



Intertidal Monitoring in the North Coast and Cascades Network

Sand Beach Monitoring 2012 Annual Report

Natural Resource Data Series NPS/NCCN/NRDS—2015/976



ON THE COVER

The sand beach at Cedar Creek on the north Olympic coast
Photograph by: courtesy of Olympic National Park

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Abstract

Sand beach monitoring is one component of the North Coast and Cascades Network Intertidal Monitoring Protocol. This monitoring component focuses on the community structure of infaunal marine invertebrates and the physical structure of 6 sand beaches within Olympic National Park. These beaches span the latitudinal gradient of the 65-mile Olympic National Park shoreline. Sand beach infauna is closely linked to its physical habitat. Sand beaches are a major habitat type in Olympic National Park, making up approximately 30% of the intertidal zone. These beaches play an important role in both nutrient cycling and food web dynamics in the nearshore ocean. Three shore-normal transects were sampled at each beach. Sampling included infaunal organism abundance, beach sediment composition, and beach elevation profiles. In the 2012 monitoring field season covered here, the physical and biological structure of beaches were very similar to each other, as was noted in 2010 and 2011. Sediments for most beaches were characterized as well sorted, fine sand beaches with shallow slopes. Infaunal community composition, diversity and taxonomic distinctness demonstrated that beaches had similar structure and dominance of infaunal taxa, with an average of 6.7 taxa present per beach. A total of 9 taxa were found on the Olympic beaches. These beaches represent a powerful latitudinal array of sites in which changes associated with climate change and oil spills along the Olympic coast can be detected.

Acknowledgments

The OLYM field crew included: B. Baccus, J. Jones, A. Pfleeger, C. Urnes, and P. Zaidel. John Boetsch constructed the database and kept it in working order. Dr. Catharine Copass (NCCN) and Melissa Miner (University of California, Santa Cruz) provided informal peer review of the draft manuscript.

Introduction

This report presents data from the 2012 field season for the sand beach component of the North Coast and Cascades Network (NCCN) Intertidal Monitoring Protocol (Fradkin and Boetsch 2012a). The Intertidal Monitoring Protocol is part of the Inventory and Monitoring Program of the National Park Service (NPS). This program focuses on “vital signs”, which are defined as “information-rich attributes that are used to track the overall condition, or “health” of park natural resources to provide early warning of situations that require intervention” (Fancy et al. 2009). Monitoring has been implemented throughout the National Park system; for this purpose, 270 park units have been organized by ecoregion into 32 networks (Fancy et al. 2009). As one of these networks, the NCCN is composed of eight NPS units, including three parks that contain intertidal resources: Olympic National Park (OLYM), Lewis and Clark National Historical Park (LEWI), and San Juan Island National Historical Park (SAJH). Intertidal communities, particularly those in sand beach habitats, were identified as a key vital sign at numerous workshops developing the NCCN Inventory and Monitoring Program from 2000-2005 (Weber et al. 2009). This prioritization was based on a combination of perceived resource value, logistical and budgetary feasibility, and the current state of scientific methodology. Emphasis was placed on vital sign components that may provide early warning responses to the effects of global climate change and pollution. In contrast to other intertidal habitats within the NCCN, such as rocky intertidal, sand beaches supporting productive infaunal communities are found only within Olympic National Park. The mixed-coarse sediment beaches occurring at the American Camp unit of SAJH are dominated by gravel and have correspondingly low productivity and diversity. Such coarse beaches require substantially different monitoring methodologies (McLachlan 1990, McLachlan and Jaramillo 1995) and are not considered in the NCCN protocol. In LEWI, there is only a single sand beach of which only a ¼-mile long segment of the entire beach (>5 mi) is within the park boundary. As an Oregon state beach, this section of beach is considered a state highway and receives heavy automobile traffic, and thus cannot be sampled safely. As such, the sand beach monitoring component is conducted solely in Olympic National Park. Other monitoring components in the protocol include rocky intertidal community and intertidal temperature monitoring. The results from these components will be presented in separate reports.

Study Area

The coastal unit of OLYM, located on the outer Pacific coast of northwest Washington on the Olympic Peninsula (Figure 1), was incorporated into Olympic National Park in 1953. The intertidal zone was added to the park in 1986. Approximately 75% of this continuous stretch of coastline was designated wilderness by Congress in 1988 (Klinger et al. 2007). The coastal unit with its offshore islands has approximately 98 miles of diverse intertidal habitats, including cliffs, rocky platforms, boulder field, cobble beaches, gravel beaches, sand/gravel beaches, high energy fine sand beaches, and several small estuaries. If considered as a separate NPS unit, the OLYM coastal strip would be the 4th largest park (of 8) in the NCCN. The OLYM intertidal is one of the most biologically- and habitat-diverse shorelines on the west coast of North America (Blanchette et al. 2008, Schoch et al. 2006). The park shoreline can be broken up into four segments, or nearshore cells (Figure 1), that are characterized by differences in temperature and salinity (Schoch 1999). There are 28 sand beaches on the OLYM coast, occupying ~30% of the park shoreline.



