Final Report for year 2009

Oregon State Parks rocky shore species inventories

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In the previous two reports, much attention has been given to spatial trends of community structure along the Oregon coast. In this report we will therefore describe previous patterns in less detail and focus more on the new sites and on temporal trends. The 2009 survey team was Beth Lenker and Kirsten Lycett, both previous State Parks inventory staff so no training period was needed this year and more sites could therefore be done during the summer.

Surveys conducted during 2009

Intertidal community inventories (biodiversity surveys) were conducted over the summer of 2009 at 7 State Park areas, the three in central Oregon that were started in summer 2007 (Otter Crest, Seal Rock, Strawberry Hill), the two in Southern Oregon that were surveyed in 2008, at Sunset Bay and Cape Arago's South Cove, and the two new ones, one further south at Harris Beach and one at the Yachats Marine Garden that is located near a PISCO core monitoring site. In each park, one high and one low human-visitation site (visitation rate based on State Park surveys) was surveyed at 3-4 shore levels (0', 3-3.5, 7-7.5, 9 feet above Mean Lower Low Water, the standard datum on this coast). Surveys were done in areas where the intertidal rocks have a gentle to moderate slope towards the ocean except for Harris Beach where non-vertical surfaces were not accessible (see below on detailed description of the new study sites). At each shore level, fifteen 38x55 cm quadrats were randomly selected along a 50 m long transect and surveyed for species percent cover (all algae and most sessile animals) or densities (all mobile animals and a few sessile ones such as sea anemones) in the field. Plots were also

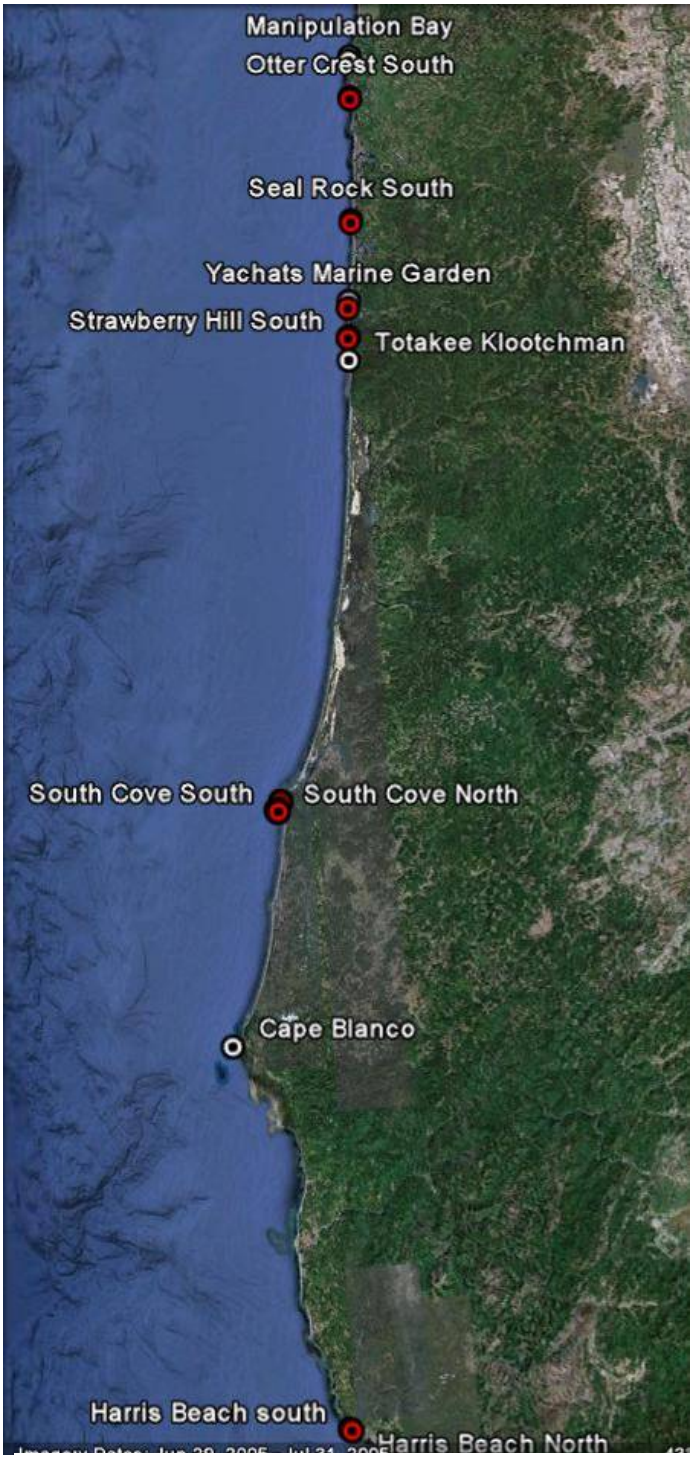


Fig. 1. Study sites along the Oregon shore during 2009, State Park sites are in red (some site names overlap and thus are not seen**).**

