis	3.2	26.59
Spiophanes norrisi	1.1	34.13
Tellina nuculoides	1.0	41.23
Axinopsida serricata	1.9	48.28
Callianax baetica	0.6	54.40
Cylichna attonsa	0.4	58.66
Aphelochaeta spp	0.5	62.77
Axiothella rubrocincta	0.3	66.80
Alia gausapata	0.2	69.94
Microspio pigmentata	0.1	72.52
Pinnixa occidentalis complex	0.1	74.65

VI. Outer Shelf <104 um South	Avg. similarity: 32.38	
	Av. Abund	Cum.%
Axinopsida serricata	14.5	13.32
Acila castrensis	3.3	22.16
Macoma carlottensis	2.9	30.88
Amphioplus strongyloplax	1.0	37.22
Onuphis iridescens	0.7	43.30
Adontorhina cyclia	0.5	47.50
Rhabdus rectius	0.5	51.15
Brisaster latifrons	0.2	53.99
Ninoe gemmea	0.2	56.69
Sternaspis fossor	0.2	59.32
Paraprionospio alata	0.1	61.93
Ennucula tenuis	0.2	64.11

VII. Outer Shelf <104 um North	Avg. similarity: 33.42	
	Av. Abund	Cum.%
Axinopsida serricata	17.7	13.92
Rhabdus rectius	4.8	22.73
Adontorhina cyclia	1.7	29.79
Pectinaria californiensis	1.7	36.61
Galathowenia oculata	2.6	42.43
Euclymeninae spp	0.5	46.18
Macoma carlottensis	0.5	49.92
Onuphis iridescens	0.4	53.60
Heterophoxus spp	0.5	57.13
Amphioplus macraspis	0.2	60.16
Ninoe gemmea	0.2	62.98
Amphiodia urtica	0.1	65.55

VIII. Outer Shelf 111-167 um	Avg. similarity: 33.37	
	Av. Abund	Cum.%
Spiochaetopterus costarum	12.5	6.23
Paraprionospio alata	1.5	11.97
Axinopsida serricata	6.2	17.65
Magelona longicornis	3.3	22.77
Rhabdus rectius	3.1	27.53
Amphioplus macraspis	2.0	32.28
Nephtys ferruginea	1.2	36.91
Paradiopatra parva	1.3	41.22
Euclymeninae spp	1.1	45.13
Myriochele gracilis	1.8	48.53
Thyasira flexuosa	0.8	51.85
Glycinde armigera	0.4	54.68

IX. Outer Shelf >170 um	Avg. similarity: 31.08	
	Av. Abund	Cum.%
Pista estevanica	1.9	5.19
Acila castrensis	1.5	9.98
Amphiodia urtica	1.1	14.70
Axinopsida serricata	2.6	19.12
Onuphis iridescens	1.0	23.36
Cylichna attonsa	1.0	27.55
Magelona berkeleyi	1.6	31.52
Ennucula tenuis	1.5	35.36
Prionospio steenstrupi	1.6	39.13
Glycera nana	0.4	42.26
Huxleyia munita	0.8	45.18
Paraprionospio alata	0.4	48.01

X. Slope Break (200 – 221 m)	Avg. similarity: 24.27		XI. Upper Slope (221–445 m)	Avg. similarity: 29.33	
	Av. Abund	Cum.%		Av. Abund	Cum.%
Axinopsida serricata	3.8	13.04	*Huxleyia munita*	8.8	16.68
Adontorhina cyclia	2.4	25.59	*Galathowenia oculata*	1.9	25.29
Galathowenia oculata	4.4	33.70	*Gadila tolmiei*	0.9	33.74
Heterophoxus spp	0.3	39.18	*Onuphis iridescens*	0.8	41.78
Onuphis iridescens	0.5	43.80	*Brisaster latifrons*	0.4	48.61
Sternaspis assimilis	0.2	48.08	*Ennucula tenuis*	0.4	54.89
Rhabdus rectius	0.2	52.26	*Chaetoderma argenteum*	0.4	60.69
Maldane sarsi	0.2	56.32	*Rhabdus rectius*	0.2	64.65
Aricidea (acmira) simplex	0.2	59.26	*Adontorhina cyclia*	0.2	67.97
Amphioplus macraspis	0.1	62.18	*Amphioplus macraspis*	0.1	70.76
Huxleyia munita	0.1	64.22	*Axinopsida serricata*	0.1	73.41
Mendicula ferruginosa	0.1	66.25	*Pectinaria californiensis*	0.1	75.86

XII. Slope (445 – 525 m)	Avg. similarity: 28.05	
	Av. Abund	Cum.%
Huxleyia munita	1.00	17.16
Rhabdus rectius	0.50	29.31
Maldane sarsi	0.70	40.54
Chaetoderma argenteum	0.30	49.52
Glycinde armigera	0.10	56.33
Phoronidae sp	0.20	61.89
Gadila tolmiei	0.06	66.47
Brisaster latifrons	0.04	70.27
Cerebratulus spp	0.03	73.44
Praxillella gracilis	0.03	76.27
Eucranta anoculata	0.03	79.08
Artacama coniferi	0.03	81.76

The first major split in the LINKTREE (C) was associated with a depth break at 89 m. We classified the shallower side of this split (left side of the tree) as mid and inner shelf habitats. Within this group, the next split (D) was a latitude split at 42°, which is essentially the Oregon-California (OR-CA) border. Stations on the left side of this split were from the site off Eureka, California, except for one: the southern-most station sampled in Oregon. This “Mid-Shelf Muddy NorCal” group (Group I) of stations ranged 52 to 77 m deep and had much higher percent fine sediment (68.4%) than the rest of the mid to inner shelf stations (average 2.5%). The mid-shelf, muddy northern California community was characterized by the ubiquitous bivalves *Axinopsida serricata* and *Ennucula tenuis*. Unique to Group I were the polychaetes *Ninoe gemmea*, *Magelona longicornis*, and *Sternaspis fossor*, which are uncommon on the sandier, mid-shelf stations of Oregon.

The next split (G) define a break between the inner- and mid-shelf. Stations on the shallower side of this split ranged 18.2 to 42.5 m deep and consisted mostly of clean sand (0 – 1.82% fines) with average median grain size of 235 µm; thus, we called this “Inner Shelf Clean Sand” (Group II). The top characteristic species of this group were the snail *Olivella (Callianax) pycna*, the nemertean, *Carinoma mutabilis*, the polychaete, *Scoloplos acmeceps*, the amphipod, *Majoxiphalus major*, and the sand dollar, *Dendraster excentricus*, of which only the polychaete was characteristic in any other habitats. Notably, no bivalves were in the top 12 characteristic species for the Inner Shelf Clean Sand habitat. A subsequent split in this group was detected at 44.5° latitude with a separation value of 18.9%.

On the mid-shelf (depths 42.8 – 88 m) the next split (N) was at </>223 µm. On the mid-shelf where grain sizes were less than 223 µm (left side of split N, Group III), stations averaged 7.8% fines and hosted slightly different assemblages in the north and south of the study region (44.0 °N split P, with a similarity of 18.6%, similar in separation value and latitude as found in Group II). As in California at these depths, the bivalves *A. serricata* and *E. tenuis* were highly characteristic, and these regions shared three other characteristic species. Additionally, the pea crab, *Pinnixa occidentalis* complex, and the bivalves*, Kurtiella tumida and Acila castrensis* were highly contributing (particularly in the south) as well as the brittle star *Amphiodia urtica* and *Onuphis iridescens* (particularly in the north). Larger than 223 µm, stations were further subdivided into <301/>315 µm (split Y, Group IV and V). Here, bivalves were abundant, particularly *Nutricola lordi* and the ubiquitous *A. serricata*, along with the gastropods *Cylichna attonsa, Callianax baetica*, and *Alia gausapata*. The larger grain sized group (Group V) had the bivalve *Tellina nuculoides* as the 4^{th} most characteristic species, which was uncommon among stations in the <301 µm group (Group IV) and *A. serricata* was far less abundant in this grain size class than anywhere else on the mid shelf. Most differences between Groups IV and V were in the characteristic polychaetes: only *Spiophanes norrisi* was shared.

The deeper waters (right side of C) were structured similarly to the inner and mid shelf groups, having three grain size groups and lower separation latitudinal breaks within four Outer Shelf and three slope groups. The four outer shelf groups (89 to 200 m and left side of AO) are defined by grain size. The smaller grain size stations (< 104 µm) split into a southern (Group VI) and northern (Group VII) groups (AQ at a latitude of 43.6°). This latitudinal break is similar to the break found in the mid-shelf within Group III at 44.0° and inner-shelf Group II at 44.5°. At these smaller grain size (< 104 µm) stations, bivalves *Macoma carlottensis* and *Adontorhina cyclia* (both regions) and *Acila castrensis* (in the south, Group VI) were more characteristic than the less abundant, *E. tenuis*. *Amphioplus* spp. brittle stars (different species in north and south) replaced *A. urtica*, and the heart urchin *Brisaster latifrons* was characteristic of the southern group (Group VI). The scaphopod, *Rhabdus rectius* was characteristic of both groups. Within the southern group (Group VI), a second latitudinal break was detected at 40.9° latitude (isolating the California stations from southern Oregon) with a Similarity (B) value of 19.1%. In the Outer Shelf > 111 µm group there was a secondary split at <167/>170 µm (BC forming Groups VIII and IX). In the Outer Shelf 111-167 µm group (Group VIII) polychaetes were the most highly contributing species along with *A. serricata*, *R. rectius*, and *A. macraspis*. In the largest grain size class on the outer shelf (>170 µm, Group IX), a different suite of polychaetes was characteristic, along with, *Amphiodia urtica, Acila castrensis* and *Cylichna attonsa*, all of which are characteristic of mid-shelf stations with similar grain size (Group III).

Split AO represents the 200 m shelf-slope break. The next split (BJ) isolated stations 445 m to 525 m with no subsequent distinctions based on sediment characteristics or latitude (although we only sampled stations that deep from 43.40°N to 43.75 °N). The Slope assemblage (Group XII) had only 28.05% within group similarity and was characterized primarily by the bivalve, *Huxleyia munita*, and the scaphopod, *Rhabdus rectius*. Polychaetes *Maldane sarsi* and *Glycinde armigera* and the "glistenworm" *Chaetoderma argenteum*, a shell-less mollusc, also were in the top five characteristic species. Split BN then isolated stations less than 217 m deep on the slope. These Slope Break stations (Group X) had the lowest within group similarity (24.27%; constituting three separate groups on the LINKTREE) and were characterized by both common shelf and slope taxa. A latitudinal break at 44 °N (BR) – as on the shelf – was detected in the remaining 56 Upper Slope stations between 224 and 445 m deep. Collectively, the Upper Slope stations were characterized primarily by the bivalve, *Huxleyia munita*, polychaetes, *Galathowenia oculata* and *Onuphis iridescens* and scaphopods *Gadila tolmiei* and *Rhabdus rectius* (particularly in the south). The bivalves *Ennucula tenuis* and *Adontorhina cyclia,* the heart urchin, *B. latifrons,* and the glistenworm *C. argenteum* also were characteristic.

3.4 Discussion

Establishing an understanding of benthic species-habitat associations over broad spatial scales is useful to marine spatial planning for many purposes including the siting and evaluating offshore renewable energy projects. Just as isolated mapping data was not sufficient for the groundfish EFH process, knowing that 100 worms were found in sand at one specific site does not alone provide the tools for resource managers to assess benthic resources or describe potential impacts from human activities on the sea floor. However, knowing the distributions of benthic invertebrates at a regional scale provides data applicable to cumulative impact assessments and context for project-specific surveys.

We sought to classify benthic sedimentary habitats across the shelf and upper slope in the PNW based on the macrofaunal organisms living in and on the sediment. This and a previous BOEM study (Henkel et al. 2014) represent the first attempts to examine spatial variability in macrofaunal communities with consistent sampling and identification methodology from the inner shelf, across the shelf break, and down the slope in the eastern north Pacific.

Previous studies in the region focused only on the mid to outer shelf, and did not find major distinctions in macrofauna assemblages based on depth but found very distinct breaks correlated with sediment characteristics (Henkel and Politano 2017, Henkel and Nelson 2018). In this current study, spanning a much broader depth range, we did find major differences in macrofauna assemblages based on depth with subsequent distinctions related to sediment characteristics within major depth zones. This pattern follows that observed by Lissner (1989) in the northern and central California planning regions, where the major pattern in benthic community sampled between 90 and 600 m deep was related first to depth and then sediment-size characteristics, while other inter-basin differences (e.g., temperature and dissolved oxygen) appeared to have minor influence. Similarly, Bergen et al. (2001) sampled fauna from 10 to 200 m deep in southern California and found depth and secondary grain size-related distinctions, but did not identify any influence of latitude in defining assemblages. Our BEST result (Rho = 0.643 using just depth and median grain size) is numerically similar to the findings of Shumchenia and King (2010) from Narragansett Bay, where they found Rho = 0.689 with water depth, percent sand, and standard deviation of backscatter as variables.

We expected the shelf-slope break to be the most dramatic break in macrofauna assemblages. In Oregon the outer edge of the shelf has been reported as ranging 130 to 183 m deep (Byrne and Panshin 1977), and BOEM defines the edge of the OCS as 200 m consistent with Mendal (1964) and Davis (1972). However, the break in physical parameters resulting in the most distinctive assemblages was depth at ~90 m. Although unexpected, a transition at this depth has been reported before. While Bergen et al. (2001) classified the outer shelf as beyond 115 m, they explained that the transition between the two assemblages was found at depths of 90 to 115 m and cited earlier surveys conducted by the Hancock Foundation that found the deeper limit of their mid-depth assemblage to be 92 m (Barnard and Hartman 1959, Barnard and Ziesenhenne 1960, Jones 1964, 1969). This assemblage break at 90 m was also found when Henkel et al. (2014) used cluster analysis on the 2003 WEMAP macrofaunal dataset in the BOEM-BHC project. In describing the distribution of organic carbon in surface sediment in the northeast Pacific Ocean, Gross et al. (1972) referred to the inner continental shelf as < 90 m and the outer continental shelf as 90 – 180 m, supporting the 90 m delineation in macrofaunal clusters found by our study; associating TOC differences with this boundary may suggest that sediment organic carbon may be the causative factor in this observed depth break on the shelf. While depth and TOC were strongly positively correlated at our sampled stations (Figure A-1) without an obvious break at 90 m (Figure A-2), deeper than 90 m, there are no stations with less than 0.15% TOC. In our current study, deeper than 90 m the next major break was at 200 m, consistent with what is considered the edge of the continental shelf (Mendal 1964, Davis 1972) and the major break in the dendrogram constructed by Lissner (1989) for central and northern California OCS macrofauna collected from 90 to 600 m deep.

Beyond 200 m, stations deeper than 445 m held distinct assemblages, a depth break similar to the edge of the mid-slope as reported by Lissner (450 m) and consistent with the break in Hyland's (1991) stations where a break was detected between 410 and 565 m (no stations in between were sampled). Shallower than 90 m, we detected a depth break at ~43 m. This is slightly shallower than the distinct break in bivalve assemblages in Oregon reported by Voohries et al. (2018; 50 m), but the same as the deeper bounds of the shallow clusters determined in Bergen et al. (2001) for southern California. The approach used by Lissner (1989) and Bergen et al. (2001) was to build cluster dendrograms based on the macrofaunal assemblages, correlate those clusters with physical parameters, and then rank which parameters most contributed. In our approach, we used the LINKTREE routine to find breaks in the physical parameters that maximized differences among the biological assemblages at the stations. Considering that the studies were conducted in three different regions with overlapping but not continuous depth ranges using different statistical approaches, it is remarkable that similar depth delineations were found among them.

In addition to the species composition changes with depth, species richness also varied with depth. The number of species per grab (sample or areal richness) and the number of organisms per grab (abundance) declined with depth, and both of these trends also were described by Lissner (1989) and Oliver et al. (2011). Since the number of species can be positively related to the number of individuals, there is an argument that a decline in the number of species per area may simply be the result of having fewer individuals in the sample (Gotelli and Colwell 2001). Standardizing by number of individuals avoids this statistical problem; although Oliver et al. (2011) argue for the importance of comparing communities in a known spatial context. In our study, when the number of species per grab was standardized by the number of organisms per grab the resulting numerical richness actually was highest at the deepest depth. At stations less than 90 m the numerical richness averaged 0.26, on the outer shelf (90 to 200 m) it averaged 0.35, the Slope Break averaged 0.38, the Upper Slope averaged 0.39, and on the Slope (445 to 525 m) it was 0.59 as has been found in other studies where numerical species richness peaks along the slope (Rex 1981, 1983; Levin et al. 2001). In contrast, Oliver et al. (2011) found that numerical species richness was quite similar across depths off California while Menot et al. (2010) found it to be highest along continental margins.

Within each of the depth zones, while further distinctions among macrofaunal assemblages were related to sediment characteristics – primarily median grain size – the biologically relevant breaks in grain size differed between the mid-shelf, outer-shelf, and slope. This lack of a consistent pattern across depths may be why other authors have reported grain size characteristics to be relatively more important at the local scale (e.g., Reiss et al. 2010). On the mid-shelf (43 – 90 m) in Oregon/Washington there appear to be three biologically defined habitats with increasing sediment grain size (III: < 223 μm, IV: <301 μm, and V: >315 μm). The </>223 μm break described herein is essentially the >/< 1% fine sediment described in Henkel and Politano (2017), and reinforces the additional break around 300 μm; it is not surprising as the 137 stations sampled in that study were a subset of the 404 analyzed in this effort. However, this > 223 μm (< 1% fines) group now includes stations from 45° to 46 °N (north of Newport and south of Nehalem, Oregon), which was a major latitudinal gap in Henkel and Politano (2017). These clean sand groups are notable due to the overall low species density (average ~ 23 taxa per grab) relative to other shelf groups (~37 taxa per grab).