Figure 1. Location of six sand beach monitoring sites within the coastal strip of Olympic National Park sampled in 2012. Colored beach segments denote nearshore cells characterized by different temperature and salinity (Schoch 1999).

Methods

The methodology for sampling sand beaches is covered in detail in the NCCN Intertidal Monitoring Protocol (Fradkin and Boetsch 2012a) and is briefly summarized here.

Field Sampling

Six beaches were sampled in 2012 (Figure 1). Toleak beach, sampled in 2010 and 2011 was dropped in 2012 as an active site because analyses of beach morphology and biota showed this beach to be a steep-sloped, mixed-coarse grain beach with a consistently different community structure than the other target beaches (Fradkin and Boetsch 2012b, Fradkin 2013). Three transects are randomly determined anew each year on each target beach. Transects were located in the field via GPS. The date, tidal elevation and time sampling commenced for each site in 2012 is presented in Table 1. Each vertical transect was shore-normal, starting from the most recent high tide line and extending to the water line. Sampling stations for biota were spaced every 7.5 m along the top 60 m of each transect. At each station, four sediment cores were extracted and individually passed through a 1 mm sieve to retain all macroscopic infaunal organisms (Figure 2). Sediment cores were 10 cm diameter, extending to a depth of 10 cm. All organisms within cores were counted and identified to the appropriate taxonomic level (Table 2). Sand beaches can have short sections where coarse sediments (gravel) accumulate via variation in wave action and long-shore currents. These areas represent very different, physically harsh, habitat types that support few infauna, and thus are not comparable to the surrounding sand beach areas. Where random transect locations landed on such coarse substrates (>40% gravel), a new random transect was selected.

Sediment samples were taken along the top 60 m of each transect at 15 m intervals (Figure 2). Cores were transported to the lab, where they were dried and sorted through a column of graded Tyler sieves. These size fractions were then weighed to determine sediment composition. Beach elevation profiles were also determined for the entirety of each transect. Profiles were surveyed using a laser auto-level to determine elevations from the most recent high tide line to the current water level at 7.5 m intervals.

Table 1. Date, time and tidal height during sampling of Olympic National park study beaches (north to south) in 2012.

Site	Date	Tide Height (ft)	Time sampling started (24 hr)
SHI	6/22/2012	-1.2	09:17
SAN	6/21/2012	-1.3	08:42
CED	6/20/2012	-1.3	08:07
SEC	6/18/2012	-1.0	06:56
RUB	6/19/2012	-1.2	09:17
KAL	7/5/2012	-1.9	09:16