photographed for archival purposes. Nine additional PISCO sites were surveyed using the same methodology for a total of 20 surveyed sites. PISCO sites were analyzed together with the State Park sites in the multivariate similarity analysis to examine coast-scale variability. As we showed in the last report, the local seascape may be an important structuring force in intertidal communities and needs to be considered. We designated sites with a rocky reef subtidal bottom as reef-to-reef (R-R) seascape, and sites with a sandy subtidal as reef-to-sand (R-S) seascape.

State Park Study sites

The five State Park areas from previous years were described in the 2007 and 2008 reports. Fig. 2 shows the locations of the new sites at Harris Beach in southern Oregon. The one in the south is the more visited site, and the northern one is at the edge of the park with lower visitation levels. Both are embedded in a sandy beach and can therefore be characterized as having a Reef-to-Sand (R-S) seascape. As is typical of the southern Oregon coast, both sites have mostly vertical intertidal surfaces (see photos below). At the north site the low and low mid shore surveyed were primary large boulders and the boulders were scattered across the sandy bottom (see the photo below). The mid shore was half vertical and half horizontal. The south site had sheer vertical surfaces at the two lowest shore levels and the higher levels had a gentler slope in some parts of the transect. Because the structure of the two sites was not comparable, and seascape is a strong determinant of community structure, it is not really appropriate to compare the sites based on visitation levels. In any case, those vertical walls in the south are probably not much affected by humans because they cannot be trampled and access to them is limited most of the time.

Fig. 2. Google Earth map of the two Harris Beach sites

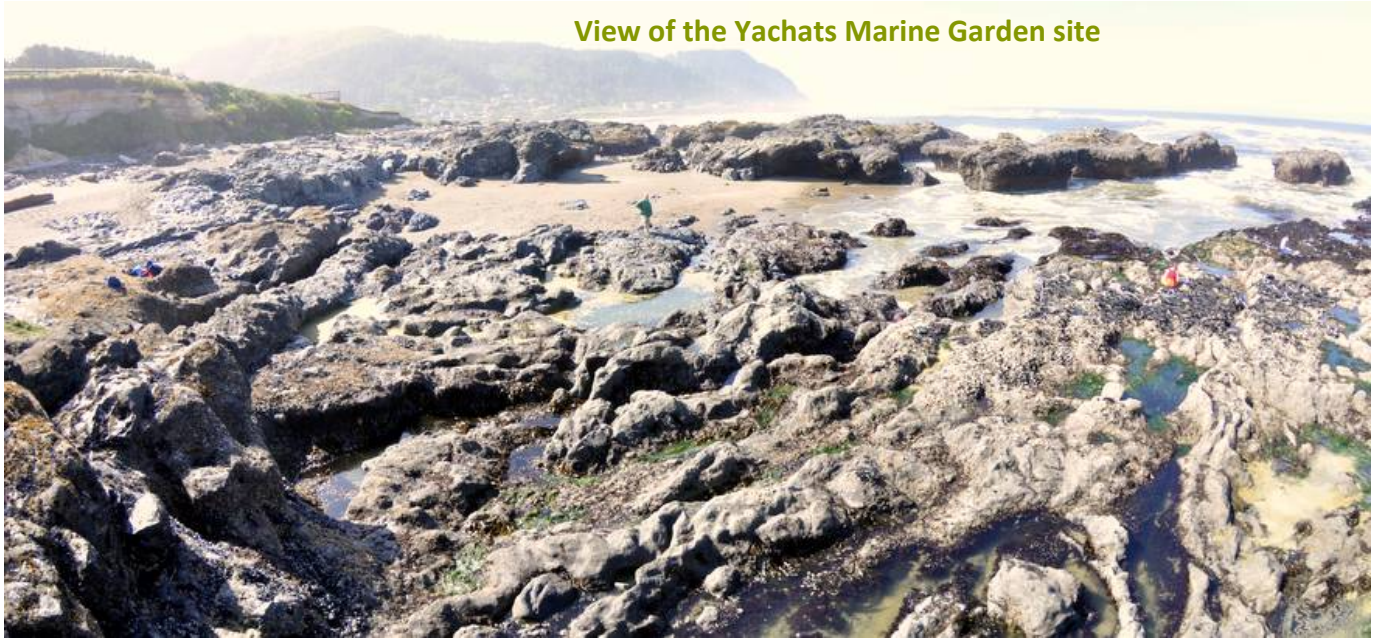
View of the Harris Beach South site

Harris Beach North – kelp growing on boulders covered by sand. Surfgrass is also visible.