In the silt-containing mid-shelf Oregon/Washington stations (< 223 μm), we detected a latitudinal gap between 43.8° and 44.5°N with groups of stations clustering north and south of that gap. This gap is, in part, due to the fact that no silt-containing stations were sampled on the mid-shelf of the central Oregon coast as the clean sand extends further offshore in this region. While these groups were delineated in the LINKTREE using latitude, they also represent a divergence of sediment types, with the northern stations averaging 189 μm (0.24% TOC) and the southern stations averaging 165 μm (0.35% TOC), although latitude was used because a clear threshold in grain size or TOC could not be correlated with the station groupings by the LINKTREE routine. Sediment grain size data are often correlated with infaunal community parameters to try to establish relationships between them (Henkel and Politano 2017). However, Snelgrove and Butman (1994) found little evidence that grain size alone was a causative factor in determining species distributions, as hydrodynamic energy and organic content of the sediment vary with grainsize and can directly influence feeding and settling dynamics of benthic fauna more so than the particle size. The mid-shelf, muddy northern California stations had ten times the percentage of fine sediment, much smaller grain size, and twice the TOC content compared to the stations at the same depth in the smallest grain size in Oregon. Although our current study did not resolve differences among sediment and other potential factors related to latitude, Henkel and Nelson (2018) also identified a latitudinal break in macrofaunal composition at the OR-CA border even after accounting for differences related to the >/< 5% fines threshold, indicating factors related to hydroclimate and/or species dispersal likely play a role.

On the outer shelf (90 – 200 m deep), differences in macrofaunal assemblages also distinguished among three grain size classes with breaks at ~110 μm and ~170 μm median grain size. Henkel and Politano (2018) reported a similar break at </>112 μm. When considering outer shelf stations with smaller grainsize (< 104 μm; groups VI and VII), northern and southern (break at 43.6°) assemblages were again distinguished as on the mid-shelf with the more northern group having slightly larger median grain size; however, on the outer shelf the northern stations also had higher percent TOC (1.38% vs. 0.91%). While this seems contrary to the classic relationship between grain size or percent fines and TOC, Gross et al. (1972) note that "although there is substantial variation, the amount of organic carbon in the sediment at any depth is usually…lowest near the OR-CA boundary", indicating a latitudinal trend in TOC that may be driven by other factors. The Outer Shelf <104 μm South group (IV) also differed from the rest of the outer shelf groups by having warmer, more oxygenated bottom water. Finally, it contained a subsequent split between southern Oregon and stations from the northern San Andreas Fault area of California. This is consistent with the split on the mid-shelf separating our Eureka stations from southern Oregon and both are consistent with the break detected by Henkel and Nelson (2018) at the OR-CA border in the 2003 EMAP samples. The Outer Shelf 111 – 167 μm group (VIII) was similar in average depth to the smaller grain size groups, but had approximately half the TOC content). The largest grain size group on the Outer Shelf (>170 um; IX) again had less than half the TOC content of group VIII.

On the slope, we identified three major depth ranges (as on the shelf) which we termed Slope Break, Upper Slope, and Slope. Further distinctions within those depth zones on the slope were not defined by the LINKTREE by breaks in sediment grain size; however, in the Upper Slope group (XI) a similar latitudinal break (at 44 °N) was detected as on mid-shelf. This latitudinal break corresponds to a break in sediment type, where more northern stations average larger grain size while the more southern stations average smaller; however, TOC conditions were similar in both regions at these Upper Slope stations. Among all the slope stations, grain sizes, percent fines, and TOC all were similar to the smallest grain size class defined on the outer shelf. However, percent fines and TOC increased with slope depth along with median grain size, temperature, oxygen, and pH decreasing, making it challenging to determine the actual drivers for assemblage differences across slope depths. Hyland et al. (1991) attributed depth-related patterns in abundances and diversity to a dissolved oxygen gradient. While we were not able to include dissolved oxygen as a potential factor in the BEST analysis (as we did not have data for all stations), it was the second highest correlate with MDS2 and is anti-correlated with depth.

3.4.1 Relationship to Offshore Development

Newer approaches are needed for sea floor planning and predicting an/or assessing impacts occurring at wide spatial scales. Macrofauna are an established tool to quantify the relative degree of anthropogenic impact, used most often in point source discharges occurring in defined areas of the ocean floor (Muxika et al. 2007, Ranasinghe et al. 2012). However, accurately assessing biotic condition over large spatial scales can be logistically challenging, especially when factoring in the water depths of the continental shelf and slope. Habitat mapping classified by surficial geology – used as a proxy for biological habitats – has commonly been used in ocean sea floor planning decisions, yet many suggest changes to the sediment classifications within EUNIS (Galparsoro et al. 2012), and CMECs (Henkel and Politano 2017) need to be made to better reflect the biological communities (Shumchenia and King 2010).

An improved approach would be to quantify the relationship between the species distributions and the environment, using local, faunal-based survey data to inform large-scale modeling of species occurrence predicted from more easily measurable environmental data (Dutertre et al. 2013). Here, we used differences in species assemblages to find meaningful breaks in more easily measured environmental data in order to develop habitat classifications. For planning, these results can be used to set expectations of what macrofaunal species are likely to occur in particular habitat types. As a case study, we can apply our soft bottom habitat characterizations to two marine hydrokinetic projects proposed in the PNW that would be expected to have direct or indirect impacts on soft sediment benthic communities (Dannheim et al. 2019; Boehlert and Gill 2010). The two projects are at different stages and follow distinct permitting pathways. Yet the results of this study can guide the design and define the reference areas and area of potential impact for both.

While both Oregon and northern California have strong wind and wave resources, are of interest for marine renewable energy development, and may have similar impacting factors to the seafloor, projects could be located in different sea floor soft bottom habitats with very different macrofaunal assemblages. PacWave South is in the final permitting stages offshore Newport, Oregon (central Oregon), to be a testing center for wave-powered marine hydrokinetic devices. The seafloor at PacWave South is Mid Shelf Clean Sand (Groups IV and V, average depth 63 m), which is a distinct medium to coarse sand-dominated stretch of the Oregon central mid shelf. In contrast, offshore Eureka, California (northern California, average depth 900 m), where there is also interest in renewable energy, the seafloor is deeper. This area is deeper than the studied area, but is most closely associated with the deepest Slope habitat group (Group XII, average depth 484 m). That group has the highest TOC and percent fines of the areas sampled in this project, while also being in the latitudinal range of the Mid Shelf California Mud group

(Group I, average depth 65 m), which has the second highest percent fines; thus we expect the area offshore Eureka to have high percentages of silt and TOC. In addition to hosting different macrofaunal assemblages, soft bottom community recovery differs depending on the local sediment and flow conditions (Kaiser et al. 2000, Bergman et al. 2015, Silberberger et al. 2019). We hypothesize then that the physical and biological responses to impacting factors and ecological recovery will be different in central mid shelf Oregon versus the upper slope of northern California. Having this expectation prior to development, instead of a post-hoc discovery, will aid in planning and the development of monitoring plans.

A regional characterization of the macrofaunal communities is needed to establish context for projects prior to development. However, the long-term need is to understand the alterations to ecological functioning and ecological processes that result from seafloor impacts (Dannheim et al. 2019). This means that to understand the macrofauna distribution at a finer temporal and spatial scale within a region, more hydrodynamic parameters need to be measured consistently (Dutertre et al. 2013). For artificial reef effects associated with offshore structures, TOC and nitrogen may become important signals as there is some evidence that artificial (oyster shell) reefs increase TOC and TN content in surface sediments (Xu et al. 2014). Further, to understand the impacts of development and the condition of the seafloor over time, the macrofauna species and communities should be linked to benthic condition indices. A site-specific response relies on knowing the functional role of the species of interest. Linking macrofauna condition to the ecological processes (Frid 2011) means that we need to next understand the forage value (Bond et al. 1999) and trophic links to groundfish species important in the PNW. Finally, ecological function needs to be evaluated in the context of many other stressors such as changing climate and fishing impacts (Cada et al. 2007, Birchenough et al. 2015, Dannheim et al. 2019). This work is a step towards utilizing predictive modeling and quantifying species abiotic relationships with the aim at identifying ecosystem consequences of changes to various environmental factors (Méléder et al. 2010; Dutertre et al. 2013).

3.4.2 Conclusions

This study classified the macrofaunal communities of the PNW continental shelf and upper slope soft bottom into 12 habitats. These habitats represent key depth and sediment-related breaks in macrofaunal community composition. Our results are consistent with the pattern of depth-related macrofauna assemblages throughout the California Current, supported by several studies in different parts of the California Current spanning over 30 years. Sediment characteristics were important parameters not just on the inner to mid-shelf as determined in Henkel and Politano (2017), but also further across the shelf and down the slope. In classifying these habitats, we can create a context for describing the current communities in the region for soft bottom; a region undergoing changes in ocean hydrology, changes in bottom trawling pressure, and of growing interest for energy development projects. Establishing a soft bottom characterization for the PNW offshore will aid in the increasingly standardized and quantitative assessments of impacts.

4 Data Gathering and Species Selection for Region-wide Habitat Suitability Modeling

4.1 Purpose

A prior regional analysis of benthic habitat distribution (referenced as Benthic Habitat Characterization BOEM-BHC, Henkel et al. 2014) was motivated by wave energy project proposals in northern California and Oregon. Since that analysis, there has been greater interest in siting marine renewable energy projects in deeper waters of the continental slope, as well as waters further south in central and southern California. In response to this increase in geographic scope, we aimed to expand the depth and latitudinal range of habitat suitability models, like those developed in the BHC project, by incorporating other survey programs in California as well as Oregon. These models will be designed and run by NCCOS (they are not updates of the same BayesNet models from the 2014 BHC project) and will be described in a separate BOEM report that NCCOS will develop under Interagency Agreement Number M16PG00014.

4.2 Study Area

The data for this chapter spanned from the California-Mexico border to Vancouver, Washington (Figure 7). Sample data are from stations 3 to 1023 m deep.

4.3 Approach

Additional BOEM-funded research by the Southern California Coastal Water Research Project (SCCWRP) offered the opportunity to incorporate the many years of macrofaunal samples collected as part of the Southern California Bight Regional Monitoring Program (Schiff et al. 2016) to potentially expand the domain of the habitat suitability models to the entire lower US west coast. However, this combination of the OSU samples (spanning Fort Bragg, California, to Grays Harbor, Washington) plus the SCCWRP data left a large portion of the California coast without observations (e.g., Monterey, San Francisco, Humboldt). To fill these spatial gaps, we sought data from previous sampling programs carried out by various entities in the central and northern California region (e.g., EPA-WEMAP, EPA-Army Corps dredge disposal sampling, NOAA, municipalities). Thus, we endeavored to obtain as many of those records as possible to gain more complete coverage of the lower states of the US west coast.

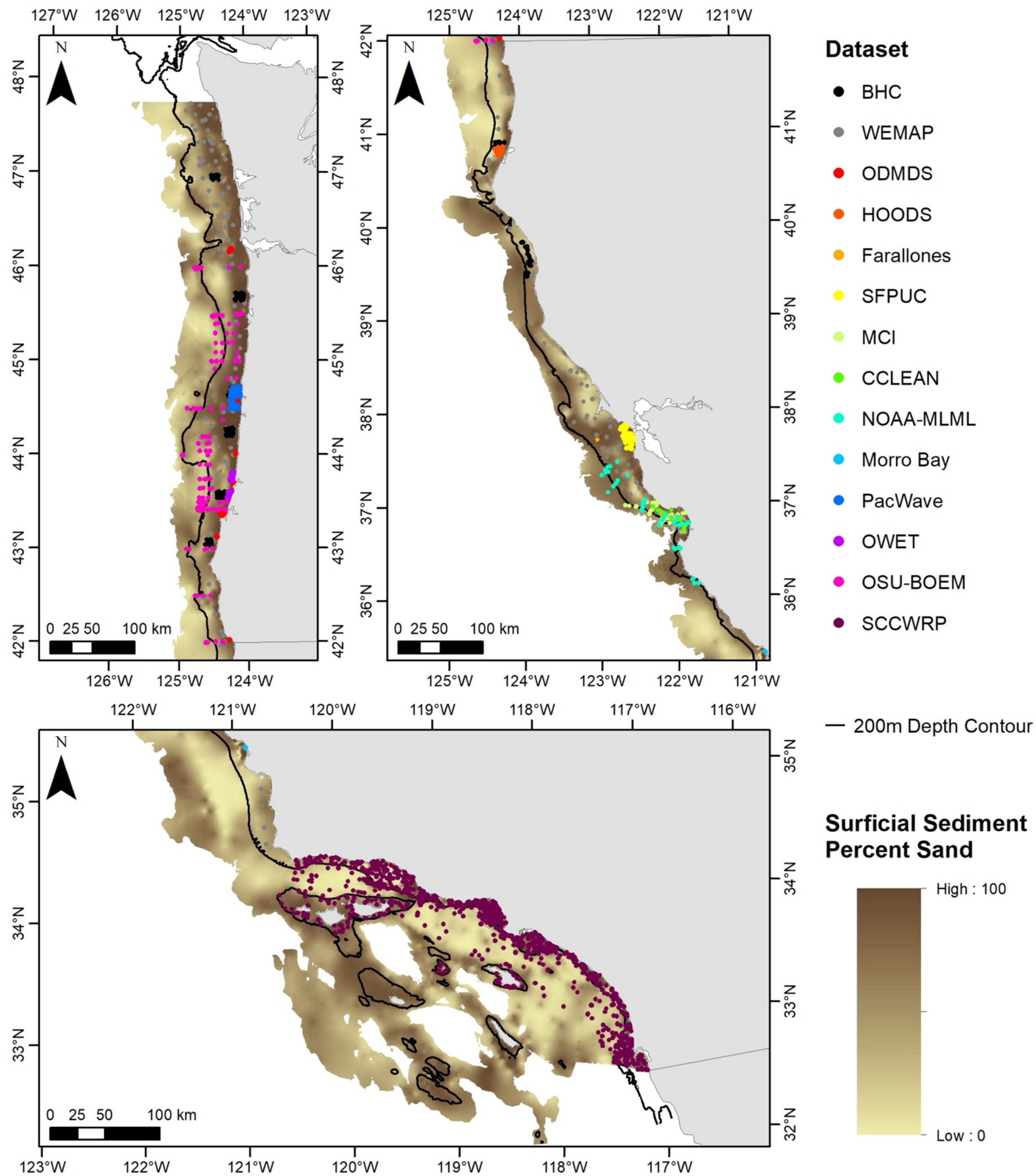

Figure 7. Station locations for the 14 datasets included for modeling.
Details of each dataset are included in Table 6. The base map shows the surficial sediment percent sand and the 200 m depth contour.

4.4 Data Collection and Processing

The Henkel lab provided many of the northern region datasets including data from this BOEM-funded study and the BOEM-BHC project as well as data from in and around the PacWave facilities operated by OSU's Pacific Marine Energy Center and from a project off Reedsport and Coos Bay, Oregon, funded by the Oregon Wave Energy Trust. The EMAP data are available for download from the National Coastal Assessment Coastal Data Search Engine: https://oaspub.epa.gov/coastal/coast.search. The 2003 EMAP data for California north of Point Conception, Oregon, and Washington were included in the MS Access database developed by the Henkel lab. Additional SCCWRP data was obtained directly from David Gillett and used for determining model species but were not included in the MS Access database. ODMDS data from Oregon was obtained directly from the US Army Corps of Engineers (USACE), facilitated by previous collaborative projects between Henkel and USACE/US Environmental Protection Agency (EPA). Metadata from the MCI, CLLEAN, and NOAA Monterey sampling are available on the MLML website and data were subsequently provided by MLML upon request. The SF Offshore and HOODS data were provided by Walt Nelson, former Asst. to Division Director of the Western Ecology Division of the EPA. Shallow water Morro Bay station data were obtained from the City of Morro Bay and Cayucos Sanitary District Offshore Monitoring and Reporting Program available from the city's website: http://www.morro-bay.ca.us/ArchiveCenter/ViewFile/Item/2757. Collectively, these datasets spanned 1994 to 2016 from 15 to 535 m deep for a total of 1835 records (Table 5). All records contained macrofaunal count data, station location, depth, and at least percent fines for the sediment. Some datasets had additional physical data.

All data from north of Point Conception were entered into a Microsoft Access database and a "taxon reduced" query was created from the various data sets. Because projects often had different spelling for the same animal (e.g., *Acteocina* sp vs *Acteocina* spp vs *Acteocina* spp.) over 3000 unique taxa were generated. Sometimes different scientific names were used, including older names no longer recognized as valid by the scientific community. Additionally, there were many misspelled entries and common names were occasionally used. In some instances, the stage of the animal was included in the text (e.g., Aeolidiacea sp. Juv.) and there were other name differences making merging the data sets difficult. So, a secondary column was created and used in a query to aggregate all the similar species together. The World Register of marine species (WoRMS; accessed in 2017) was used to cross check species names and select valid species names. In some instances, it was not possible to determine what the animal was at the species level and a taxa name was chosen at the lowest possible level (e.g., Cuke-like Anemone became *Actiniaria* sp). It was from this query "Total Taxon Reduced" that all data were pulled for the statistical analyses described below.

Table 6. Datasets collated by Henkel lab and included in Microsoft Access Database.