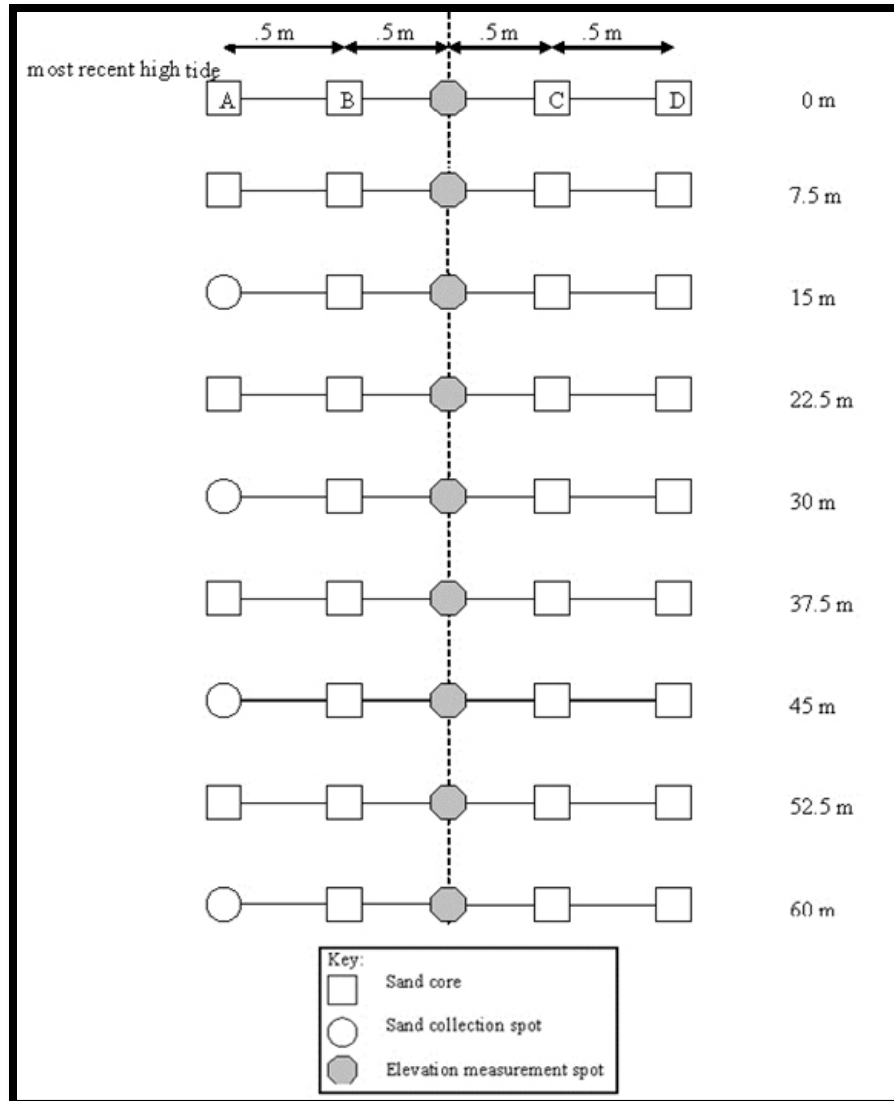


Figure 2. Schematic diagram of a sand beach monitoring transect. Each transect spans a shore normal 2 m wide belt from the most recent high tide line to 60 m seaward. Elevations were measured at each level along the centerline (shaded symbol), and beach infauna were sampled at four stations (open symbols) at each level. Sand cores were collected for sediment size composition at four levels (open circles).

Analysis

Sediment composition and description was determined using the GRADISTAT (version 8.0) particle size analysis software (Blott and Pye 2001) following the analytic methods of Folk (1954). Beach Index (BI), a composite index of beach morphology incorporating slope, sand, and tidal values was computed according to McLaughlin and Brown (2006):

$$BI = \log_{10} (\text{sand} * \text{tide/slope})$$

where sand is the mean particle size (Φ), tide is the maximum spring tidal range (m), and slope is the beach face slope of each transect. Beach elevation profile data were analyzed in JMP 7.0 (SAS 2007) to determine beach face slopes.

Comparisons of sand beach infaunal community structure were made between beaches and among nearshore cells. For each transect, invertebrate count data were used to estimate the number of individuals per strip transect (IST), after Defeo and Rueda (2002):

$$IST = \frac{\sum_i q_i}{n} w$$

where q_i is the density of infauna in each sediment core sample, n is the number of cores per transect and w is the width of the transect. IST data were analyzed using the multivariate methods in PRIMER-V6 (Clarke and Gorley 2006). Data were fourth root transformed to deemphasize the most abundant organisms (*sensu* Clarke and Warwick 2001). Bray-Curtis similarities were generated and represented with multidimensional scaling (MDS). Similarity percentage analyses (SIMPER) were used to identify taxa contributing the most to average similarity, a comparative measure community structure on beaches. Analysis of similarity (ANOSIM) was used to test the significance of differences in community structure between beaches. Taxonomic distinctness, a biodiversity analysis, used to measure the relatedness of species within samples (Warwick and Clarke 1995), was conducted for each transect on each beach using the TAXTDEST procedure and a master taxa list for all beaches.

Results and Discussion

Sediment Composition and Beach Slope

The six OLYM sand beaches sampled in 2012 are classified as intermediate meso-tidal beaches as defined by McLachlan and Brown (2006). These beaches were all well sorted (i.e., relatively uniform sediment composition), fine sand, moderately sloping beaches that were intermediate in their dissipation of wave energy across their face (Table 1). The sediment grain size composition was dominated by fine sand ($(\Phi = 2)$, Table 3, Figure 3).

Beach face profiles illustrate the moderate slopes found on the target beaches (Table 1, Figure 4). Beaches with slopes less than 10 generally indicate coarse sand and gravel beaches (McLachlan and Brown 2006).

Infaunal Taxa Patterns

Among the six sample beaches there were 4 to 9 infaunal taxa per beach. The highest taxon diversity per transect was at Kalaloch (8.3 taxa/transect), followed by Shi Shi (7.3 taxa per transect) and Sand Point (7 taxa/ transect). The fewest species were observed at Cedar Creek, with 4.7 taxa per strip transect. As found in previous sample years (Fradkin 2014), the amphipod *Eohaustorius* spp. was the most abundant taxa group at all beach study sites. *Eohaustorius* spp was more abundant by far than all other taxa combined at each of the beach study sites. Other taxa detected at all six beaches were Phoxocephalidae, Polychaete (spp.). The amphipod *Probosciniotus loquax* and the isopod *Excirolana* spp. were detected at five of the beaches. The least abundant taxa, those typically less than 1 individual per strip transect, were the amphipods *Megalorchestia* spp. and Phoxocephalidae, and the worms *Nyphlys* spp., and Nemerteans.

The highest abundance of organisms was found at Kalaloch beach, with substantially more *Eohaustorius* spp., *Probosciniotus loquax*, and Polychaete worms found than any other beach. The lowest abundance of organisms was found at Cedar Creek beach site.