View of the Harris Beach North site

In Yachats, we added a site within the Marine Garden area that is located a few hundred meters south of the core PISCO site (Fig. 3). The Marine Garden site is characterized by a broad, flat bench at the low-mid and low shore levels, a vertical mid shore and a relatively horizontal high shore. The core PISCO site is quite similar. Both are R-S sites.

Fig. 3. Google Earth map of the two Yachats sites



Community similarity analysis

To assess among-site and among-region similarity and to determine temporal change in community structure we applied multivariate analysis using the PRIMER6 software package. Specifically we used non-parametric multidimensional scaling (MDS) methods to visually illustrate community similarity. We included all of the PISCO sites in the analysis to achieve a more regional perspective. In this analysis we pooled the data for cover and densities and performed the analysis after a log(x+1) transformation to reduce the effects that the use of these different abundance estimation methods may have on the results. For each shore level, we highlight the clustering of sites by region or seascape (whether a site has a sandy or a rocky subtidal bottom seaward of the intertidal rocks). As the Harris Beach sites can be considered R-S sites it was interesting to see if they would cluster with the rest of the R-S sites in other regions, especially in the low shore where the differences were most notable. In this analysis, regions are as follows, Central-Cape Foulweather sites (Central-CF), Central-Cape Perpetua sites that this year also included the Seal Rock site (Central-CP), the sites further south that include the Cape Blanco site and the Cape Arago State Park sites (South-Central), and lastly the Harris Beach sites (Southern). This year, we also examined the similarities of the communities across time because we have a 3-yr database for the State Park sites and 11-yr for several core PISCO sites.

We also conducted the SIMPER analysis to determine which species are contributing most to the dissimilarity among communities (in space and in time) at each shore level separately. For brevity, we show and discuss only the most relevant and interesting results in figures and tables. The summary of the State Park data is also given as a separate excel file as an appendix so that further examination of the dataset can be done by OPRD if needed.

Spatial patterns

High shore patterns

At the high-shore level there is weak clustering by region, and the Harris Beach sites seem to cluster more with the CP sites and most but not all of the South-Central sites (Fig. 4). Harris Beach North is separated from the rest of the sites on the MDS plot indicating that it has some unique features. The most noticeable differences in these sites are the near absence of periwinkles and the relatively high (10%) cover of *Mazzaella cornucopiea*. There is no pronounced clustering by seascape (Fig. 4). It seems that this zone is much more similar across regions and seascapes than the other ones. This may be because it is less affected by the surrounding bottom (seascape). One exception is the interesting mosaic distribution of the brown algae *Pelvetiopsis limitata* that at some sites can cover more than 50% of the rocks and at other sites is almost absent (Fig. 5).

Fig. 4. MDS ordinations of the high shore depicting the characterization of the sites by region and seascape