Dataset label (Fig 7)	Collection type	Sieve mesh size (mm)	Region	Years	Depth range (m)	No. of Records	Dataset sources
BHC	Box core	1	WA, OR, northern CA	2010-2012	49-133	150	Benthic habitat characterization (BHC) surveys from Oregon State University (OSU); Henkel et al. 2014
WEMAP	van Veen	1	WA, OR, CA	2003	28-126	147	Environmental monitoring & assessment program (EMAP) data provided by Environmental Protection Agency (EPA); Nelson et al. 2008.
ODMDS	Box core	0.5	OR	2008, 2009, 2013, 2014, 2016	10-85	309	Designated ocean dredged material disposal sites (ODMDS) from 7 Oregon sites provided by EPA Region 10
HOODS	van Veen	0.5	northern CA	2008, 2014	31-92	44	Humboldt open ocean disposal site (HOODS) data provided by EPA Region 9
Farallones	van Veen	1	central CA	2009	8-34	12	Assessing potential resource utilization by Gray Whales in the Gulf of the Farallones National Marine Sanctuary; data provided by EPA Region 9
SFPUC	van Veen	0.5	central CA	2004, 2005, 2010	12-35	154	San Francisco offshore provided by the San Francisco Public Utility Commission
MCI	Smith-McIntyre	0.5	central CA	1999	10-450	83	Surveys in Monterey Bay National Marine Sanctuary for MCI Worldcom (ABA Consultants 2000) data provided by Moss Landing Marine Laboratories (MLML) Benthic Lab
CCLEAN	Smith-McIntyre/ van Veen	0.5	central CA	2001-06, 2008-10, 2015	80	90	Central Coast Long-term Environmental Assessment Network (CCLEAN) data provided by MLML Benthic Lab
NOAA-MLML	Smith-McIntyre	0.5	central CA	2004, 2005	80-476	53	Data collected by NOAA and provided by MLML Benthic Lab
Morro Bay	Young Modified van Veen	1	central CA	2015	15	7	City of Morro Bay and Cayucos Sanitary District Offshore Monitoring and Reporting Program
PacWave	Box core	1	central OR	2010-2016	20-70	597	PacWave test sites data collected by Henkel funded by various sources
OWET	Box core	1	southern OR	2011	24-90	42	Data collected by Henkel funded by Oregon Wave Energy Trust (OWET)
OSU-BOEM	Box core	1	OR	2014-2016	60-525	147	Current report

4.5 Statistical Analyses

We first attempted to conduct multivariate analyses on the entire dataset. These analyses included creating a dissimilarity matrix and producing non-parametric MDS plots and cluster dendrograms to visualize how stations grouped together based on the macrofaunal assemblages collected. Including all of the records from the southern California Bight made the dataset too big for PRIMER or R to handle in a timely manner. So, we first analyzed the data included in the MS Access database only north of Point Conception. Within this study area, multivariate analysis indicated a strong break between samples collected using a 1.0 mm mesh sieve and those collected using a 0.5 mm mesh. Thus, analyses to identify candidate species for modeling (not the final modeling) were conducted using only samples obtained by using a 1.0 mm mesh size. Once this approach was decided, we then used the Bight Survey data from just 2003 at this stage as those were temporally consistent with the rest of the WEMAP samples, which was the major source of station data for central and northern California (Nelson et al. 2008). Using this final dataset for assemblage determination (n = 1483 stations), we conducted cluster analysis with SIMPROF set at the 1% significance level to determine statistically significant groups of the 1483 stations followed by SIMPER analyses to determine which species contributed to the similarities within groups and differences between them.

We then determined the number of times each species was indicated as being significant contributors to the similarities within groups overall and within each ecoregion (OR/WA, NorCal, Southern California Bight). Species were then considered for potential as model species if they were frequently significant contributors to the similarities within group, or if they were determined to be frequent distinguishers between the 12 major habitat groups in the in the previous chapter. These species were added separately because they included species that were discriminating on the slope, where we had little coverage in the remainder of the study region. Thus, in the analysis of the entire region, they were not necessarily frequently occurring characteristic species. Additional refinements were made for the final list of candidate species for modeling. For example, species that were significant contributors to the similarities within groups for only one ecoregion were only considered if we had additional evidence that their presence/absence contributed to differences among habitats within that region (and weren't just defining the region). Because samples were biased to the northern part of the region, when one species in a genus was a frequent distinguisher in the north and a conspecific was more common in the south, we added the southern conspecific to the list of species to be modeled. We also prioritized species that had a p-code pollution tolerance scores of less than 30 in the SCCWRP database, favoring species that were representative of non-impacted conditions. (For the p-codes, a higher number indicates greater tolerance to pollution; Smith et al. 2001). Finally, if not already included, we added taxa that we had previously modeled in the BOEM-BHC project in order to compare model outputs between model approaches.

Finally, we checked the frequency of occurrence of each of the selected species to ensure there were enough occurrences (not just large abundances at a few stations) to be useful for modeling. In order to be considered for modeling, we aimed for at least 10% overall occurrence in the northern study region; however, this was not always possible for slope species as the number of slope samples was low relative to the entire dataset. While the initial lists of potential model species were derived based only on the 1 mm mesh sieve studies, occurrence data was based on all the datasets.

4.6 Results

The cluster analysis with a SIMPROF threshold of 1% resulted in 303 significantly different groups. There were 147 significant groups detected in the PNW Region (Oregon and Washington), 29 groups in the Northern California (above Point Conception) Region, and 127 groups in Southern California (the Bight data). Forty-three taxa were selected as the final list recommended for future habitat suitability modeling (Table 7). Polychaetes were the most frequent group considered to be characteristic of and/or distinguishing between macrofaunal assembalges and 22 taxa were selected for modeling; taxonomic changes over the course of the sampling efforts resulted in some suspected synomyns being lumped together. Molluscs were the second most frequent characteristic/distinguishing taxa, and eight bivalves, six gastropods, and the caudofoveatan, *Chaetoderma argenteum* (which was a slope distinguishing species), were selected for modeling. The most frequently overall characteristic species (contributing to the similarity of the stations within a group) was the ubiquitous bivalve, *Axinopsida serricata*, which was characteristic in 95 of the 303 groups. Thus, while widespread, we would expect to model some unsuitable habitat for this species as it was not found to be highly characteristics of all macrofaunal assemblages. Only three crustacea were determined to be highly characteristic of assemblages or distinguishing among them: the mud-tolerant shelf amphipod, *Ampelisca careyi*, the highly abundant pea crab, *Pinnixa occidentalis* complex, and the ostracod, *Euphilomedes carcharodonta*. Three echinoderms were also determined to be highly characteristic of assemblages or distinguishing among them: two ophiuroids and the heart urchin, *Brisaster latifrons*, which was indicative of the outer shelf and slope with the smallest grain sizes.

The results of the models (maps, envrionmental predictors, and model summaries) will be provided and discussed in a subsequent publication from NCCOS.

Table 7. The 43 taxa recommended for future habitat suitability modeling.
The Times Characteristic Total column (Times Char Total) indicates the number of times a taxon was characteristic in statistically significant clustered groups (n = 303 total clusters). The percentage of groups for which a taxon was characteristic are separated into three latitudinal areas from north to south: PNW (Oregon and Washington), NorCal (California, north of Point Conception), and Bight (California, south of Point Conception, Southern California Bight). The North Occur column indicates the number of stations at which taxa were collected north of Point Conception (PWN and NorCal combined). The Bight Occur column indicates the number of times taxa were collected during sampling in the Southern California Bight (Gillet et al. 2017). The total possible number of occurrences in the north is 1795 (the total number of sampling events or station visits) and 1209 in the Southern California Bight. Bight p-code values are the relative degree of pollution tolerance/sensitivity quantified by taxon and by depth in the Southern California Bight (Smith et al. 2001). The plus symbol ([+]) indicates species discriminating among habitats in the previous chapter. The asterisk symbol (*) indicates the seven species that were modeled for the BOEM-BHC project (Henkel et al. 2014).

	Times Char Total	% of Groups PNW	% of Groups NorCal	% of Groups Bight	North Occur	Bight Occur	Bight p-code (0-30 m)	Bight p-code (30-120 m)	Bight p-code (120-300 m)
Acila castrensis	29	18%	7%	1%	302	33		-10.711	25.26
Adontorhina cyclia[+]	30	16%	10%	3%	171	107		-21.116	-7.526
_Alia (Astyris) gausapata_*	28	19%			562	1		No p-code	
Ampelisca careyi	57	22%	28%	13%	597	426	16.113	-11.303	-7.789
Amphiodia urtica	51	12%	24%	21%	452	133	48.713	-8.565	-12.225
Amphioplus macraspis[+]	11	7%			84	0		Not present	
_Axinopsida serricata_*	95	48%	34%	12%	936	367	69.746	26.965	60.36
Brisaster latifrons[+]	18	9%	3%	3%	158	0	_Brisaster_ sp.		2.95
_Callianax pycna_*	18	12%			423	1		No p-code	
Chaetoderma argenteum[+]	5	3%			62	0	Not present; other _Chaetoderma spp_ listed		
Chloeia pinnata[+]	31	3%	10%	19%	179	400	37.607	19.019	26.917
Cylichna attonsa	53	36%			812	0	Not present; other _Cylichna spp_ listed		
_Ennucula tenuis_*	34	18%	10%	4%	412	141	15.558	-0.374	-4.549
Euphilomedes carcharodonta	52	12%	24%	21%	368	432	71.111	59.539	42.635
Gadila tolmiei[+]	7	5%			59	35		No p-code	
Galathowenia oculata[+]	25	15%	10%		323	4	-2.075	-3.221	-2.633
Glycera nana/tesselata	44	11%	28%	16%	416	509	50.612	39.829	53.637
Glycinde armigera[+]	52	22%	17%	12%	750	372	19.129	19.126	38.526
Huxleyia munita[+]	18	12%		1%	126	30			-66.319

	Times Char Total	% of Groups PNW	% of Groups NorCal	% of Groups Bight	North Occur	Bight Occur	Bight p-code (0-30 m)	Bight p-code (30-120 m)	Bight p-code (120-300 m)
Kurtiella tumida	42	11%	31%	13%	585	361	45.575	59.199	51.633
Leitoscoloplos pugettensis+	51	20%		17%	600	206	42.489	47.53	8.019
Macoma carlottensis	35	22%	10%		441	87	106.04	115.822	76.711
*Magelona berkeleyi**	4	3%			125	66	26.808	29.525	-29.055
Magelona sacculata	40	27%	3%		895	25	-8.299	32.344	
Maldane sarsi+	27	7%	24%	7%	312	364	18.308	9.273	17.309
Ninoe gemmea	12	5%	14%		127	0	42.018	23.234	41.577
Ninoe tridentata	3		3.4%	1.6%	76	205	42.018	23.234	41.577
Nutricola lordi+	27	18%			305	3		No p-code	
*Onuphis iridescens**	55	30%	24%	3%	755	140	19.245	29.726	35.694
Paraprionospio alata/pinnata	60	12%	31%	26%	498	795	10.608	21.746	38.608
Phoronidae sp+	36	11%	7%	14%	75	449	17.859	8.077	-2.306
Pinnixa occidentalis complex	29	11%	31%	3%	292	29	39.228	24.216	41.247
Polycirrus spp	8		7%	5%	246	439	-1.05	-5.026	1.856
Praxillella gracilis+	3	1%	3%		98	33	12.968	15.645	10.416
Prionospio (prionospio) jubata	42	6%	21%	21%	159	596	55.502	31.466	32.647
Pulsellum salishorum+	11	7%			135	0		Not present	
Rhabdus rectius+	23	14%	7%		210	58	34.765	41.919	29.978
Scoletoma luti	24	12%	21%		455	0	49.381	30.228	19.076
Spiophanes berkeleyorum/kimballi	62	16%	38%	22%	734	692	24.199	33.753	38.763
Spiophanes duplex	54		14%	39%	0	800	6.131	8.546	-1.569
Spiophanes norrisi	60	29%	14%	10%	102	353	-2.309	12.055	-23.746
Sternaspis assimilis+	3	2%			39	0	Not present; other *Sternaspis spp* listed		
*Sternaspis affinis/fossor**	37	9%	24%	13%	283	405	34.246	-17.301	-1.458

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Appendix: Additional Tables and Figures in Support of Chapter 3

Table A-1. Station data for the 404 samples considered in Chapter 3.

Station	Year	Latitude	Longitude	Depth
42.0_060m2014	2014	42.0035	-124.366	56
42.0_060m2015	2015	42.00153	-124.373	64
42.0_100m2014	2014	42.00345	-124.471	99
42.0_100m2015	2015	42.01683	-124.470	103
42.0_200m2014	2014	41.99835	-124.589	215
42.0_200m2015	2015	42.00127	-124.586	202
42.0_300m2014	2014	41.9948	-124.605	329
42.0_300m2015	2015	42.00163	-124.602	306
42.0_400m2014	2014	41.99827	-124.617	394
42.0_400m2015	2015	42.00193	-124.618	400
42.5_100m2014	2014	42.50048	-124.657	100
42.5_200m2015	2015	42.50198	-124.731	216
42.5_300m2014	2014	42.50257	-124.749	308
42.5_300m2015	2015	42.50048	-124.756	302
42.5_400m2014	2014	42.50205	-124.768	400
42.5_400m2015	2015	42.50128	-124.770	396
43.0_060m2014	2014	43.00450	-124.521	59
43.0_100m2014	2014	43.00667	-124.594	99
43.0_100m2015	2015	42.99173	-124.628	112
43.0_200m2014	2014	42.99922	-124.854	202
43.0_300m2014	2014	43.00203	-124.869	288
43.0_300m2015	2015	43.00000	-124.870	295
43.0_400m2014	2014	43.00275	-124.899	398
43.0_400m2015	2015	42.99938	-124.898	395
43.5_060m2014	2014	43.51248	-124.297	61
43.5_060m2015	2015	43.50038	-124.302	63
43.5_100m2014	2014	43.49880	-124.381	101
43.5_100m2015	2015	43.49542	-124.413	110
43.5_200m2014	2014	43.49990	-124.599	204
43.5_200m2015	2015	43.49928	-124.598	206
43.5_300m2014	2014	43.50262	-124.644	299
43.5_300m2015	2015	43.49900	-124.644	300
43.5_400m2014	2014	43.50285	-124.678	399
43.5_400m2015	2015	43.49900	-124.677	401
43.5_500m2014	2014	43.50272	-124.720	497
43.5_500m2015	2015	43.50017	-124.721	507
44.0_150m2014	2014	43.99732	-124.569	148
44.0_150m2015	2015	43.99983	-124.581	155

Station	Year	Latitude	Longitude	Depth
44.0_200m2014	2014	44.00373	-124.940	217
44.0_200m2015	2015	43.99917	-124.940	209
44.0_300m2014	2014	44.00635	-124.953	309
44.0_300m2015	2015	43.99815	-124.955	306
44.0_400m2014	2014	44.00435	-124.957	352
44.0_400m2015	2015	43.99680	-124.960	393
44.5_100m2015	2015	44.49817	-124.532	107
44.5_200m2015	2015	44.49983	-124.688	202
44.5_300m2015	2015	44.49983	-124.746	307
44.5_400m2014	2014	44.50278	-124.884	359
44.5_400m2015	2015	44.50333	-124.792	394
45.0_060m2014	2014	44.99967	-124.090	61
45.0_060m2015	2015	44.9967	-124.090	65
45.0_100m2014	2014	44.99977	-124.164	101
45.0_100m2015	2015	44.99917	-124.165	107
45.0_200m2014	2014	45.00467	-124.359	200
45.0_200m2015	2015	44.99983	-124.359	204
45.0_300m2014	2014	45.00338	-124.439	300
45.0_300m2015	2015	45.00067	-124.438	304
45.0_400m2014	2014	45.00492	-124.521	402
45.0_400m2015	2015	44.99983	-124.517	407
45.5_060m2014	2014	45.49530	-124.088	66
45.5_060m2015	2015	45.51250	-124.053	64
45.5_100m2014	2014	45.50303	-124.150	107
45.5_100m2015	2015	45.50583	-124.133	104
45.5_200m2014	2014	45.49460	-124.424	208
45.5_200m2015	2015	45.49600	-124.414	207
45.5_300m2014	2014	45.48427	-124.469	294
45.5_300m2015	2015	45.48850	-124.471	306
45.5_400m2014	2014	45.48588	-124.502	408
45.5_400m2015	2015	45.48100	-124.497	405
46.0_060m2015	2015	46.00150	-124.066	61
46.0_100m2015	2015	46.00000	-124.239	106
46.0_200m2014	2014	46.00088	-124.673	201
46.0_200m2015	2015	45.99950	-124.678	206
46.0_300m2014	2014	45.98730	-124.722	300
46.0_300m2015	2015	46.00000	-124.728	296
46.0_400m2014	2014	45.98842	-124.762	409
46.0_400m2015	2015	45.99917	-124.770	405
BA543_Sept12	2012	43.04990	-124.620	128
BA544_Sept12	2012	43.0331	-124.584	100

Station	Year	Latitude	Longitude	Depth
BA548_Aug12	2012	43.0657	-124.568	91
BA551_Sept12	2012	43.0502	-124.604	128
BA552_Aug12	2012	43.1016	-124.602	128
BA555_Sept12	2012	43.0486	-124.533	91
BA556_Aug12	2012	43.1007	-124.551	91
BA560_Sept12	2012	43.0674	-124.585	109
BA563_Sept12	2012	43.0333	-124.533	73
BA564_Aug12	2012	43.0827	-124.534	73
BA568_Aug12	2012	43.0998	-124.584	100
BA572_Aug12	2012	43.0664	-124.534	109
BA576_Sept12	2012	43.0659	-124.587	118
BA579_Sept12	2012	43.0495	-124.568	100
BA580_Aug12	2012	43.0994	-124.539	67
BB20A_Jun11	2011	44.726	-124.090	21.9
BB20B_Jun11	2011	44.72633	-124.090	21.1
BB30A_Jun11	2011	44.72633	-124.100	30.2
BB30B_Jun11	2011	44.72633	-124.100	29.9
BB40A_Jun11	2011	44.72467	-124.110	42.5
BB40B_Jun11	2011	44.72467	-124.110	42
BB50A_Jun11	2011	44.72367	-124.120	49.7
BB50B_Jun11	2011	44.72333	-124.120	49.5
BB60A_Jun11	2011	44.7275	-124.150	59.7
BB60B_Jun11	2011	44.72667	-124.150	59.6
BB70A_Jun11	2011	44.71767	-124.210	72.5
BB70B_Jun11	2011	44.72217	-124.210	72.1
CABLE12016	2016	43.42262	-124.637	193
CABLE22016	2016	43.41898	-124.578	144
CABLE32016	2016	43.42395	-124.519	114
CABLE42016	2016	43.42493	-124.459	104
CABLE52016	2016	43.41992	-124.415	89
CABLE62016	2016	43.42522	-124.341	34
CABLE72016	2016	43.42648	-124.311	20
CABLE82016	2016	43.42322	-124.683	338
CP541_Oct12	2012	44.283	-124.248	70
CP542_Oct12	2012	44.2355	-124.269	74
CP545_Oct12	2012	44.2583	-124.234	66
CP546_Oct12	2012	44.2287	-124.242	69
CP549_Oct12	2012	44.2943	-124.216	61
CP550_Oct12	2012	44.2473	-124.284	75
CP553_Oct12	2012	44.2412	-124.220	62
CP554_Oct12	2012	44.2867	-124.272	73