Infaunal Community Structure

The infaunal community composition of replicate beach transects was similar, as illustrated by the clustering of triplicate points in the MDS analysis (Figure 5). There were no significant differences in community structure between any of the four nearshore cells (ANOSIM $R=0.138$, $p=0.103$, Figure 5). This result is consistent with the similarity of sediment composition and slopes across beaches implying a similar physical structure to the sites and that potential latitudinal differences in temperature and salinity do not lead to different community composition.

A SIMPER analysis examining similarities in community structure shows Olympic sand beaches in 2012 were structured around *Eohaustorius* amphipods, in addition to the amphipod *Probosciniotus loquax*, *Excirolana* isopods, the bloodworm *Euzonus mucronatus*, and polychaete worms (Table 4). The mean IST of *Eohaustorius* spp., *Probosciniotus loquax*, *Euzonus mucronatus*, and *Excirolana* spp. are illustrated in Figure 6.

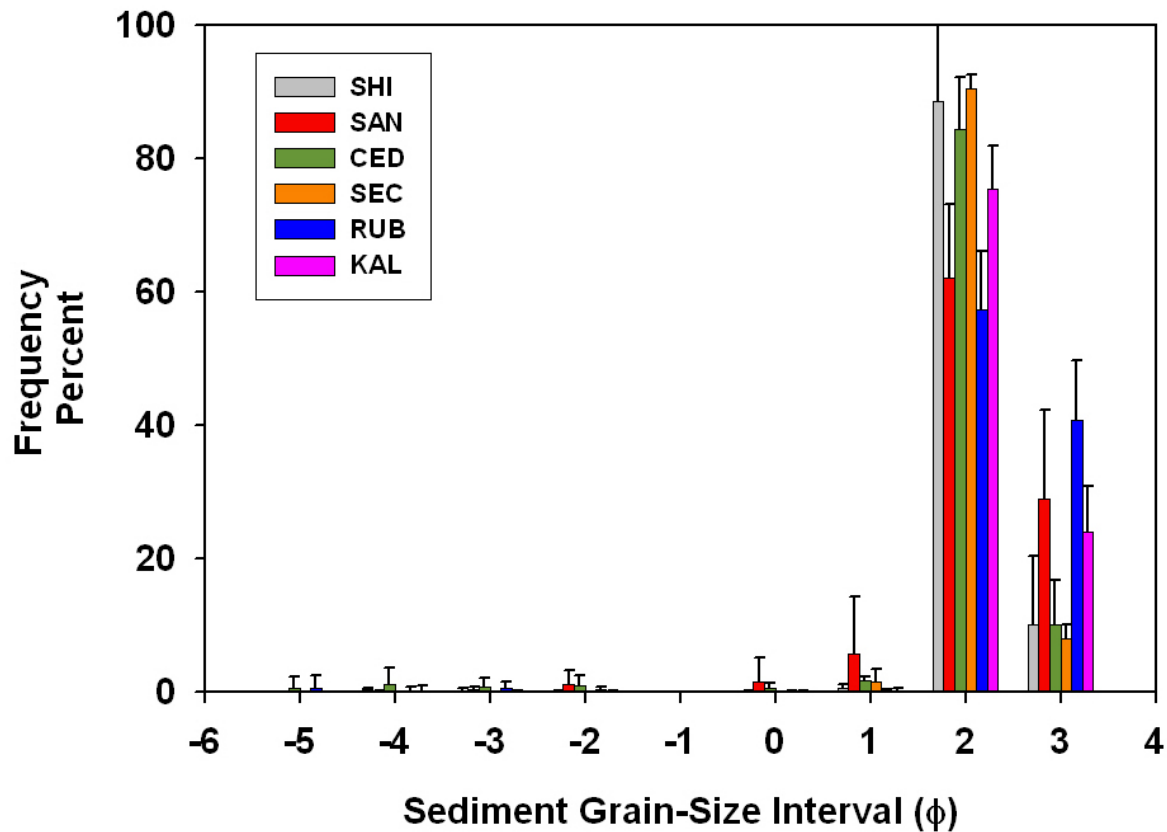


Figure 3. Beach sediment grain-size (Phi) frequency histogram for all six Olympic National Park study beaches in 2012 (from North to South). Histogram bars are average values (± 1 SE) for three replicate transects per beach. Small phi (Φ) values denote larger grain sizes. Sand has Φ values between -1 and 4, while gravel has values < -1 .

Taxonomic Distinctness

Average taxonomic distinctness is the average taxonomic distance apart (phylogenetically) of all species pairs within a species list (Clarke and Gorley 2006). Taxonomic distinctness measures the taxonomic breadth of a sample. Figure 7 displays a funnel plot with simulated 95% probability limits for average taxonomic distinctness based on 999 taxa sub-lists drawn randomly from a master list of 9 taxa. The average number of taxa found on all beaches was 6.7 (Table 2). None of the transects on any of the six beaches in 2012 had significantly narrower taxonomic breadths (i.e., low average taxonomic distinctness as determined by points falling outside of the 95% probability limit).