Station	Year	Latitude	Longitude	Depth
CP557_Oct12	2012	44.2735	-124.196	56
CP558_Oct12	2012	44.222	-124.292	77
CP561_Oct12	2012	44.2112	-124.216	62
CP562_Oct12	2012	44.2823	-124.309	78
CP565_Oct12	2012	44.2792	-124.250	69
CP566_Oct12	2012	44.2182	-124.252	72
CP569_Oct12	2012	44.209	-124.248	71
CP570_Oct12	2012	44.2058	-124.294	78
CP573_Oct12	2012	44.263	-124.223	62
CP574_Oct12	2012	44.2143	-124.305	80
CP577_Oct12	2012	44.2368	-124.203	58
CP578_Oct12	2012	44.2573	-124.297	77
EUR002_Oct10	2010	40.914	-124.222	52
EUR006_Oct10	2010	40.8789	-124.260	61
EUR018_Oct10	2010	40.9021	-124.236	55
EUR022_Oct10	2010	40.8593	-124.254	55
EUR034_Oct10	2010	40.9139	-124.283	75
EUR038_Oct10	2010	40.8656	-124.374	123
EUR045_Oct10	2010	40.8841	-124.292	73
EUR050_Oct10	2010	40.9204	-124.314	89
EUR054_Oct10	2010	40.9144	-124.337	102
EUR061_Oct10	2010	40.8676	-124.309	75
EUR066_Oct10	2010	40.9086	-124.261	64
EUR074_Oct10	2010	40.9197	-124.289	77
EUR082_Oct10	2010	40.9116	-124.330	97
EUR090_Oct10	2010	40.8728	-124.253	57
EUR098_Oct10	2010	40.8759	-124.354	104
EUR101_Oct10	2010	40.8578	-124.295	68
EUR106_Oct10	2010	40.8432	-124.339	79
EUR109_Oct10	2010	40.8862	-124.285	71
EUR114_Oct10	2010	40.9159	-124.354	118
EUR117_Oct10	2010	40.8429	-124.310	57
GH004_Sept10	2010	46.9312	-124.393	58
GH020_Sept10	2010	46.9783	-124.397	56
GH047_Sept10	2010	46.9468	-124.502	82
GH063_Sept10	2010	46.9296	-124.481	78
GH076_Sept10	2010	46.9781	-124.449	66
GH084_Sept10	2010	46.9688	-124.404	60
GH092_Sept10	2010	46.9815	-124.423	63
GH103_Sept10	2010	46.9758	-124.465	71
GH111_Sept10	2010	46.9571	-124.500	80

Station	Year	Latitude	Longitude	Depth
GH119_Sept10	2010	46.9783	-124.509	79
GH122_Sept10	2010	46.9619	-124.463	71
GH165_Sept10	2010	46.956	-124.420	63
GH221_Sept10	2010	46.9783	-124.418	61
MB20A_Jun11	2011	44.69567	-124.090	19.9
MB20B_Jun11	2011	44.69567	-124.090	19.6
MB30A_Jun11	2011	44.691	-124.100	30.1
MB30B_Jun11	2011	44.69383	-124.100	30.2
MB40A_Jun11	2011	44.6925	-124.110	41.7
MB40B_Jun11	2011	44.6925	-124.110	40.6
MB50A_Jun11	2011	44.692	-124.140	52.6
MB50B_Jun11	2011	44.69183	-124.140	52.2
MB60A_Jun11	2011	44.6905	-124.150	59.6
MB60B_Jun11	2011	44.52267	-124.160	59.4
MB70A_Jun11	2011	44.69033	-124.220	69.6
MB70B_Jun11	2011	44.68967	-124.230	69.6
MC102016	2016	43.74947	-124.621	307
MC112016	2016	43.74995	-124.700	459
MC12016	2016	43.55032	-124.568	195
MC122016	2016	43.900	-124.550	162
MC132016	2016	43.89965	-124.600	215
MC142016	2016	43.89992	-124.699	224
MC152016	2016	44.05037	-124.550	132
MC162016	2016	44.05015	-124.600	138
MC172016	2016	44.12985	-124.720	112
MC182016	2016	44.13042	-124.550	114
MC192016	2016	44.12983	-124.589	123
MC202016	2016	44.05	-124.70	126
MC212016	2016	44.1984	-124.551	105
MC22016	2016	43.5507	-124.706	500
MC222016	2016	44.20003	-124.598	110
MC232016	2016	44.19985	-124.654	114
MC242016	2016	44.37492	-124.353	75
MC272016	2016	44.82057	-124.149	64
MC282016	2016	44.82028	-124.272	116
MC312016	2016	44.9203	-124.463	252
MC32016	2016	43.54563	-124.652	363
MC332016	2016	45.02668	-124.146	102
MC342016	2016	45.00078	-124.360	201
MC362016	2016	45.09857	-124.121	92
MC372016	2016	45.09978	-124.350	240

Station	Year	Latitude	Longitude	Depth
MC382016	2016	45.0999	-124.450	352
MC392016	2016	45.19963	-124.195	151
MC402016	2016	45.20003	-124.270	180
MC412016	2016	45.1996	-124.352	330
MC42016	2016	43.64325	-124.551	195
MC422016	2016	45.19977	-124.452	405
MC432016	2016	45.2996	-124.179	132
MC442016	2016	45.30025	-124.280	186
MC452016	2016	45.30383	-124.458	265
MC462016	2016	45.29953	-124.455	400
MC472016	2016	45.39643	-124.106	93
MC482016	2016	45.40038	-124.249	162
MC492016	2016	45.40818	-124.405	245
MC502016	2016	45.39978	-124.453	377
MC52016	2016	43.64968	-124.520	162
MC522016	2016	45.48963	-124.353	183
MC62016	2016	43.649	-124.700	493
MC72016	2016	43.65158	-124.648	375
MC82016	2016	43.75062	-124.550	185
MC92016	2016	43.74967	-124.600	260
NEH007_Sept10	2010	45.7112	-124.109	87
NEH011_Sept10	2010	45.6586	-124.156	104
NEH015_Sept10	2010	45.6552	-124.033	63
NEH023_Sept10	2010	45.6713	-124.140	99
NEH027_Sept10	2010	45.653	-124.053	70
NEH031_Sept10	2010	45.7269	-124.068	76
NEH035_Sept10	2010	45.6469	-124.147	101
NEH039_Sept10	2010	45.6702	-124.085	81
NEH043_Sept10	2010	45.6924	-124.049	71
NEH051_Sept10	2010	45.7264	-124.135	94
NEH055_Sept10	2010	45.7094	-124.130	94
NEH059_Sept10	2010	45.705	-124.027	64
NEH071_Sept10	2010	45.6552	-124.070	76
NEH075_Sept10	2010	45.646	-124.061	73
NEH079_Sept10	2010	45.6997	-124.043	69
NEH083_Sept10	2010	45.7208	-124.109	86
NEH087_Sept10	2010	45.6749	-124.036	67
NEH091_Sept10	2010	45.6908	-124.102	86
NEH095_Sept10	2010	45.7229	-124.039	62
NEH099_Sept10	2010	45.6625	-124.122	94
NEH107_Sept10	2010	45.6968	-124.114	88

Station	Year	Latitude	Longitude	Depth
NEH115_Sept10	2010	45.7288	-124.153	100
NH20A_Jun11	2011	44.6535	-124.090	22.4
NH20B_Jun11	2011	44.65333	-124.090	21.6
NH30A_Jun11	2011	44.6535	-124.100	32.6
NH30B_Jun11	2011	44.6535	-124.100	32
NH40A_Jun11	2011	44.652	-124.110	40.9
NH40B_Jun11	2011	44.652	-124.110	41.6
NH50A_Jun11	2011	44.65283	-124.150	49.3
NH50B_Jun11	2011	44.6525	-124.150	49.2
NH60A_Jun11	2011	44.65383	-124.180	58.9
NH60B_Jun11	2011	44.65317	-124.180	58.8
NH70A_Jun11	2011	44.65167	-124.230	71
NH70B_Jun11	2011	44.65117	-124.230	70.9
NPT003_Oct10	2010	44.6545	-124.243	74
NPT010_Oct10	2010	44.687	-124.197	69
NPT013_Oct10	2010	44.6323	-124.225	67
NPT014_Oct10	2010	44.704	-124.197	67
NPT019_Oct10	2010	44.6375	-124.271	77
NPT026_Oct10	2010	44.67	-124.192	67
NPT030_Oct10	2010	44.718	-124.158	61
NPT042_Oct10	2010	44.6838	-124.152	55
NPT046_Oct10	2010	44.6553	-124.226	70
NPT057_Oct10	2010	44.626	-124.148	50
NPT058_Oct10	2010	44.658	-124.188	62
NPT062_Oct10	2010	44.6888	-124.226	69
NPT067_Oct10	2010	44.7253	-124.223	73
NPT070_Oct10	2010	44.686	-124.161	58
NPT078_Oct10	2010	44.6472	-124.206	66
NPT085_Oct10	2010	44.6185	-124.190	57
NPT086_Oct10	2010	44.63	-124.150	49
NPT093_Oct10	2010	44.6265	-124.260	74
NPT094_Oct10	2010	44.7203	-124.206	70
NPT102_Oct10	2010	44.6585	-124.210	68
NPT110_Oct10	2010	44.6785	-124.243	72
NPT118_Oct10	2010	44.6745	-124.225	70
NS20A_Jun11	2011	44.62817	-124.090	18.4
NS20B_Jun11	2011	44.62817	-124.090	18.2
NS30A_Jun11	2011	44.62583	-124.110	35.3
NS30B_Jun11	2011	44.62583	-124.110	36.7
NS40A_Jun11	2011	44.6215	-124.120	40.3
NS40B_Jun11	2011	44.62133	-124.120	40.3

Station	Year	Latitude	Longitude	Depth
NS50A_Jun11	2011	44.6265	-124.130	48.6
NS50B_Jun11	2011	44.62633	-124.130	48.7
NS60A_Jun11	2011	44.62317	-124.190	57.7
NS60B_Jun11	2011	44.62067	-124.190	56.5
NS70A_Jun11	2011	44.624	-124.240	73.8
NS70B_Jun11	2011	44.622	-124.240	71.5
NSAF012_Oct10	2010	39.6979	-123.895	118
NSAF016_Oct10	2010	39.6441	-123.882	115
NSAF024_Oct10	2010	39.858	-124.335	122
NSAF028_Oct10	2010	39.8007	-123.920	102
NSAF032_Oct10	2010	39.5877	-123.864	107
NSAF040_Oct10	2010	39.842	-123.969	115
NSAF044_Oct10	2010	39.7632	-123.914	116
NSAF048_Oct10	2010	39.5948	-123.882	118
NSAF056_Oct10	2010	39.8499	-123.976	113
NSAF060_Oct10	2010	39.6791	-123.879	111
NSAF064_Oct10	2010	39.5177	-123.909	125
NSAF072_Oct10	2010	39.7913	-123.943	127
NSAF080_Oct10	2010	39.642	-123.855	95
NSAF088_Oct10	2010	39.6255	-123.889	120
NSAF096_Oct10	2010	39.6335	-123.905	127
NSAF100_Oct10	2010	39.8725	-124.071	122
NSAF104_Oct10	2010	39.6123	-123.883	98
NSAF108_Oct10	2010	39.8462	-123.996	122
NSAF112_Oct10	2010	39.6128	-123.899	125
NSAF116_Oct10	2010	39.718	-123.915	129
NSAF120_Oct10	2010	39.48	-123.923	118
PD30_Jun15	2015	44.591	-124.115	30.5
PD40_Jun15	2015	44.5923	-124.121	39.7
PD50_Jun15	2015	44.5937	-124.160	51.8
PD60_Jun15	2015	44.5937	-124.206	60.6
PD70_Jun15	2015	44.5902	-124.233	70.1
RP301_Jun11	2011	43.7325	-124.215	28.4
RP302_Jun11	2011	43.8182	-124.192	24.3
RP304_Jun11	2011	43.7663	-124.212	35.1
RP305_Jun11	2011	43.7883	-124.209	35.9
RP306_Jun11	2011	43.7407	-124.216	32.4
RP307_Jun11	2011	43.7352	-124.228	42.8
RP308_Jun11	2011	43.7913	-124.210	37.8
RP309_Jun11	2011	43.7625	-124.218	39.4
RP310_Jun11	2011	43.7965	-124.231	63.1

Station	Year	Latitude	Longitude	Depth
RP312_Jun11	2011	43.7445	-124.240	61.5
RP313_Jun11	2011	43.7834	-124.235	65.7
RP314_Jun11	2011	43.7408	-124.243	65
RP315_Jun11	2011	43.816	-124.229	64.1
RP316_Jun11	2011	43.7385	-124.251	72.7
RP317_Jun11	2011	43.766	-124.244	71.7
RP318_Jun11	2011	43.8003	-124.242	73.7
RP319_Jun11	2011	43.74	-124.255	79.5
RP320_Jun11	2011	43.7333	-124.257	79.2
RP321_Jun11	2011	43.7387	-124.255	77.9
RP326_Jun11	2011	43.7485	-124.214	32.1
RP336_Jun11	2011	43.741	-124.236	54.8
RS40_Jun15	2015	44.5588	-124.127	42.2
RS50_Jun15	2015	44.5602	-124.157	50.7
RS60_Jun15	2015	44.5625	-124.205	60.3
RS70_Jun15	2015	44.5588	-124.232	72.1
SB40_Jun15	2015	44.5277	-124.128	41.1
SB50_Jun15	2015	44.526	-124.165	50
SB60_Jun15	2015	44.526	-124.205	59.4
SB70_Jun15	2015	44.526	-124.235	70.5
SC001_Aug10	2010	43.607	-124.309	100
SC005_Aug10	2010	43.6037	-124.448	133
SC009_Aug10	2010	43.599	-124.363	112
SC017_Oct10	2010	43.556	-124.309	91
SC021_Aug10	2010	43.5773	-124.443	130
SC029_Aug10	2010	43.6014	-124.408	124
SC033_Aug10	2010	43.5476	-124.443	126
SC037_Oct10	2010	43.5478	-124.331	97
SC041_Aug10	2010	43.5385	-124.390	113
SC065_Aug10	2010	43.6116	-124.331	106
SC069_Aug10	2010	43.592	-124.378	117
SC073_Aug10	2010	43.5854	-124.419	125
SC077_Oct10	2010	43.5533	-124.348	104
SC097_Aug10	2010	43.5477	-124.379	112
SC105_Aug10	2010	43.5857	-124.375	108
SC128_Aug10	2010	43.5741	-124.403	119
SC134_Aug10	2010	43.5758	-124.440	129
SC136_Aug10	2010	43.5828	-124.353	110
SC150_Aug10	2010	43.6123	-124.415	127
SC401_Jun11	2011	43.6228	-124.235	24.9
SC402_Jun11	2011	43.569	-124.252	28.6

Station	Year	Latitude	Longitude	Depth
SC403_Jun11	2011	43.5788	-124.251	31.3
SC404_Jun11	2011	43.5957	-124.244	29.8
SC405_Jun11	2011	43.5765	-124.255	35.1
SC406_Jun11	2011	43.5508	-124.268	40.9
SC407_Jun11	2011	43.6057	-124.252	33.9
SC408_Jun11	2011	43.538	-124.278	52.5
SC409_Jun11	2011	43.5465	-124.272	47.1
SC410_Jun11	2011	43.5772	-124.267	60.8
SC411_Jun11	2011	43.602	-124.260	59.2
SC412_Jun11	2011	43.5725	-124.267	55.9
SC413_Jun11	2011	43.5953	-124.255	68.6
SC414_Jun11	2011	43.5507	-124.282	69.9
SC415_Jun11	2011	43.5805	-124.269	66
SC416_Jun11	2011	43.5512	-124.287	80.5
SC417_Jun11	2011	43.5923	-124.271	74.6
SC418_Jun11	2011	43.608	-124.270	78.4
SC419_Jun11	2011	43.6058	-124.283	89.5
SC420_Jun11	2011	43.5472	-124.297	81
SC421_Jun11	2011	43.5725	-124.285	82.7
SR30_Jun15	2015	44.4915	-124.114	31.2
SR40_Jun15	2015	44.492	-124.125	38.3
SR60_Jun15	2015	44.4943	-124.210	60
SR70_Jun15	2015	44.494	-124.251	70.1
WFP102016	2016	43.43728	-124.711	466
WFP112016	2016	43.4374	-124.683	373
WFP12016	2016	43.40523	-124.696	408
WFP122016	2016	43.458	-124.698	450
WFP132016	2016	43.46337	-124.633	243
WFP142016	2016	43.43862	-124.734	525
WFP152016	2016	43.44755	-124.721	510
WFP22016	2016	43.40605	-124.71	451
WFP32016	2016	43.4132	-124.681	348
WFP42016	2016	43.41298	-124.681	315
WFP52016	2016	43.41452	-124.727	490
WFP62016	2016	43.41447	-124.701	445
WFP72016	2016	43.41602	-124.696	406
WFP82016	2016	43.42633	-124.700	421
WFP92016	2016	43.436	-124.725	501

Table A-2. Abundance of all Annelids collected at the 404 stations considered in Chapter 3.

Class	Subclass/Order	Family	Taxon	Total Abund
Clitellata	Rhynchobdellida	Piscicolidae	Piscicolidae sp	13
Clitellata	Oligochaeta		Oligochaeta spp	1
Polychaeta	Echiuroidea	Bonellidae	Bonellia sp	27
Polychaeta	Echiuroidea	Echiuridae	Echiura spp	1
Polychaeta	Echiuroidea	Echiuridae	Echiuridae spp	22
Polychaeta	Echiuroidea	Echiuridae	Echiurus echiurus	4
Polychaeta	Echiuroidea	Echiuridae	Echiurus echiurus alascanus	6
Polychaeta	Terebellida	Acrocirridae	Macrochaeta pege	2
Polychaeta	Terebellida	Ampharetidae	Amage anops	5
Polychaeta	Terebellida	Ampharetidae	Ampharete acutifrons	3
Polychaeta	Terebellida	Ampharetidae	Ampharete finmarchica	9
Polychaeta	Terebellida	Ampharetidae	Ampharete spp	17
Polychaeta	Terebellida	Ampharetidae	Ampharetidae spp	10
Polychaeta	Terebellida	Ampharetidae	Amphicteis mucronata	4
Polychaeta	Terebellida	Ampharetidae	Amphicteis spp	6
Polychaeta	Terebellida	Ampharetidae	Amphisamytha bioculata	1
Polychaeta	Terebellida	Ampharetidae	Anobothrus gracilis	23
Polychaeta	Terebellida	Ampharetidae	Asabellides lineata	4
Polychaeta	Terebellida	Ampharetidae	Lysippe labiata	7
Polychaeta	Terebellida	Ampharetidae	Melinna heterodonta	20
Polychaeta	Terebellida	Ampharetidae	Melinna oculata	6
Polychaeta	Terebellida	Ampharetidae	Melinna spp	3
Polychaeta	Terebellida	Ampharetidae	Samytha californiensis	4
Polychaeta	Amphinomida	Amphinomidae	Amphinomidae sp	2
Polychaeta	Amphinomida	Amphinomidae	Chloeia pinnata	150
Polychaeta	Phyllodocida	Aphroditidae	Aphrodita refulgida	3
Polychaeta	Phyllodocida	Aphroditidae	Aphrodita spp	1
Polychaeta	Spionida	Apistobranchidae	Apistobranchus tullbergi	10
Polychaeta	Sedentaria	Capitellidae	Barantolla americana	1
Polychaeta	Sedentaria	Capitellidae	Capitellidae spp	92
Polychaeta	Sedentaria	Capitellidae	Decamastus gracilis	7
Polychaeta	Sedentaria	Capitellidae	Heteromastus filobranchus	2
Polychaeta	Sedentaria	Capitellidae	Mediomastus californiensis	248
Polychaeta	Sedentaria	Capitellidae	Notomastus hemipodus	158
Polychaeta	Sedentaria	Capitellidae	Notomastus latericeus	152
Polychaeta	Sedentaria	Capitellidae	Notomastus lineatus	90
Polychaeta	Sedentaria	Capitellidae	Notomastus magnus	2
Polychaeta	Sedentaria	Capitellidae	Notomastus spp	114
Polychaeta	Sedentaria	Capitellidae	Notomastus tenuis	145
Polychaeta	Sedentaria	Chaetopteridae	Chaetopteridae sp	2
Polychaeta	Sedentaria	Chaetopteridae	Chaetopterus sp	1

Class	Subclass/Order	Family	Taxon	Total Abund
Polychaeta	Sedentaria	Chaetopteridae	Chaetopterus variopedatus cmplx	1
Polychaeta	Sedentaria	Chaetopteridae	Mesochaetopterus spp	3
Polychaeta	Sedentaria	Chaetopteridae	Mesochaetopterus taylori	26
Polychaeta	Sedentaria	Chaetopteridae	Phyllochaetopterus limicolus	3
Polychaeta	Sedentaria	Chaetopteridae	Phyllochaetopterus prolifica	1
Polychaeta	Sedentaria	Chaetopteridae	Spiochaetopterus costarum	618
Polychaeta	Sedentaria	Chaetopteridae	Spiochaetopterus spp	25
Polychaeta	Terebellida	Cirratulidae	Aphelochaeta spp	237
Polychaeta	Terebellida	Cirratulidae	Aphelochaeta tigrina	18
Polychaeta	Terebellida	Cirratulidae	Chaetozone bansei	124
Polychaeta	Terebellida	Cirratulidae	Chaetozone columbiana	3
Polychaeta	Terebellida	Cirratulidae	Chaetozone nr setosa	3
Polychaeta	Terebellida	Cirratulidae	Chaetozone spp	19
Polychaeta	Terebellida	Cirratulidae	Cirratulidae spp	5
Polychaeta	Terebellida	Cirratulidae	Kirkegaardia dutchae	3
Polychaeta	Terebellida	Cirratulidae	Kirkegaardia secunda	4
Polychaeta	Terebellida	Cirratulidae	Kirkegaardia serratiseta	2
Polychaeta	Terebellida	Cirratulidae	Kirkegaardia tesselata	29
Polychaeta	Terebellida	Cirratulidae	Monticellina cryptica	5
Polychaeta	Terebellida	Cirratulidae	Monticellina serratiseta	2
Polychaeta	Terebellida	Cirratulidae	Monticellina spp	3
Polychaeta	Terebellida	Cirratulidae	Monticellina tesselata	59
Polychaeta	Sedentaria	Cossuridae	Cossura bansei	1
Polychaeta	Sedentaria	Cossuridae	Cossura candida	11
Polychaeta	Sedentaria	Cossuridae	Cossura pygodactylata	1
Polychaeta	Eunicida	Dorvilleidae	Dorvillea annulata	7
Polychaeta	Eunicida	Dorvilleidae	Protodorvillea gracilis	8
Polychaeta	Eunicida	Dorvilleidae	Schistomeringos longicornis	3
Polychaeta	Terebellida	Fauveliopsidae	Fauveliopsis magna	6
Polychaeta	Terebellida	Flabelligeridae	Brada sachalina	15
Polychaeta	Terebellida	Flabelligeridae	Brada villosa	13
Polychaeta	Terebellida	Flabelligeridae	Flabelligera affinis	1
Polychaeta	Terebellida	Flabelligeridae	Flabelligeridae spp	1
Polychaeta	Terebellida	Flabelligeridae	Pherusa neopapillata	5
Polychaeta	Terebellida	Flabelligeridae	Pherusa plumosa	3
Polychaeta	Terebellida	Flabelligeridae	Piromis hospitis	1
Polychaeta	Phyllodocida	Glyceridae	Glycera americana	5
Polychaeta	Phyllodocida	Glyceridae	Glycera macrobranchia	2
Polychaeta	Phyllodocida	Glyceridae	Glycera nana	103
Polychaeta	Phyllodocida	Glyceridae	Glycera oxycephala	117
Polychaeta	Phyllodocida	Glyceridae	Glycera spp	6
Polychaeta	Phyllodocida	Glyceridae	Glycera tesselata	1

Class	Subclass/Order	Family	Taxon	Total Abund
Polychaeta	Phyllodocida	Goniadidae	Glycinde armigera	239
Polychaeta	Phyllodocida	Goniadidae	Glycinde picta	21
Polychaeta	Phyllodocida	Goniadidae	Glycinde spp	6
Polychaeta	Phyllodocida	Goniadidae	Goniada brunnea	15
Polychaeta	Phyllodocida	Goniadidae	Goniada maculata	57
Polychaeta	Phyllodocida	Goniadidae	Goniada spp	4
Polychaeta	Phyllodocida	Hesionidae	Heteropodarke heteromorpha	2
Polychaeta	Phyllodocida	Hesionidae	Ophiodromus pugettensis	4
Polychaeta	Phyllodocida	Hesionidae	Podarkeopsis glabrus	7
Polychaeta	Eunicida	Lumbrineridae	Eranno bicirrata	79
Polychaeta	Eunicida	Lumbrineridae	Eranno lagunae	24
Polychaeta	Eunicida	Lumbrineridae	Eranno sp	11
Polychaeta	Eunicida	Lumbrineridae	Lumbrineridae spp	20
Polychaeta	Eunicida	Lumbrineridae	Lumbrineris californiensis	9
Polychaeta	Eunicida	Lumbrineridae	Lumbrineris cruzensis	23
Polychaeta	Eunicida	Lumbrineridae	Lumbrineris japonica	7
Polychaeta	Eunicida	Lumbrineridae	Lumbrineris latreilli	15
Polychaeta	Eunicida	Lumbrineridae	Lumbrineris spp	85
Polychaeta	Eunicida	Lumbrineridae	Ninoe gemmea	246
Polychaeta	Eunicida	Lumbrineridae	Scoletoma luti	294
Polychaeta	Eunicida	Lumbrineridae	Scoletoma tetraura	7
Polychaeta	Eunicida	Lumbrineridae	Scoletoma zonata	4
Polychaeta	Spionida	Magelonidae	Magelona berkeleyi	931
Polychaeta	Spionida	Magelonidae	Magelona hartmanae	109
Polychaeta	Spionida	Magelonidae	Magelona longicornis	180
Polychaeta	Spionida	Magelonidae	Magelona sacculata	275
Polychaeta	Spionida	Magelonidae	Magelona spp	2
Polychaeta	Sedentaria	Maldanidae	Axiothella rubrocincta	119
Polychaeta	Capitellida	Maldanidae	Chirimia similis	69
Polychaeta	Sedentaria	Maldanidae	Clymenura gracilis	24
Polychaeta	Sedentaria	Maldanidae	Clymenura spp	8
Polychaeta	Sedentaria	Maldanidae	Euclymene zonalis	25
Polychaeta	Sedentaria	Maldanidae	Euclymeninae spp	319
Polychaeta	Sedentaria	Maldanidae	Maldane cristata	5
Polychaeta	Sedentaria	Maldanidae	Maldane sarsi	247
Polychaeta	Sedentaria	Maldanidae	Maldanidae spp	4
Polychaeta	Sedentaria	Maldanidae	Metasychis disparidentatus	14
Polychaeta	Sedentaria	Maldanidae	Nicomache lumbricalis	1
Polychaeta	Sedentaria	Maldanidae	Nicomache personata	1
Polychaeta	Sedentaria	Maldanidae	Notoproctus pacificus	11
Polychaeta	Sedentaria	Maldanidae	Petaloproctus borealis	8
Polychaeta	Sedentaria	Maldanidae	Praxillella gracilis	89

Class	Subclass/Order	Family	Taxon	Total Abund
Polychaeta	Sedentaria	Maldanidae	Praxillella pacifica	13
Polychaeta	Sedentaria	Maldanidae	Praxillella spp	28
Polychaeta	Sedentaria	Maldanidae	Rhodine bitorquata	70
Polychaeta	Phyllodocida	Nephtyidae	Bipalponephtys cornuta	9
Polychaeta	Phyllodocida	Nephtyidae	Nephtys caeca	4
Polychaeta	Phyllodocida	Nephtyidae	Nephtys caecoides	217
Polychaeta	Phyllodocida	Nephtyidae	Nephtys ferruginea	146
Polychaeta	Phyllodocida	Nephtyidae	Nephtys glabra	5
Polychaeta	Phyllodocida	Nephtyidae	Nephtys punctata	61
Polychaeta	Phyllodocida	Nephtyidae	Nephtys spp	233
Polychaeta	Phyllodocida	Nereididae	Cheilonereis cyclurus	3
Polychaeta	Phyllodocida	Nereididae	Nereididae spp	1
Polychaeta	Phyllodocida	Nereididae	Nereis pelagica	2
Polychaeta	Phyllodocida	Nereididae	Nereis procera	24
Polychaeta	Phyllodocida	Nereididae	Nereis spp	4
Polychaeta	Phyllodocida	Nereididae	Nereis zonata	33
Polychaeta	Eunicida	Oenonidae	Drilonereis falcata	5
Polychaeta	Eunicida	Oenonidae	Drilonereis longa	7
Polychaeta	Eunicida	Oenonidae	Notocirrus californiensis	5
Polychaeta	Eunicida	Onuphidae	Diopatra ornata	43
Polychaeta	Eunicida	Onuphidae	Onuphidae spp	20
Polychaeta	Eunicida	Onuphidae	Onuphis elegans	7
Polychaeta	Eunicida	Onuphidae	Onuphis iridescens	647
Polychaeta	Eunicida	Onuphidae	Onuphis spp	21
Polychaeta	Eunicida	Onuphidae	Paradiopatra parva	98
Polychaeta	Sedentaria	Opheliidae	Armandia brevis	1
Polychaeta	Sedentaria	Opheliidae	Ophelia assimilis	357
Polychaeta	Sedentaria	Opheliidae	Ophelia pulchella	16
Polychaeta	Sedentaria	Opheliidae	Ophelina acuminata	67
Polychaeta	Sedentaria	Opheliidae	Ophelina cylindricaudata	1
Polychaeta	Sedentaria	Orbiniidae	Leitoscoloplos pugettensis	266
Polychaeta	Sedentaria	Orbiniidae	Naineris grubei	2
Polychaeta	Sedentaria	Orbiniidae	Naineris uncinata	6
Polychaeta	Sedentaria	Orbiniidae	Phylo felix	118
Polychaeta	Sedentaria	Orbiniidae	Scoloplos acmeceps	317
Polychaeta	Sedentaria	Orbiniidae	Scoloplos armiger	3
Polychaeta	Sabellida	Oweniidae	Galathowenia oculata	1347
Polychaeta	Sabellida	Oweniidae	Myriochele gracilis	174
Polychaeta	Sabellida	Oweniidae	Myriochele spp	1
Polychaeta	Sabellida	Oweniidae	Owenia fusiformis	88
Polychaeta	Sedentaria	Paraonidae	Aricidea (acmira) catherinae	4
Polychaeta	Sedentaria	Paraonidae	Aricidea (acmira) cerrutii	4

Class	Subclass/Order	Family	Taxon	Total Abund
Polychaeta	Sedentaria	Paraonidae	Aricidea (acmira) simplex	36
Polychaeta	Sedentaria	Paraonidae	Aricidea (aedicira) pacifica	25
Polychaeta	Sedentaria	Paraonidae	Aricidea (allia) antennata	8
Polychaeta	Sedentaria	Paraonidae	Aricidea (allia) ramosa	11
Polychaeta	Sedentaria	Paraonidae	Aricidea spp	34
Polychaeta	Sedentaria	Paraonidae	Cirrophorus branchiatus	3
Polychaeta	Sedentaria	Paraonidae	Levinsenia gracilis	5
Polychaeta	Sedentaria	Paraonidae	Paradoneis spinifera	1
Polychaeta	Terebellida	Pectinariidae	Pectinaria californiensis	199
Polychaeta	Terebellida	Pectinariidae	Pectinaria granulata	13
Polychaeta	Terebellida	Pectinariidae	Pectinaria spp	15
Polychaeta	Phyllodocida	Pholoidae	Pholoe spp	39
Polychaeta	Phyllodocida	Phyllodocidae	Eteone leptotes	1
Polychaeta	Phyllodocida	Phyllodocidae	Eteone spp	30
Polychaeta	Phyllodocida	Phyllodocidae	Eulalia californiensis	2
Polychaeta	Phyllodocida	Phyllodocidae	Eumida longicornuta	2
Polychaeta	Phyllodocida	Phyllodocidae	Hesionura coineaui difficilis	1
Polychaeta	Phyllodocida	Phyllodocidae	Paranaitis polynoides	15
Polychaeta	Phyllodocida	Phyllodocidae	Phyllodoce cuspidata	20
Polychaeta	Phyllodocida	Phyllodocidae	Phyllodoce groenlandica	12
Polychaeta	Phyllodocida	Phyllodocidae	Phyllodoce hartmanae	41
Polychaeta	Phyllodocida	Phyllodocidae	Phyllodoce longipes	1
Polychaeta	Phyllodocida	Phyllodocidae	Phyllodoce spp	7
Polychaeta	Phyllodocida	Pilargidae	Ancistrosyllis groenlandica	1
Polychaeta	Phyllodocida	Pilargidae	Hermundura fauveli	48
Polychaeta	Phyllodocida	Pilargidae	Hermundura ocularis	9
Polychaeta	Phyllodocida	Pilargidae	Pilargis berkeleyae	5
Polychaeta	Phyllodocida	Pilargidae	Pilargis maculata	21
Polychaeta	Phyllodocida	Pilargidae	Sigambra bassi	2
Polychaeta	Phyllodocida	Pilargidae	Sigambra spp	1
Polychaeta	Polychaeta incertae sedis	Polygordiidae	Polygordius spp	9
Polychaeta	Phyllodocida	Polynoidae	Arcteobia anticostiensis	2
Polychaeta	Phyllodocida	Polynoidae	Bylgides macrolepidus	7
Polychaeta	Phyllodocida	Polynoidae	Eucranta anoculata	9
Polychaeta	Phyllodocida	Polynoidae	Gattyana ciliata	1
Polychaeta	Phyllodocida	Polynoidae	Harmothoe extenuata	3
Polychaeta	Phyllodocida	Polynoidae	Harmothoe spp	3
Polychaeta	Phyllodocida	Polynoidae	Hesperonoe complanata	9
Polychaeta	Phyllodocida	Polynoidae	Hesperonoe laevis	6
Polychaeta	Phyllodocida	Polynoidae	Lepidasthenia berkeleyae	13
Polychaeta	Phyllodocida	Polynoidae	Lepidasthenia longicirrata	10
Polychaeta	Phyllodocida	Polynoidae	Lepidonotus spiculus	2

Class	Subclass/Order	Family	Taxon	Total Abund
Polychaeta	Phyllodocida	Polynoidae	Lepidonotus squamatus	5
Polychaeta	Phyllodocida	Polynoidae	Malmgreniella bansei	21
Polychaeta	Phyllodocida	Polynoidae	Malmgreniella baschi	2
Polychaeta	Phyllodocida	Polynoidae	Malmgreniella berkeleyorum	1
Polychaeta	Phyllodocida	Polynoidae	Malmgreniella liei	1
Polychaeta	Phyllodocida	Polynoidae	Malmgreniella macginitiei	1
Polychaeta	Phyllodocida	Polynoidae	Malmgreniella sanpedroensis	46
Polychaeta	Phyllodocida	Polynoidae	Malmgreniella scriptoria	51
Polychaeta	Phyllodocida	Polynoidae	Malmgreniella spp	7
Polychaeta	Phyllodocida	Polynoidae	Nemidia microlepida	6
Polychaeta	Phyllodocida	Polynoidae	Polynoidae spp	9
Polychaeta	Phyllodocida	Polynoidae	Tenonia priops	15
Polychaeta	Sabellida	Sabellidae	Bispira spp	1
Polychaeta	Sabellida	Sabellidae	Chone magna	1
Polychaeta	Sabellida	Sabellidae	Chone spp	5
Polychaeta	Sabellida	Sabellidae	Chone veleronis	1
Polychaeta	Sabellida	Sabellidae	Dialychone albocincta	8
Polychaeta	Sabellida	Sabellidae	Dialychone veleronis	6
Polychaeta	Sabellida	Sabellidae	Euchone analis	8
Polychaeta	Sabellida	Sabellidae	Euchone spp	2
Polychaeta	Sabellida	Sabellidae	Myxicola infundibulum	1
Polychaeta	Sabellida	Sabellidae	Paradialychone ecaudata	14
Polychaeta	Sabellida	Sabellidae	Parasabella rugosa	1
Polychaeta	Sabellida	Sabellidae	Pseudopotamilla intermedia	1
Polychaeta	Sabellida	Sabellidae	Sabellidae spp	3
Polychaeta	Polychaeta incertae sedis	Saccocirridae	Saccocirrus spp	2
Polychaeta	Sedentaria	Scalibregmatidae	Scalibregma californicum	77
Polychaeta	Sedentaria	Scalibregmatidae	Scalibregma inflatum	8
Polychaeta	Phyllodocida	Sigalionidae	Leanira alba	3
Polychaeta	Phyllodocida	Sigalionidae	Pholoides asperus	40
Polychaeta	Phyllodocida	Sigalionidae	Pisione spp	3
Polychaeta	Phyllodocida	Sigalionidae	Sigalion spinosus	75
Polychaeta	Phyllodocida	Sigalionidae	Sthenelais berkeleyi	7
Polychaeta	Phyllodocida	Sigalionidae	Sthenelais verruculosa	12
Polychaeta	Spionida	Spionidae	Aonides glandulosa	2
Polychaeta	Spionida	Spionidae	Apoprionospio pygmaea	1
Polychaeta	Spionida	Spionidae	Boccardia pugettensis	21
Polychaeta	Spionida	Spionidae	Boccardia sp	9
Polychaeta	Spionida	Spionidae	Dipolydora brachycephala	2
Polychaeta	Spionida	Spionidae	Dipolydora cardalia	5
Polychaeta	Spionida	Spionidae	Dipolydora caulleryi	2
Polychaeta	Spionida	Spionidae	Dipolydora socialis	13