Table 2. Number of individuals per strip transect (IST) at each replicate transect on the six study beaches in Olympic National Park in 2012.

Taxa	SHI			SAN			CED			SEC			RUB			KAL		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Arthropoda																		
Crustacea																		
Amphipoda																		
<i>Eohaustorius spp.</i>	7.50	24.00	9.67	30.83	26.72	0.28	0.43	1.29	4.43	0.44	14.39	17.28	7.00	26.17	3.83	107.28	125.39	110.72
<i>Megalorchestia spp.</i>	0.89	0.00	0.33	1.89	1.56	1.50	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.28	0.06	0.33
Phoxocephalidae	0.33	0.13	0.06	0.06	0.00	0.00	0.00	0.00	0.14	0.17	0.11	0.11	0.06	0.00	0.17	0.22	0.00	0.28
<i>Probosciniotus loquax</i>	1.06	29.44	6.11	0.78	0.61	0.00	0.00	0.00	0.00	1.50	1.06	4.39	0.06	0.11	1.22	18.83	30.17	45.94
Isopoda																		
<i>Excirrolana spp.</i>	0.89	1.56	1.06	1.00	2.72	0.67	0.07	0.07	0.14	0.00	0.72	0.33	0.00	0.00	0.00	0.17	0.44	3.83
Annelida																		
Polychaeta																		
<i>Euzonus mucronatus</i>	2.33	0.44	2.83	0.56	0.89	0.06	3.00	0.00	0.00	0.00	0.06	0.00	0.06	0.00	0.22	0.89	0.11	1.39
<i>Nephtys spp.</i>	0.00	0.00	0.00	0.06	0.00	0.00	0.07	0.29	0.14	0.17	0.00	0.06	0.11	0.11	0.22	0.00	0.17	0.06
Polychaete spp.	3.83	1.75	1.44	0.44	0.33	0.11	0.14	1.07	0.29	0.44	0.39	0.56	1.00	0.44	43.56	8.72	4.61	2.28
Nemertea																		
Nemertean spp.	0.11	0.00	0.11	0.06	0.33	0.00	0.00	0.00	0.00	0.00	0.06	0.06	0.11	0.00	0.17	0.22	0.50	0.17
Number of taxa	8	6	8	9	7	5	5	4	5	5	8	7	7	4	7	8	8	9
Mean taxa abundance	1.9	6.4	2.4	4.0	3.7	0.3	0.4	0.3	0.6	0.3	1.9	2.5	0.9	3.0	5.5	15.2	17.9	18.3

Table 3. Beach slope*, beach index, sediment grain-size composition measures, and composition type description. Values are averages of three replicate transects per beach. Beach slope* is the reciprocal of the beach face slope. Beach index combines slope, mean sand particle size, and maximum spring tidal range (4.12 m) into a single beach characterization measure ranging from 0 to 4. 0 represents beaches with coarse sand, small tides and small waves, while 4 represents fine sand, large tides, and big waves. Olympic National Park study beaches are intermediate meso-tidal beaches (McLachlan and Brown 2006).

Beach	Beach slope*	Beach index (log Φ m)	Mean grain size	Mean Φ	Sediment type	Mean sorting value	Sorting type	Mean skewness	Skewness type	Mean kurtosis	Kurtosis type
SHI	17.3	2.35	228.3	2.1	fine sand	0.21	Very Well	0.33	Very Fine	3.33	Extremely Leptokurtic
SAN	19.3	2.42	213.8	2.3	fine sand	0.58	Moderately Well	0.34	Very Fine	2.44	Very Leptokurtic
CED	15.9	2.31	227.4	2.1	fine sand	0.48	Well	0.08	Symmetrical	6.76	Extremely Leptokurtic
SEC	13.5	2.24	228.8	2.1	fine sand	0.22	Very Well Sorted	0.36	Very Fine	3.53	Extremely Leptokurtic
RUB	16.0	2.36	178.5	2.5	fine sand	0.59	Moderately Well	0.48	Very Fine	1.06	Mesokurtic
KAL	17.7	2.40	189.2	2.4	fine sand	0.42	Well	0.74	Very Fine	2.08	Very Leptokurtic