Class	Subclass/Order	Family	Taxon	Total Abund
Polychaeta	Spionida	Spionidae	Laonice cirrata	29
Polychaeta	Spionida	Spionidae	Microspio pigmentata	68
Polychaeta	Spionida	Spionidae	Paraprionospio alata	246
Polychaeta	Spionida	Spionidae	Prionospio ehlersi	8
Polychaeta	Spionida	Spionidae	Prionospio lighti	16
Polychaeta	Spionida	Spionidae	Prionospio steenstrupi	209
Polychaeta	Spionida	Spionidae	Pseudopolydora sp	1
Polychaeta	Spionida	Spionidae	Scolelepis squamata	48
Polychaeta	Spionida	Spionidae	Scolelepis tridentata	2
Polychaeta	Spionida	Spionidae	Spio spp	1
Polychaeta	Spionida	Spionidae	Spio thulini	38
Polychaeta	Spionida	Spionidae	Spionidae spp	5
Polychaeta	Spionida	Spionidae	Spiophanes berkeleyorum	185
Polychaeta	Spionida	Spionidae	Spiophanes norrisi	300
Polychaeta	Terebellida	Sternaspidae	Sternaspis assimilis	65
Polychaeta	Terebellida	Sternaspidae	Sternaspis fossor	324
Polychaeta	Phyllodocida	Syllidae	Exogone lourei	28
Polychaeta	Phyllodocida	Syllidae	Exogone spp	33
Polychaeta	Phyllodocida	Syllidae	Geminosyllis ohma	2
Polychaeta	Phyllodocida	Syllidae	Pionosyllis sp	1
Polychaeta	Phyllodocida	Syllidae	Proceraea cornuta	1
Polychaeta	Phyllodocida	Syllidae	Sphaerosyllis californiensis	42
Polychaeta	Phyllodocida	Syllidae	Syllides longocirratus	3
Polychaeta	Phyllodocida	Syllidae	Syllis spp	2
Polychaeta	Phyllodocida	Syllidae	Typosyllis cornuta	12
Polychaeta	Phyllodocida	Syllidae	Typosyllis heterochaeta	24
Polychaeta	Phyllodocida	Syllidae	Typosyllis hyperioni	2
Polychaeta	Phyllodocida	Syllidae	Typosyllis pigmentata	9
Polychaeta	Phyllodocida	Syllidae	Typosyllis spp	10
Polychaeta	Terebellida	Terebellidae	Amaeana occidentalis	45
Polychaeta	Terebellida	Terebellidae	Artacama coniferi	27
Polychaeta	Terebellida	Terebellidae	Lanassa sp	1
Polychaeta	Terebellida	Terebellidae	Lanassa venusta	3
Polychaeta	Terebellida	Terebellidae	Pista agassizi	3
Polychaeta	Terebellida	Terebellidae	Pista brevibranchiata	24
Polychaeta	Terebellida	Terebellidae	Pista estevanica	142
Polychaeta	Terebellida	Terebellidae	Pista moorei	6
Polychaeta	Terebellida	Terebellidae	Pista spp	27
Polychaeta	Terebellida	Terebellidae	Pista wui	107
Polychaeta	Terebellida	Terebellidae	Polycirrus californicus	5
Polychaeta	Terebellida	Terebellidae	Polycirrus spp	145
Polychaeta	Terebellida	Terebellidae	Proclea graffi	9

Class	Subclass/Order	Family	Taxon	Total Abund
Polychaeta	Terebellida	Terebellidae	Proclea graffii	3
Polychaeta	Terebellida	Terebellidae	Scionella japonica	2
Polychaeta	Terebellida	Terebellidae	Streblosoma bairdi	39
Polychaeta	Terebellida	Terebellidae	Thelepus setosus	3
Polychaeta	Echiuroidea	Thalassematidae	Arhynchite pugettensis	16
Polychaeta	Sedentaria	Travisiidae	Travisia brevis	41
Polychaeta	Sedentaria	Travisiidae	Travisia forbesii	20
Polychaeta	Sedentaria	Travisiidae	Travisia japonica	8
Polychaeta	Sedentaria	Travisiidae	Travisia pupa	6
Polychaeta	Terebellida	Trichobranchidae	Artacamella hancocki	9
Polychaeta	Terebellida	Trichobranchidae	Terebellidae spp	2
Polychaeta	Terebellida	Trichobranchidae	Terebellides californica	16
Polychaeta	Terebellida	Trichobranchidae	Terebellides reishi	29
Polychaeta	Terebellida	Trichobranchidae	Terebellides spp	21
Polychaeta	Terebellida	Trichobranchidae	Trichobranchus glacialis	3
Polychaeta	Spionida	Trochochaetidae	Trochochaeta multisetosa	4
Polychaeta			Polychaete spp	1

Table A-3. Abundance of all Crustaceans collected at the 404 stations considered in Chapter 3.

Class	Subclass/Order	Family	Taxon	Total Abund
Hexanauplia	Calanoida	Calanidae	Calanus spp	51
Hexanauplia	Calanoida	Metridinidae	Metridia pacifica	1
Hexanauplia	Calanoida	Pontellidae	Epilabidocera longipedata	7
Hexanauplia	Cyclopoida	Clausidiidae	Hemicyclops sp	27
Hexanauplia	Cyclopoida		Poecilostomatoida sp	1
Hexanauplia	Sessilia	Balanidae	Balanus crenatus	1
Hexanauplia	Sessilia	Balanidae	Balanus sp	1
Malacostraca	Amphipoda	Acidostomatidae	Acidostoma sp	2
Malacostraca	Amphipoda	Ampeliscidae	Ampelisca agassizi	41
Malacostraca	Amphipoda	Ampeliscidae	Ampelisca brevisimulata	5
Malacostraca	Amphipoda	Ampeliscidae	Ampelisca careyi	364
Malacostraca	Amphipoda	Ampeliscidae	Ampelisca cristata	29
Malacostraca	Amphipoda	Ampeliscidae	Ampelisca hancocki	13
Malacostraca	Amphipoda	Ampeliscidae	Ampelisca lobata	2
Malacostraca	Amphipoda	Ampeliscidae	Ampelisca pugetica	7
Malacostraca	Amphipoda	Ampeliscidae	Ampelisca spp	6
Malacostraca	Amphipoda	Ampeliscidae	Ampelisca unsocalae	10
Malacostraca	Amphipoda	Ampeliscidae	Ampeliscidae sp	1
Malacostraca	Amphipoda	Ampeliscidae	Byblis millsi	1
Malacostraca	Amphipoda	Ampeliscidae	Byblis mulleni	2
Malacostraca	Amphipoda	Ampeliscidae	Byblis spp	4
Malacostraca	Amphipoda	Aoridae	Aoroides inermis	20
Malacostraca	Amphipoda	Aoridae	Aoroides sp	10
Malacostraca	Amphipoda	Aoridae	Aoroides spp	4
Malacostraca	Amphipoda	Argissidae	Argissa hamatipes	7
Malacostraca	Amphipoda	Caprellidae	Caprella mendax	13
Malacostraca	Amphipoda	Caprellidae	Caprella spp	1
Malacostraca	Amphipoda	Caprellidae	Tritella pilimana	1
Malacostraca	Amphipoda	Caprellidae	Tritella tenuissima	17
Malacostraca	Amphipoda	Corophiidae	Cheirimedeia macrocarpa	13
Malacostraca	Amphipoda	Corophiidae	Cheirimedeia macrodactyla	16
Malacostraca	Amphipoda	Corophiidae	Cheirimedeia spp	2
Malacostraca	Amphipoda	Corophiidae	Cheirimedeia zotea	26
Malacostraca	Amphipoda	Corophiidae	Laticorophium baconi	4
Malacostraca	Amphipoda	Corophiidae	Protomedeia articulata	13
Malacostraca	Amphipoda	Corophiidae	Protomedeia prudens	28
Malacostraca	Amphipoda	Corophiidae	Protomedeia spp	2
Malacostraca	Amphipoda	Dulichiidae	Dulichia sp	1
Malacostraca	Amphipoda	Eusiridae	Rhachotropis sp	1
Malacostraca	Amphipoda	Eusiridae	Rhacotropis barnardi	1
Malacostraca	Amphipoda	Eusiridae	Rhacotropis boreopacifica	1
Malacostraca	Amphipoda	Haustoriidae	Eohaustorius sawyeri	181
Malacostraca	Amphipoda	Haustoriidae	Eohaustorius sencillus	158
Malacostraca	Amphipoda	Hyperiidae	Hyperiidae sp	5
Malacostraca	Amphipoda	Isaeidae	Isaeidae spp	79
Malacostraca	Amphipoda	Ischyroceridae	Ischyrocerus spp	2

Class	Subclass/Order	Family	Taxon	Total Abund
Malacostraca	Amphipoda	Liljeborgiidae	Idunella sp	4
Malacostraca	Amphipoda	Liljeborgiidae	Liljeborgia sp	10
Malacostraca	Amphipoda	Liljeborgiidae	Listriella albina	3
Malacostraca	Amphipoda	Lysianassidae	Hippomedon coecus	2
Malacostraca	Amphipoda	Lysianassidae	Hippomedon columbianus	1
Malacostraca	Amphipoda	Lysianassidae	Hippomedon spp	1
Malacostraca	Amphipoda	Lysianassidae	Lepidepecreum garthi	6
Malacostraca	Amphipoda	Lysianassidae	Lysianassidae spp	11
Malacostraca	Amphipoda	Lysianassidae	Orchomenella decipiens	1
Malacostraca	Amphipoda	Lysianassidae	Orchomenella pacifica	18
Malacostraca	Amphipoda	Lysianassidae	Orchomenella pinguis	115
Malacostraca	Amphipoda	Lysianassidae	Psammonyx longimerus	4
Malacostraca	Amphipoda	Lysianassidae	Wecomedon wecomus	9
Malacostraca	Amphipoda	Maeridae	Maera loveni	1
Malacostraca	Amphipoda	Maeridae	Maera sp	1
Malacostraca	Amphipoda	Megaluropidae	Gibberosus myersi	42
Malacostraca	Amphipoda	Melitidae	Desdimelita desdichada	6
Malacostraca	Amphipoda	Melitidae	Melitidae sp	5
Malacostraca	Amphipoda	Oedicerotidae	Americhelidium pectinatum	1
Malacostraca	Amphipoda	Oedicerotidae	Americhelidium shoemakeri	15
Malacostraca	Amphipoda	Oedicerotidae	Bathymedon covilhani	1
Malacostraca	Amphipoda	Oedicerotidae	Bathymedon pumilis	1
Malacostraca	Amphipoda	Oedicerotidae	Hartmanodes hartmanae	1
Malacostraca	Amphipoda	Oedicerotidae	Monoculodes emarginatus	3
Malacostraca	Amphipoda	Oedicerotidae	Monoculodes latissimus	1
Malacostraca	Amphipoda	Oedicerotidae	Oedicerotidae spp	2
Malacostraca	Amphipoda	Oedicerotidae	Pacifoculodes spinipes	36
Malacostraca	Amphipoda	Oedicerotidae	Westwoodilla tone	18
Malacostraca	Amphipoda	Opisidae	Opisa tridentata	2
Malacostraca	Amphipoda	Pachynidae	Prachynella lodo	4
Malacostraca	Amphipoda	Pardaliscidae	Nicippe tumida	7
Malacostraca	Amphipoda	Pardaliscidae	Pardaliscella symmetrica	2
Malacostraca	Amphipoda	Photidae	Gammaropsis ellisi	1
Malacostraca	Amphipoda	Photidae	Gammaropsis spp	7
Malacostraca	Amphipoda	Photidae	Photis brevipes	81
Malacostraca	Amphipoda	Photidae	Photis chiconola	1
Malacostraca	Amphipoda	Photidae	Photis macinerneyi	14
Malacostraca	Amphipoda	Photidae	Photis spp	21
Malacostraca	Amphipoda	Phoxocephalidae	Foxiphalus golfensis	2
Malacostraca	Amphipoda	Phoxocephalidae	Foxiphalus similis	12
Malacostraca	Amphipoda	Phoxocephalidae	Foxiphalus xiximeus	4
Malacostraca	Amphipoda	Phoxocephalidae	Grandifoxus longirostris	24
Malacostraca	Amphipoda	Phoxocephalidae	Harpiniopsis emeryi	7
Malacostraca	Amphipoda	Phoxocephalidae	Harpiniopsis fulgens	5
Malacostraca	Amphipoda	Phoxocephalidae	Harpiniopsis spp	8
Malacostraca	Amphipoda	Phoxocephalidae	Heterophoxus affinis	60
Malacostraca	Amphipoda	Phoxocephalidae	Heterophoxus ellisi	11

Class	Subclass/Order	Family	Taxon	Total Abund
Malacostraca	Amphipoda	Phoxocephalidae	Heterophoxus frequens	1
Malacostraca	Amphipoda	Phoxocephalidae	Heterophoxus oculatus	1
Malacostraca	Amphipoda	Phoxocephalidae	Heterophoxus spp	121
Malacostraca	Amphipoda	Phoxocephalidae	Majoxiphalus major	152
Malacostraca	Amphipoda	Phoxocephalidae	Mandibulophoxus mayi	45
Malacostraca	Amphipoda	Phoxocephalidae	Metaphoxus frequens	9
Malacostraca	Amphipoda	Phoxocephalidae	Paraphoxus sp	2
Malacostraca	Amphipoda	Phoxocephalidae	Pseudharpina inexpectata	1
Malacostraca	Amphipoda	Phoxocephalidae	Rhepoxynius abronius	10
Malacostraca	Amphipoda	Phoxocephalidae	Rhepoxynius bicuspidatus	28
Malacostraca	Amphipoda	Phoxocephalidae	Rhepoxynius boreovariatus	67
Malacostraca	Amphipoda	Phoxocephalidae	Rhepoxynius dabouis	63
Malacostraca	Amphipoda	Phoxocephalidae	Rhepoxynius fatigans	214
Malacostraca	Amphipoda	Phoxocephalidae	Rhepoxynius spp	317
Malacostraca	Amphipoda	Phoxocephalidae	Rhepoxynius variatus	56
Malacostraca	Amphipoda	Phoxocephalidae	Rhepoxynius vigitegus	276
Malacostraca	Amphipoda	Pleustidae	Kamptopleustes coquillus	2
Malacostraca	Amphipoda	Pleustidae	Pleusymtes spp	4
Malacostraca	Amphipoda	Stenothoidae	Stenothoidae spp	6
Malacostraca	Amphipoda	Synopiidae	Bruzelia tuberculata	1
Malacostraca	Amphipoda	Synopiidae	Syrrhoe longifrons	5
Malacostraca	Amphipoda	Uristidae	Anonyx sp	1
Malacostraca	Cumacea	Diastylidae	Anchicolurus occidentalis	33
Malacostraca	Cumacea	Diastylidae	Diastylidae spp	2
Malacostraca	Cumacea	Diastylidae	Diastylis abboti	1
Malacostraca	Cumacea	Diastylidae	Diastylis bidentata	3
Malacostraca	Cumacea	Diastylidae	Diastylis dalli	1
Malacostraca	Cumacea	Diastylidae	Diastylis paraspinulosa	7
Malacostraca	Cumacea	Diastylidae	Diastylis pellucida	9
Malacostraca	Cumacea	Diastylidae	Diastylis quadriplicata	3
Malacostraca	Cumacea	Diastylidae	Diastylis santamariensis	13
Malacostraca	Cumacea	Diastylidae	Diastylis spp	5
Malacostraca	Cumacea	Diastylidae	Diastylopsis dawsoni	33
Malacostraca	Cumacea	Diastylidae	Diastylopsis tenuis	3
Malacostraca	Cumacea	Lampropidae	Hemilamprops californicus	14
Malacostraca	Cumacea	Leuconidae	Eudorella emarginata	7
Malacostraca	Cumacea	Leuconidae	Eudorella pacifica	26
Malacostraca	Cumacea	Leuconidae	Eudorellopsis longirostris	7
Malacostraca	Cumacea	Leuconidae	Leucon spp	3
Malacostraca	Cumacea	Leuconidae	Leuconidae sp	3
Malacostraca	Cumacea	Nannastacidae	Campylaspis hartae	1
Malacostraca	Cumacea	Nannastacidae	Campylaspis papillata	3
Malacostraca	Cumacea	Nannastacidae	Campylaspis rubromaculata	1
Malacostraca	Cumacea	Nannastacidae	Campylaspis rufa	1
Malacostraca	Cumacea	Nannastacidae	Campylaspis spp	6
Malacostraca	Cumacea		Cumacea spp	1
Malacostraca	Decapoda	Axiidae	Calocarides (Acanthaxius) spinulicauda	2

Class	Subclass/Order	Family	Taxon	Total Abund
Malacostraca	Decapoda	Callianassidae	Neotrypaea californiensis	18
Malacostraca	Decapoda	Callianassidae	Neotrypaea gigas	10
Malacostraca	Decapoda	Callianassidae	Neotrypaea spp	99
Malacostraca	Decapoda	Cancridae	Metacarcinus spp	8
Malacostraca	Decapoda	Cancridae	Romaleon jordani	1
Malacostraca	Decapoda	Caridea	Caridea spp	15
Malacostraca	Decapoda	Crangonidae	Crangon alaskensis	13
Malacostraca	Decapoda	Crangonidae	Crangon franciscorum	1
Malacostraca	Decapoda	Crangonidae	Crangon spp	21
Malacostraca	Decapoda	Crangonidae	Crangon stylirostris	16
Malacostraca	Decapoda	Crangonidae	Lissocrangon stylirostris	14
Malacostraca	Decapoda	Crangonidae	Neocrangon communis	6
Malacostraca	Decapoda	Diogenidae	Paguristes turgidus	1
Malacostraca	Decapoda	Oregoniidae	Oregonia gracilis	1
Malacostraca	Decapoda	Paguridae	Pagurus armatus	15
Malacostraca	Decapoda	Paguridae	Pagurus capillatus	1
Malacostraca	Decapoda	Paguridae	Pagurus caurinus	1
Malacostraca	Decapoda	Paguridae	Pagurus dalli	1
Malacostraca	Decapoda	Paguridae	Pagurus ochotensis	4
Malacostraca	Decapoda	Paguridae	Pagurus quaylei	6
Malacostraca	Decapoda	Paguridae	Pagurus spp	33
Malacostraca	Decapoda	Pandalidae	Pandalus jordani	3
Malacostraca	Decapoda	Pasiphaeidae	Pasiphaea pacifica	1
Malacostraca	Decapoda	Pinnotheridae	Pinnixa occidentalis complex	1041
Malacostraca	Decapoda	Pinnotheridae	Pinnixa spp	162
Malacostraca	Decapoda	Pinnotheridae	Pinnotheridae sp	17
Malacostraca	Decapoda	Thoridae	Eualus berkeleyorum	1
Malacostraca	Decapoda	Thoridae	Spirontocaris lamellicornis	1
Malacostraca	Decapoda	Thoridae	Spirontocaris snyderi	2
Malacostraca	Decapoda	Thoridae	Spirontocaris sp	2
Malacostraca	Euphausiacea	Euphausiidae	Euphausia pacifica	2
Malacostraca	Euphausiacea	Euphausiidae	Thysanoessa spp	2
Malacostraca	Isopoda	Aegidae	Rocinela angustata	2
Malacostraca	Isopoda	Ancinidae	Bathycopea daltonae	8
Malacostraca	Isopoda	Anthuridae	Haliophasma geminata	2
Malacostraca	Isopoda	Gnathiidae	Gnathia spp	1
Malacostraca	Isopoda	Gnathiidae	Gnathia tridens	1
Malacostraca	Isopoda	Idoteidae	Edotia sublittoralis	4
Malacostraca	Isopoda	Idoteidae	Synidotea media	3
Malacostraca	Isopoda	Idoteidae	Synidotea spp	21
Malacostraca	Leptostraca	Nebaliidae	Nebalia spp	7
Malacostraca	Mysida	Mysidae	Alienacanthomysis macropsis	2
Malacostraca	Mysida	Mysidae	Archaeomysis grebnitzkii	96
Malacostraca	Mysida	Mysidae	Exacanthomysis davisi	1
Malacostraca	Mysida	Mysidae	Holmesiella anomala	2
Malacostraca	Mysida	Mysidae	Inusitatomysis insolita	1
Malacostraca	Mysida	Mysidae	Mysidae sp	6

Class	Subclass/Order	Family	Taxon	Total Abund
Malacostraca	Mysida	Mysidae	Mysidella americana	1
Malacostraca	Mysida	Mysidae	Neomysis kadiakensis	2
Malacostraca	Mysida	Mysidae	Pacifacanthomysis nephrophthalma	3
Malacostraca	Tanaidacea	Paratanaoidea incertae sedis	Scoloura phillipsi	3
Malacostraca	Tanaidacea	Tanaellidae	Araphura breviaria	1
Ostracoda	Myodocopida	Cylindroleberididae	Cylindroleberididae spp	43
Ostracoda	Myodocopida	Philomedidae	Euphilomedes carcharadonta	22
Ostracoda	Myodocopida	Philomedidae	Euphilomedes carcharodonta	262
Ostracoda	Myodocopida	Philomedidae	Euphilomedes producta	29
Ostracoda	Myodocopida	Philomedidae	Scleroconcha trituberculata	22
Ostracoda	Myodocopida	Rutidermatidae	Rutiderma lomae	3
Ostracoda			Ostracoda spp	4

Table A-4. Abundance of all Molluscs collected at the 404 stations considered in Chapter 3.

Class	Subclass/Order	Family	Taxon	Total Abund
Bivalvia	Adapedonta	Hiatellidae	Hiatella arctica	14
Bivalvia	Adapedonta	Pharidae	Pharidae sp	2
Bivalvia	Adapedonta	Pharidae	Siliqua alta	7
Bivalvia	Adapedonta	Pharidae	Siliqua patula	24
Bivalvia	Adapedonta	Pharidae	Siliqua spp	4
Bivalvia	Adapedonta	Solenidae	Solen sicarius	1
Bivalvia	Cardiida	Cardiidae	Keenaea centifilosa	6
Bivalvia	Cardiida	Tellinidae	Ameritella carpenteri	143
Bivalvia	Cardiida	Tellinidae	Ameritella modesta	60
Bivalvia	Cardiida	Tellinidae	Macoma calcarea	1
Bivalvia	Cardiida	Tellinidae	Macoma carlottensis	725
Bivalvia	Cardiida	Tellinidae	Macoma elimata	223
Bivalvia	Cardiida	Tellinidae	Macoma inquinata	1
Bivalvia	Cardiida	Tellinidae	Macoma spp	62
Bivalvia	Cardiida	Tellinidae	Macoma yoldiformis	1
Bivalvia	Cardiida	Tellinidae	Megangulus bodegensis	17
Bivalvia	Cardiida	Tellinidae	Tellina nuculoides	230
Bivalvia	Carditida	Carditidae	Cyclocardia ventricosa	140
Bivalvia	Galeommatida	Lasaeidae	Kurtiella tumida	868
Bivalvia	Heterodonta	Cuspidariidae	Cardiomya pectinata	13
Bivalvia	Heterodonta	Cuspidariidae	Cardiomya planetica	3
Bivalvia	Heterodonta	Cuspidariidae	Cuspidaria glacialis	4
Bivalvia	Heterodonta	Cuspidariidae	Cuspidariidae sp	3
Bivalvia	Heterodonta	Cuspidariidae	Pseudoneaera (Austroneaera) semipellucida	1
Bivalvia	Heterodonta	Laternulidae	Laternula marilina	28
Bivalvia	Heterodonta	Lyonsiidae	Lyonsia californica	3
Bivalvia	Heterodonta	Pandoridae	Pandora bilirata	20
Bivalvia	Heterodonta	Pandoridae	Pandora filosa	2
Bivalvia	Heterodonta	Thraciidae	Thracia challisiana	2
Bivalvia	Heterodonta	Thraciidae	Thracia trapezoides	6
Bivalvia	Heterodonta	Basterotiidae	Saxicavella pacifica	25
Bivalvia	Lucinida	Lucinidae	Lucinoma annulata	15
Bivalvia	Lucinida	Lucinidae	Lucinoma annulatum	2
Bivalvia	Lucinida	Lucinidae	Parvilucina tenuisculpta	1
Bivalvia	Lucinida	Thyasiridae	Adontorhina cyclia	394
Bivalvia	Lucinida	Thyasiridae	Adontorhina sphaericosa	31
Bivalvia	Lucinida	Thyasiridae	Axinopsida serricata	8806
Bivalvia	Lucinida	Thyasiridae	Mendicula ferruginosa	41
Bivalvia	Lucinida	Thyasiridae	Thyasira flexuosa	110
Bivalvia	Myida	Pholadoidea	Pholadoidea sp	12
Bivalvia	Mytilida	Mytilidae	Modiolus rectus	5

Class	Subclass/Order	Family	Taxon	Total Abund
Bivalvia	Mytilida	Mytilidae	Mytilidae spp	4
Bivalvia	Mytilida	Mytilidae	Solamen columbianum	60
Bivalvia	Nuculanida	Nuculanidae	Nuculana conceptionis	2
Bivalvia	Nuculanida	Nuculanidae	Nuculana fossa	17
Bivalvia	Nuculanida	Nuculanidae	Nuculana hamata	23
Bivalvia	Nuculanida	Nuculanidae	Nuculana minuta	1
Bivalvia	Nuculanida	Nuculanidae	Nuculana spp	3
Bivalvia	Nuculanida	Yoldiidae	Megayoldia martyria	22
Bivalvia	Nuculanida	Yoldiidae	Megayoldia thraciaeformis	2
Bivalvia	Nuculanida	Yoldiidae	Yoldia scissurata	15
Bivalvia	Nuculanida	Yoldiidae	Yoldia seminuda	51
Bivalvia	Nuculanida	Yoldiidae	Yoldiella spp	3
Bivalvia	Nuculanida	Yoldiidae	Yolida scissurata	14
Bivalvia	Nuculida	Nuculidae	Acila castrensis	1311
Bivalvia	Nuculida	Nuculidae	Ennucula tenuis	903
Bivalvia	Pectinida	Pectinidae	Delectopecten vancouverensis	1
Bivalvia	Solemyida	Nucinellidae	Huxleyia munita	1171
Bivalvia	Solemyida	Solemyidae	Solemya reidi	11
Bivalvia	Venerida	Mactridae	Mactridae spp	1
Bivalvia	Venerida	Veneridae	Compsomyax subdiaphana	85
Bivalvia	Venerida	Veneridae	Humilaria kennerleyi	2
Bivalvia	Venerida	Veneridae	Nutricola lordi	4041
Bivalvia			Bivalvia spp	11
Caudofoveata	Chaetodermatida	Chaetodermatidae	Chaetoderma argenteum	135
Caudofoveata	Chaetodermatida	Chaetodermatidae	Chaetoderma spp	28
Gastropoda	Caenogastropoda	Cerithiidae	Lirobittium sp	38
Gastropoda	Caenogastropoda	Epitoniidae	Epitonium hindsii	1
Gastropoda	Caenogastropoda	Epitoniidae	Epitonium indianorum	7
Gastropoda	Caenogastropoda	Epitoniidae	Epitonium spp	15
Gastropoda	Cephalaspidea	Acteocinidae	Acteocina cerealis	6
Gastropoda	Cephalaspidea	Acteocinidae	Acteocina eximia	121
Gastropoda	Cephalaspidea	Acteocinidae	Acteocina spp	160
Gastropoda	Cephalaspidea	Aglajidae	Melanochlamys diomedea	6
Gastropoda	Cephalaspidea	Cylichnidae	Cylichna attonsa	547
Gastropoda	Cephalaspidea	Cylichnidae	Cylichna spp	1
Gastropoda	Cephalaspidea	Diaphanidae	Diaphana californica	8
Gastropoda	Cephalaspidea	Gastropteridae	Gastropteron pacificum	9
Gastropoda	Cephalaspidea	Haminoeidae	Haminoea vesicula	7
Gastropoda	Cephalaspidea	Retusidae	Retusa xystrum	1
Gastropoda	Cephalaspidea	Rhizoridae	Volvulella cylindrica	23
Gastropoda	Heterobranchia	Acteonidae	Rictaxis punctocaelatus	17
Gastropoda	Heterobranchia	Pyramidellidae	Boonea oregensis	18

Class	Subclass/Order	Family	Taxon	Total Abund
Gastropoda	Heterobranchia	Pyramidellidae	Odostomia spp	187
Gastropoda	Heterobranchia	Pyramidellidae	Turbonilla spp	116
Gastropoda	Lepetellida	Fissurellidae	Fissurellidae sp	1
Gastropoda	Lepetellida	Scissurellidae	Anatoma (Scissurella) crispata	1
Gastropoda	Littorinimorpha	Eulimidae	Polygireulima rutila	9
Gastropoda	Littorinimorpha	Littorinidae	Lacuna vincta	2
Gastropoda	Littorinimorpha	Naticidae	Cryptonatica affinis	9
Gastropoda	Littorinimorpha	Naticidae	Sinum scopulosum	1
Gastropoda	Littorinimorpha	Rissoidae	Alvania compacta	50
Gastropoda	Neogastropoda	Borsoniidae	Ophiodermella cancellata	4
Gastropoda	Neogastropoda	Buccinidae	Ancistrolepis eucosmius	4
Gastropoda	Neogastropoda	Buccinidae	Buccinidae sp	2
Gastropoda	Neogastropoda	Buccinidae	Buccinum strigillatum fucanum	7
Gastropoda	Neogastropoda	Buccinidae	Colus halli	3
Gastropoda	Neogastropoda	Cancellariidae	Admete gracilior	2
Gastropoda	Neogastropoda	Cancellariidae	Admete viridula	16
Gastropoda	Neogastropoda	Columbellidae	Mitrella (Alia/Astyris) aurantiaca	35
Gastropoda	Neogastropoda	Columbellidae	Mitrella (Alia/Astyris) gausapata	729
Gastropoda	Neogastropoda	Mangeliidae	Kurtzia arteaga	47
Gastropoda	Neogastropoda	Mangeliidae	Kurtziella plumbea	10
Gastropoda	Neogastropoda	Mangeliidae	Oenopota fidicula	14
Gastropoda	Neogastropoda	Mangeliidae	Oenopota spp	3
Gastropoda	Neogastropoda	Mangeliidae	Oenopota turricula	1
Gastropoda	Neogastropoda	Muricidae	Boreotrophon dalli	1
Gastropoda	Neogastropoda	Muricidae	Boreotrophon orpheus	5
Gastropoda	Neogastropoda	Muricidae	Scabrotrophon lasius	2
Gastropoda	Neogastropoda	Nassariidae	Hima mendica	1
Gastropoda	Neogastropoda	Nassariidae	Nassarius fossatus (Caesia fossata)	17
Gastropoda	Neogastropoda	Olividae	Callianax baetica	363
Gastropoda	Neogastropoda	Olividae	Callianax biplicata	37
Gastropoda	Neogastropoda	Olividae	Callianax pycna	293
Gastropoda	Neogastropoda	Olividae	Olivella baetica	24
Gastropoda	Neogastropoda	Pseudomelatomidae	Antiplanes catalinae (voyi)	5
Gastropoda	Neogastropoda	Pseudomelatomidae	Antiplanes santarosana	1
Gastropoda	Neogastropoda	Pseudomelatomidae	Antiplanes spp	3
Gastropoda	Neogastropoda	Ptychatractidae	Exilioidea rectirostris	1
Gastropoda	Neogastropoda	Turridae	Turridae spp	5
Gastropoda	Nudibranchia	Arminidae	Armina californica	1
Gastropoda	Patellogastropoda	Lottiidae	Lottia sp	2
Gastropoda	Trochida	Colloniidae	Homalopoma radiatum	9
Gastropoda	Trochida	Margaritidae	Margarites pupillus	1
Gastropoda	Trochida	Solariellidae	Solariella peramabilis	13

Class	Subclass/Order	Family	Taxon	Total Abund
Gastropoda	Trochida	Solariellidae	Solariella sp	1
Gastropoda	Trochida	Trochidae	Lirularia lirulata	8
Gastropoda	Trochida	Trochidae	Trochidae sp	3
Gastropoda			Gastropoda spp	5
Polyplacophora	Chitonida	Ischnochitonidae	Ischnochiton willetti	21
Polyplacophora	Chitonida	Ischnochitonidae	Tripoplax trifida	5
Polyplacophora	Chitonida	Mopaliidae	Mopalia imporcata	1
Polyplacophora	Chitonida	Mopaliidae	Mopalia sp	2
Polyplacophora			Polyplacophora sp	1
Scaphopoda	Dentaliida	Dentaliidae	Antalis pretiosum	45
Scaphopoda	Dentaliida	Dentaliidae	Dentaliidae spp	4
Scaphopoda	Dentaliida	Rhabdidae	Rhabdus rectius	562
Scaphopoda	Gadilida	Gadilidae	Gadila aberrans	105
Scaphopoda	Gadilida	Gadilidae	Gadila tolmiei	164
Scaphopoda	Gadilida	Pulsellidae	Pulsellidae sp	84
Scaphopoda	Gadilida	Pulsellidae	Pulsellum salishorum	266
Scaphopoda			Scaphopoda spp	4

Table A-5. Abundance of all other organisms not listed above collected at the 404 stations considered in Chapter 3.