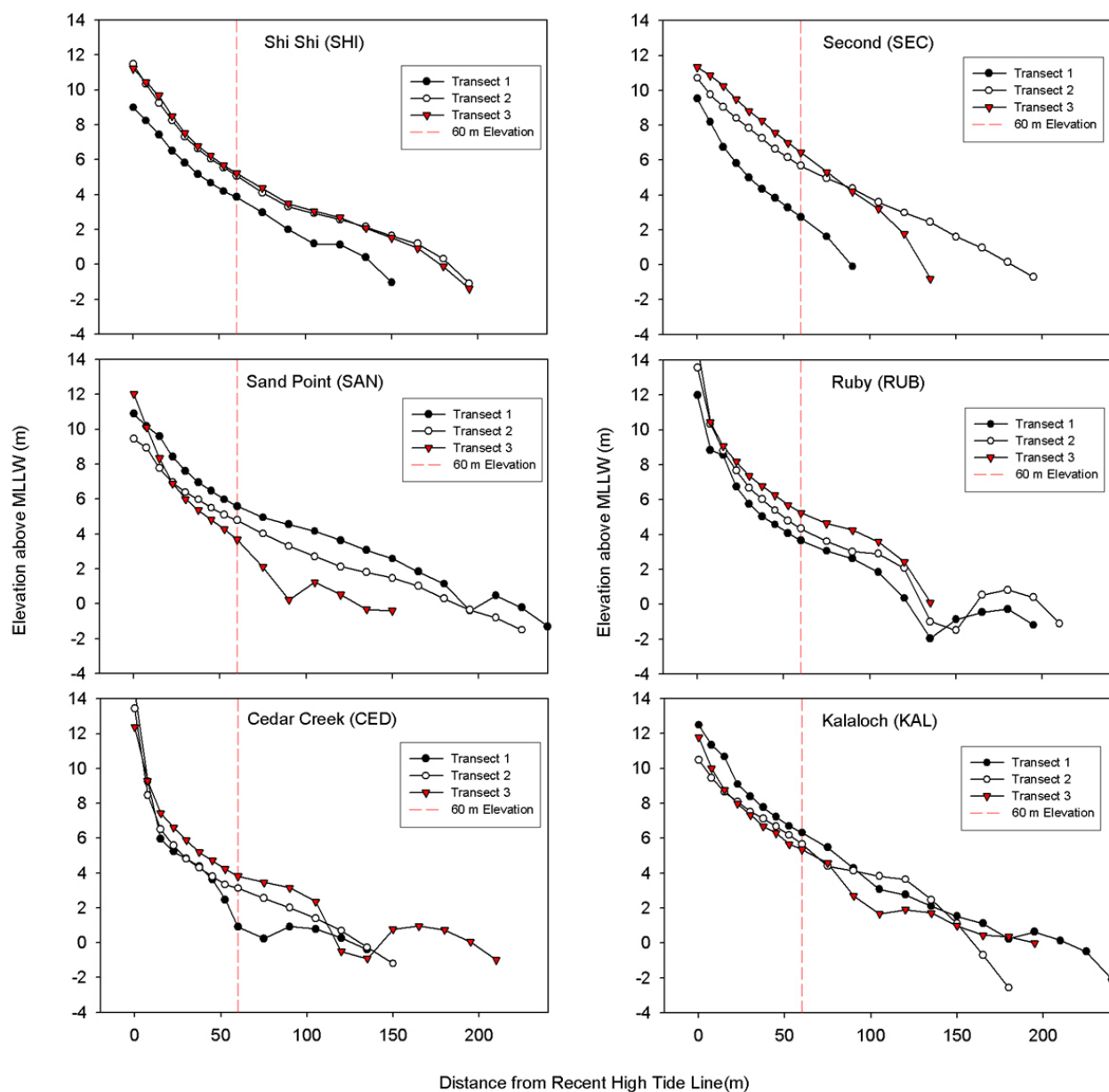


Figure 4. Beach face profiles relative to the mean lower low water (MLLW) tidal elevation of triplicate shore normal transects at each sand beach monitoring site in Olympic National Park in 2012. Transects start from most recent high tide line and extend to water level at time of sampling. Red vertical dotted lines denote the lowest extent of benthic infaunal sampling (60 m).

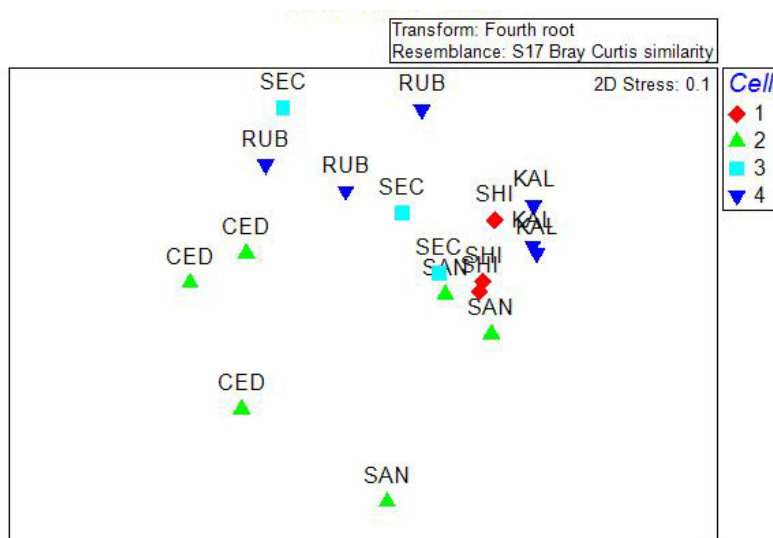


Figure 5. Sand beach infaunal assemblages from all 2012 Olympic National Park study beaches. MDS plot for fourth transformed taxa counts of nine taxa from three replicate transects within each of six beaches. Symbols represent nearshore cells and labels represent beach codes

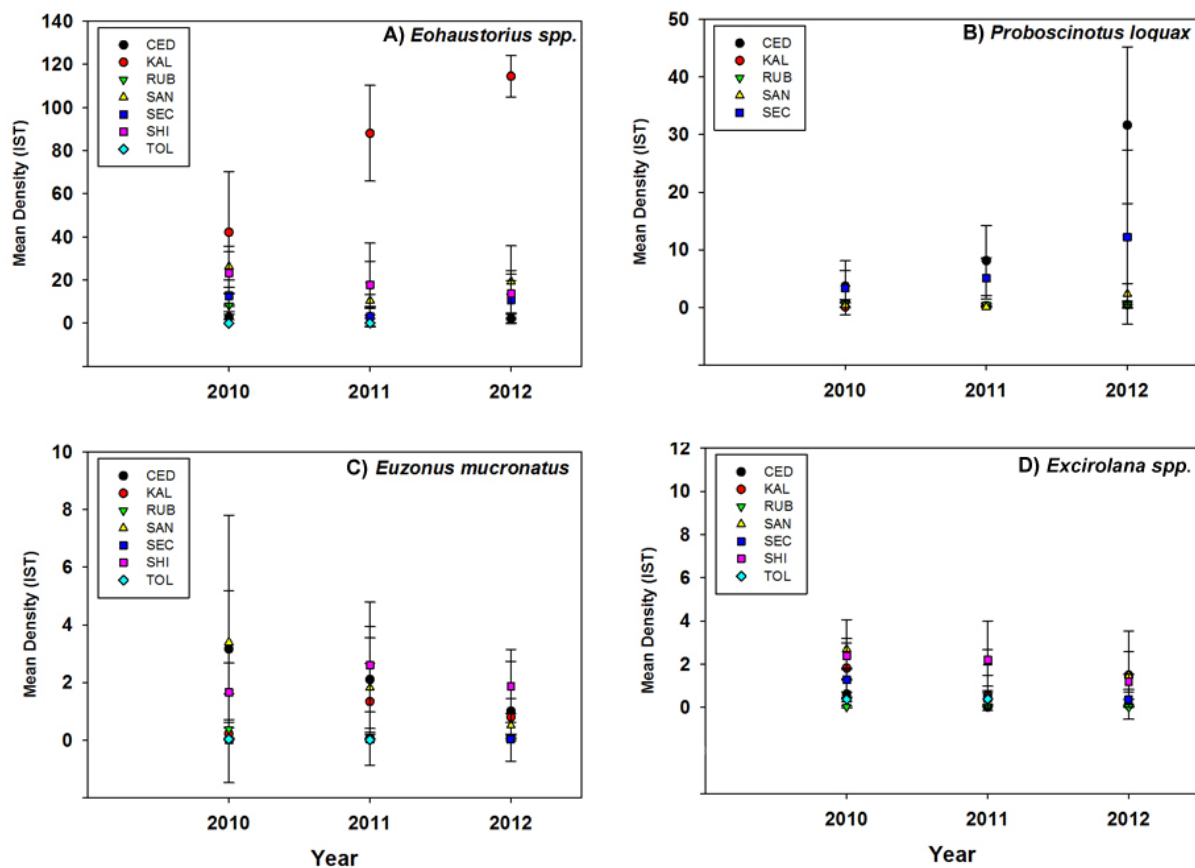


Figure 6. Mean individuals per strip transect (IST $\pm$ 1 SD) of the four dominant sand beach infaunal taxa present on Olympic National Park study beaches from 2010-2012. A). The amphipod *Eohaustorius* spp., B) the amphipod *Probosciniotus loquax*, C) the polychaete *Euzonus mucronatus*, D) the isopod *Excirolana* spp.

Table 4. Infaunal taxonomic contribution to similarity of community structure at six Olympic National Park study beaches in 2012 as determined by Similarity Percentage Analysis (SIMPER). Taxa shown are those contributing up to a cut-off of ~80% cumulative percent contribution. Beaches are arranged latitudinally from north to south. Average abundance is the mean number of organisms per strip transect (N=3 transects). Average similarity is the contribution each taxon contributes towards similarity of community structure within a beach. The Similarity:SD ratio is a measure of variation in similarity across replicate transects. Percent Contribution is the percent each taxon adds to community structure similarity. Cumulative percent is the additive percent contribution.