Phylum	Class	Subclass/Order	Family	Taxon	Total Abund
Brachiopoda	Rhynchonellata	Terebratulida	Laqueidae	Laqueus californianus	4
Bryozoa	Gymnolaemata	Ctenostomatida	Clavoporidae	Clavopora occidentalis	1
Chaetognatha	Sagittoidea	Aphragmophora	Sagittidae	Sagitta spp	4
Chordata	Ascidacea	Phlebobranchia	Corellidae	Chelysoma columbianum	12
Cnidaria	Anthozoa	Actiniaria	Edwardsiidae	Edwardsia juliae	3
Cnidaria	Anthozoa	Actiniaria	Edwardsiidae	Edwardsia profunda	1
Cnidaria	Anthozoa	Actiniaria	Edwardsiidae	Edwardsia spp	12
Cnidaria	Anthozoa	Actiniaria	Halcampidae	Halcampa crypta	2
Cnidaria	Anthozoa	Actiniaria	Halcampidae	Halcampa decemtentaculata	19
Cnidaria	Anthozoa	Actiniaria	Halcampidae	Halcampidae sp	9
Cnidaria	Anthozoa	Actiniaria	Halcampidae	Halcampoides purpureus	2
Cnidaria	Anthozoa	Actiniaria	Haloclavidae	Peachia quinquecapitata	11
Cnidaria	Anthozoa	Actiniaria	Metridiidae	Metridium sp	12
Cnidaria	Anthozoa	Actiniaria		Acontiaria sp	1
Cnidaria	Anthozoa	Actiniaria		Actiniaria sp	1
Cnidaria	Anthozoa	Actiniaria		Athenaria sp	2
Cnidaria	Anthozoa	Pennatulacea	Halipteridae	Halipteris sp	3
Cnidaria	Anthozoa	Pennatulacea	Pennatulidae	Ptilosarcus gurneyi	2
Cnidaria	Anthozoa	Pennatulacea	Virgulariidae	Stylatula elongata	17
Cnidaria	Anthozoa	Pennatulacea	Virgulariidae	Virgularia spp	2
Cnidaria	Anthozoa	Pennatulacea	Virgulariidae	Virgulariidae spp	3
Cnidaria	Anthozoa	Spirularia	Cerianthidae	Cerianthidae sp	6
Cnidaria	Anthozoa	Spirularia	Cerianthidae	Pachycerianthus fimbriatus	2
Cnidaria	Anthozoa	Spirularia	Cerianthidae	Pachycerianthus sp	25
Cnidaria	Anthozoa			Hexacorallia spp	1
Cnidaria	Hydrozoa	Anthoathecata	Tubulariidae	Ectopleura sp	1
Echinodermata	Asteroidea	Paxillosida	Ctenodiscidae	Ctenodiscus crispatus	3
Echinodermata	Echinoidea	Camarodonta	Strongylocentrotidae	Strongylocentrotus fragilis	2
Echinodermata	Echinoidea	Clypeasteroida	Dendrasteridae	Dendraster excentricus	219
Echinodermata	Echinoidea	Spatangoida	Schizasteridae	Brisaster latifrons	159
Echinodermata	Holothuroidea	Apodida	Chiridotidae	Chiridota spp	2
Echinodermata	Holothuroidea	Apodida	Synaptidae	Leptosynapta spp	8
Echinodermata	Holothuroidea	Dendrochirotida	Cucumariidae	Cucumaria piperata	1
Echinodermata	Holothuroidea	Dendrochirotida	Cucumariidae	Cucumariidae sp	1
Echinodermata	Holothuroidea	Dendrochirotida	Phyllophoridae	Pentamera populifera	1
Echinodermata	Holothuroidea	Dendrochirotida	Phyllophoridae	Pentamera pseudocalcigera	4

Phylum	Class	Subclass/Order	Family	Taxon	Total Abund
Echinodermata	Holothuroidea	Dendrochirotida	Phyllophoridae	Pentamera rigida	2
Echinodermata	Holothuroidea	Dendrochirotida	Phyllophoridae	Pentamera spp	13
Echinodermata	Holothuroidea	Molpadida	Caudinidae	Paracaudina chilensis	27
Echinodermata	Holothuroidea	Molpadida	Molpadiidae	Molpadia intermedia	2
Echinodermata	Ophiuroidea	Ophiurida	Amphiuridae	Amphiodia occidentalis	41
Echinodermata	Ophiuroidea	Ophiurida	Amphiuridae	Amphiodia periercta	2
Echinodermata	Ophiuroidea	Ophiurida	Amphiuridae	Amphiodia spp	1
Echinodermata	Ophiuroidea	Ophiurida	Amphiuridae	Amphiodia urtica	364
Echinodermata	Ophiuroidea	Ophiurida	Amphiuridae	Amphioplus macraspis	133
Echinodermata	Ophiuroidea	Ophiurida	Amphiuridae	Amphioplus strongyloplax	230
Echinodermata	Ophiuroidea	Ophiurida	Amphiuridae	Amphipholis pugetana	2
Echinodermata	Ophiuroidea	Ophiurida	Amphiuridae	Amphiuridae spp	20
Echinodermata	Ophiuroidea	Ophiurida	Ophiactidae	Ophiopholis bakeri	3
Echinodermata	Ophiuroidea	Ophiurida	Ophiuridae	Ophiura lutkeni	68
Echinodermata	Ophiuroidea	Ophiurida	Ophiuridae	Ophiura spp	12
Echinodermata	Ophiuroidea			Ophiuroidea spp	10
Entoprocta		Solitaria	Barentsiidae	Barentsia parva	1
Foraminifera		Foraminifera sp Biserial type 1			2
Foraminifera		Foraminifera sp Biserial type 2			1
Foraminifera		Foraminifera sp Planispiral evolute type 1			34
Foraminifera		Foraminifera sp Planispiral involute type 1			12
Foraminifera		Foraminifera sp Planispiral involute type 2			41
Foraminifera		Foraminifera sp Star type 1			1
Foraminifera		Foraminifera sp Streptospiral type 1			1
Foraminifera		Foraminifera sp Streptospiral type 2			1
Foraminifera		Foraminifera sp Triserial type 1			250
Foraminifera		Foraminifera sp Triserial type 2			17
Foraminifera		Foraminifera sp Trochospiral type 1			24
Foraminifera		Foraminifera sp Trochospiral type 2			7
Foraminifera		Foraminifera sp Uniserial type 1			43
Foraminifera		Foraminifera sp Uniserial type 2			52
Foraminifera		Foraminifera sp Uniserial type 3			7
Foraminifera		Foraminifera spp			3
Hemichordata	Enteropneusta	Enteropneusta	Harrimaniidae	Saccoglossus sp	1
Hemichordata	Enteropneusta	Enteropneusta	Ptychoderidae	Glossobalanus sp	5
Nematoda				Nematoda spp	71
Nemertea	Enopla	Monostilifera	Amphiporidae	Amphiporus spp	4
Nemertea	Enopla	Monostilifera	Emplectonematidae	Paranemertes californica	3
Nemertea	Enopla	Monostilifera	Tetrastemmatidae	Tetrastemma spp	10
Nemertea	Hoplonemertea			Hoplonemertea spp	33
Nemertea	Palaeonemertea	Carinomidae		Carinoma mutabilis	216

Phylum	Class	Subclass/Order	Family	Taxon	Total Abund
Nemertea	Palaeonemertea	Tubulanidae		Tubulanus polymorphus	51
Nemertea	Palaeonemertea	Tubulanidae		Tubulanus spp	19
Nemertea	Pilidiophora	Heteronemertea	Lineidae	Cerebratulus marginatus	1
Nemertea	Pilidiophora	Heteronemertea	Lineidae	Cerebratulus montgomeryi	2
Nemertea	Pilidiophora	Heteronemertea	Lineidae	Cerebratulus spp	33
Nemertea	Pilidiophora	Heteronemertea	Lineidae	Lineidae spp	19
Nemertea	Pilidiophora	Heteronemertea	Lineidae	Lineus bilineatus	19
Nemertea	Pilidiophora	Heteronemertea	Lineidae	Lineus sp	4
Nemertea	Pilidiophora	Heteronemertea	Lineidae	Micrura spp	75
Nemertea				Nemertea spp	3
Phoronida			Phoronidae	Phoronidae sp	118
Phoronida			Phoronidae	Phoronis spp	101
Platyhelminthes	Rhabditophora	Polycladida	Leptoplanidae	Leptoplanidae sp	6
Porifera	Hexactinellid			Hexactinellid sp	9
Porifera				Porifera spp	5
Retaria	Radiolaria			Radiolarian spp	65
Sipuncula	Sipunculidea	Golfingiida	Golfingiidae	Golfingia spp	1
Sipuncula	Sipunculidea	Golfingiida	Golfingiidae	Golfingiidae sp	18
Sipuncula	Sipunculidea	Golfingiida	Golfingiidae	Nephasoma diaphanes	69
Sipuncula	Sipunculidea	Golfingiida	Golfingiidae	Nephasoma spp	11
Sipuncula	Sipunculidea	Golfingiida	Golfingiidae	Thysanocardia nigra	33
Sipuncula	Sipunculidea			Phascolosoma agassizii	2
Sipuncula				Sipuncula spp	1
Sipuncula				Sipunculida sp	1

Table A-6. All combinations of variables considered for the LINKTREE analysis.
Rows are sort by trees with the fewest number of splits at the top. The most parsimonious tree used all environmental factors with majority coverage (see Table 1 in Chapter 3). An equivalent tree was determined using only latitude, depth, median grain size, and total organic carbon (TOC). Since many sampling programs do not include analysis of TOC, and a tree with only two additional spits could be constructed without the use of that additional variable, we chose latitude, depth, and median grain size as the most parsimonious tree with the fewest variables (highlighted).

# Factors	Variables	Breaks to
all	all	BQ
4	latitude, depth, medianGS, TOC	BQ
4	latitude, depth, medianGS, UpYear	BR
4	latitude, depth, medianGS, pH	BR
4	latitude, depth, medianGS, temp	BR
3	**latitude, depth, medianGS**	**BS**
4	latitude, depth, medianGS, UpMon	BT
5	latitude, depth, medianGS, TOC, UpPrev	BV
4	latitude, depth, medianGS, sal	BW
4	latitude, depth, medianGS, DO	BW
4	latitude, depth, fines, UpMon	BX
4	latitude, depth, medianGS, UpPrev	BX
4	latitude, depth, fines, UpYear	BX
5	latitude, depth, medianGS, fines, upPrev	BY
1	depth	BY
4	latitude, depth, fines, UpPrev	BY
4	latitude, depth, medianGS, fines	BZ
3	latitude, depth, fines	BZ
4	latitude, depth, fines, temp	BZ
4	latitude, depth, fines, pH	BZ
3	latitude, depth, salinity	CA
4	latitude, depth, fines, DO	CB
4	latitude, depth, fines, sal	CB
3	depth, medianGS, upYear	CC
3	latitude, depth, pH	CC
3	depth, medianGS, UpMon	CC
3	depth, medianGS, UpYear	CC
1	fines	CD
1	latitude	CD
2	latitude, depth	CD
3	latitude, depth, temp	CE
3	latitude, depth, TOC	CE
3	latitude, depth, DO	CF
3	latitude, medianGS, DO	CG
3	depth, medianGS, upPrev	CI
3	depth, medianGS, temp	CJ
3	depth, medianGS, DO	CJ

# Factors	Variables	Breaks to
5	depth, fines, medianGS, temp, pH	CM
3	latitude, medianGS, salinity	CM
3	latitude, medianGS, pH	CP
3	latitude, medianGS, temp	CP
3	depth, medianGS, pH	CQ
3	depth, medianGS, sal	CQ
3	depth, medianGS, UpYear	CR
2	latitude, medianGS	CS
3	depth, medianGS, fines	CU
2	depth, medianGS	CW
3	depth, medianGS, temp	CY
2	latitude, fines	CZ
2	depth, fines	DB
3	median grain size	DF

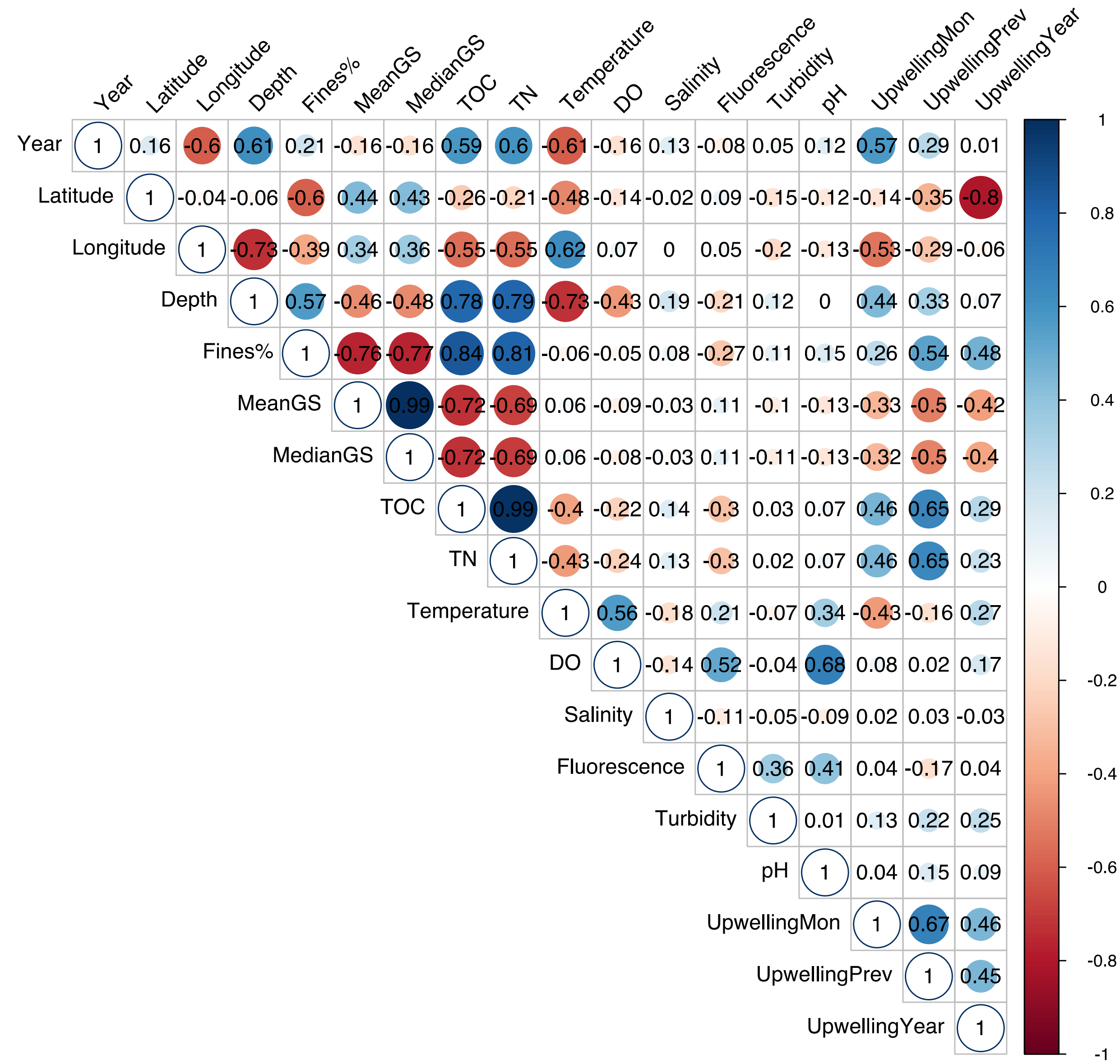

Figure A-1. Correlations among all the environmental variables collected in the study.

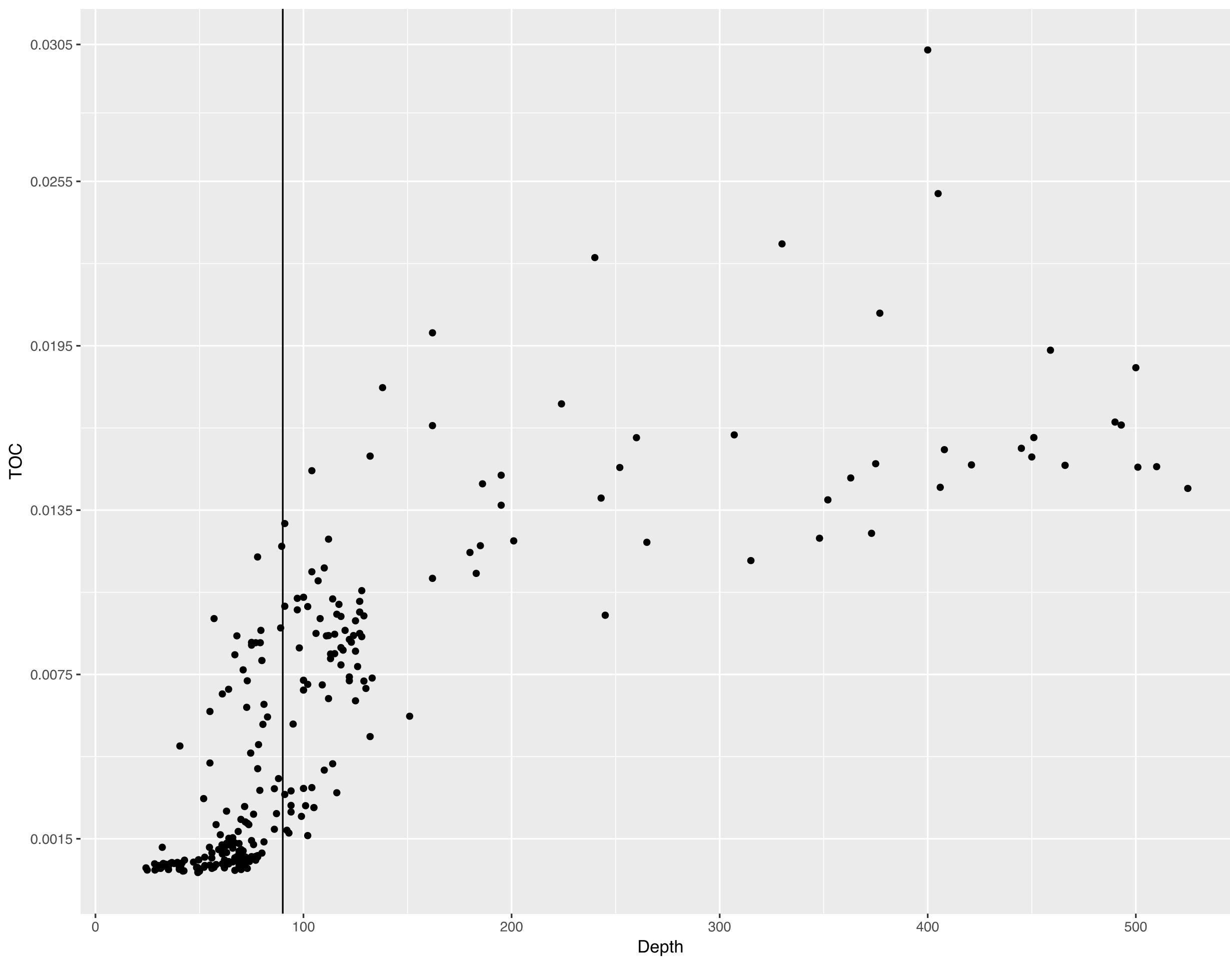

Figure A-2. Total Organic Carbon (TOC) versus depth for the 256 stations (of 378 analyzed) for which we had TOC data.

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