Beach	Species	Average Abundance	Average Similarity	Similarity: SD ratio	Percent Contribution	Cumulative Percent
SHI	<i>Eohaustorius spp.</i>	12.49	20.00	22.48	24.46	24.46
	<i>Probosciniotus loquax</i>	7.23	14.21	3.64	17.38	41.84
	<i>Polychaete spp.</i>	2.14	13.17	28.03	16.11	57.95
	<i>Excirolana spp.</i>	1.13	11.66	30.11	14.26	72.21
	<i>Euzonus mucronatus</i>	1.57	11.27	4.14	13.78	85.99
SAN	<i>Eohaustorius spp.</i>	10.27	17.08	1.93	23.92	23.92
	<i>Megalorchestia spp.</i>	1.63	16.62	5.89	23.28	47.20
	<i>Excirolana spp.</i>	1.26	13.93	8.11	19.52	66.72
	<i>Polychaete spp.</i>	0.27	9.35	28.84	13.10	79.82
CED	<i>Eohaustorius spp.</i>	1.52	24.21	5.67	34.32	34.32
	<i>Polychaete spp.</i>	0.39	17.64	8.18	25.01	59.33
	<i>Nephtys spp.</i>	0.15	14.78	8.53	20.96	80.29
SEC	<i>Eohaustorius spp.</i>	6.55	19.81	2.48	27.79	27.79
	<i>Probosciniotus loquax</i>	2.01	18.23	6.43	25.58	53.37
	<i>Polychaete spp.</i>	0.45	13.90	7.50	19.51	72.87
	<i>Phoxocephalidae</i>	0.13	10.02	8.07	14.06	86.93
RUB	<i>Eohaustorius spp.</i>	9.60	26.47	3.88	38.10	38.10
	<i>Polychaete spp.</i>	4.54	15.44	8.88	22.22	60.33
	<i>Nephtys spp.</i>	0.14	10.24	6.07	14.74	75.06
	<i>Probosciniotus loquax</i>	0.25	9.25	6.44	13.32	88.38
KAL	<i>Eohaustorius spp.</i>	114.34	28.98	25.14	33.20	33.20
	<i>Probosciniotus loquax</i>	29.98	19.48	15.77	22.31	55.51
	<i>Polychaete spp.</i>	4.67	11.78	6.77	13.49	69.00
	<i>Euzonus mucronatus</i>	0.60	6.32	3.37	7.24	76.24
	<i>Excirolana spp.</i>	0.81	6.27	7.75	7.19	83.43

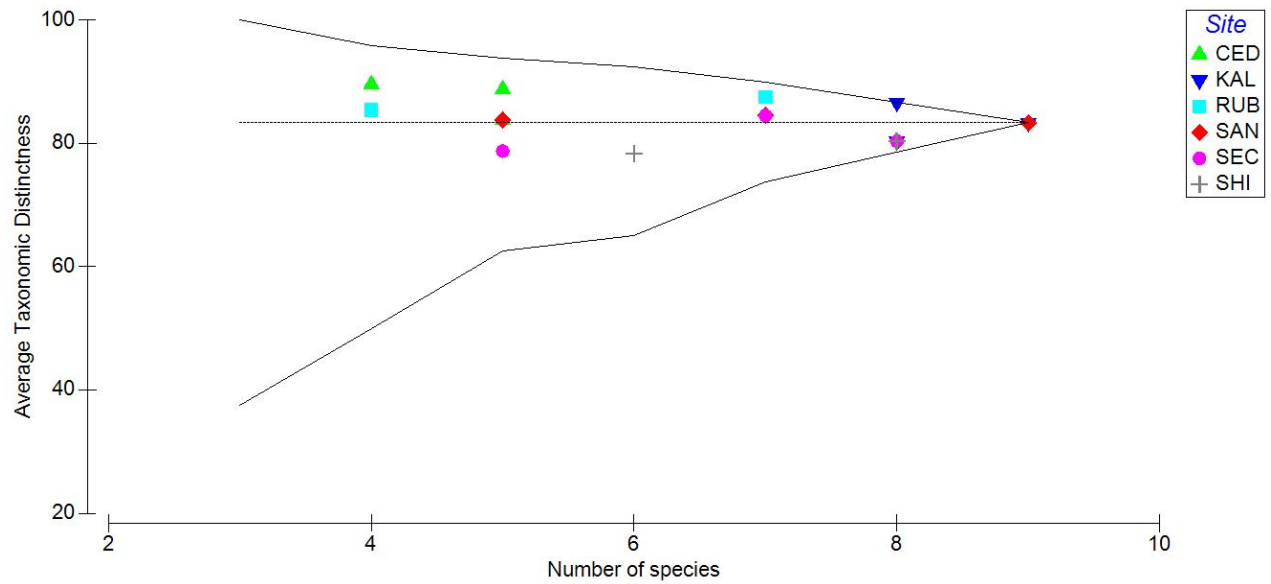


Figure 7. Funnel plot of average taxonomic distinctness ($\Delta+$) versus number of species in taxonomic sub-list for 2012 sand beach infaunal assemblages in each transect at each Olympic National Park study beach. Thick lines indicate 95% probability limits for simulated $\Delta+$ values. The dotted line denotes $\Delta+$ for the entire taxa list. Symbols denote actual $\Delta+$ values for the beach/transect combinations. Not all symbols are visible due to overlap of symbols.

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