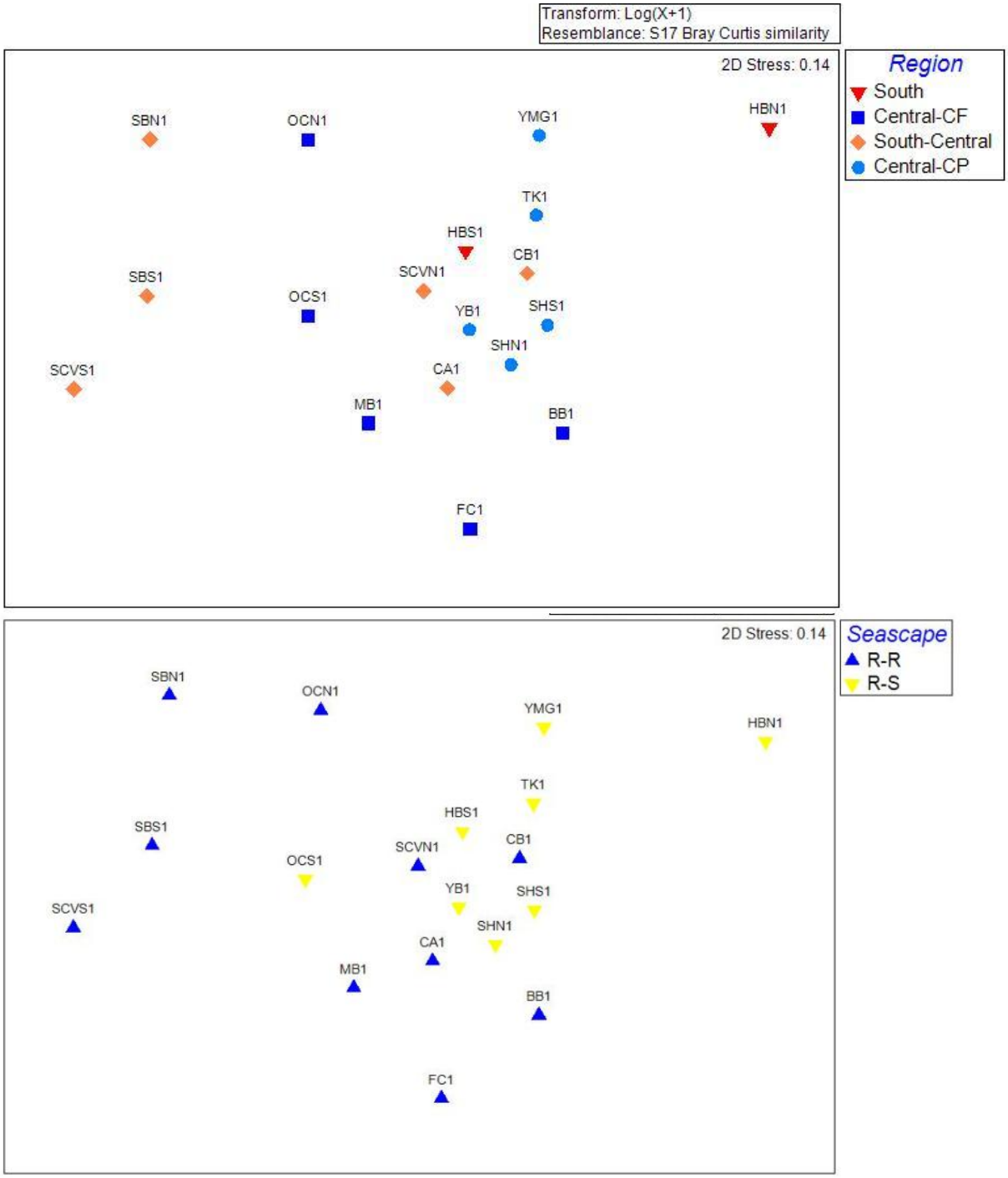
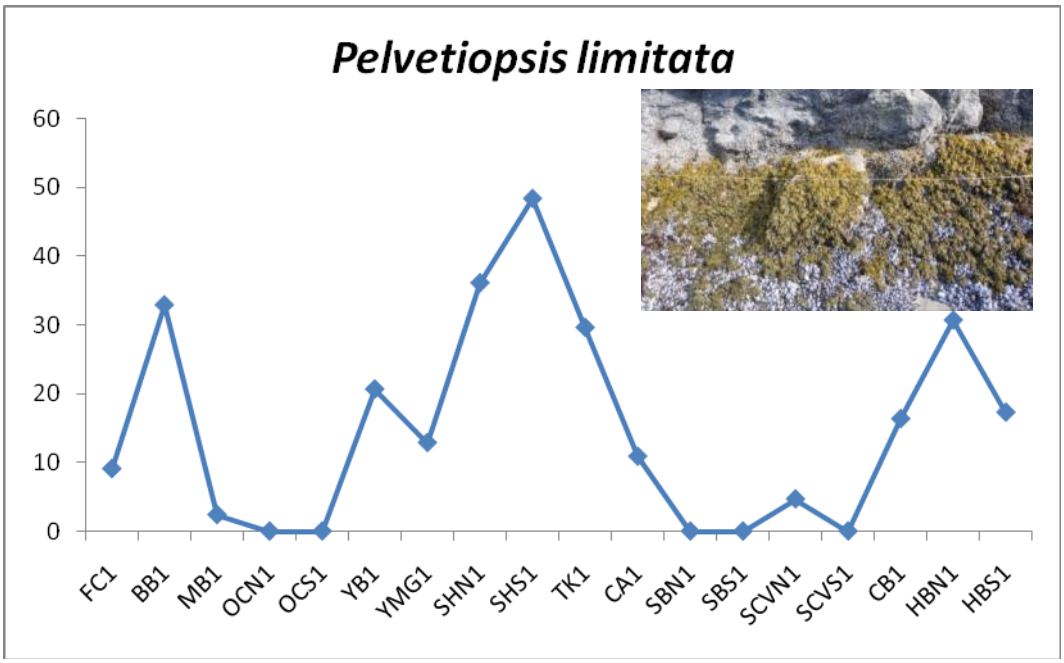


Fig. 5. Percent cover of the brown algae *Pelvetiopsis limitata* at the high shore level at the survey sites (from north to south) on summer 2009. The *Pelvetiopsis* belt is shown here in a photo from the HBN1 site.

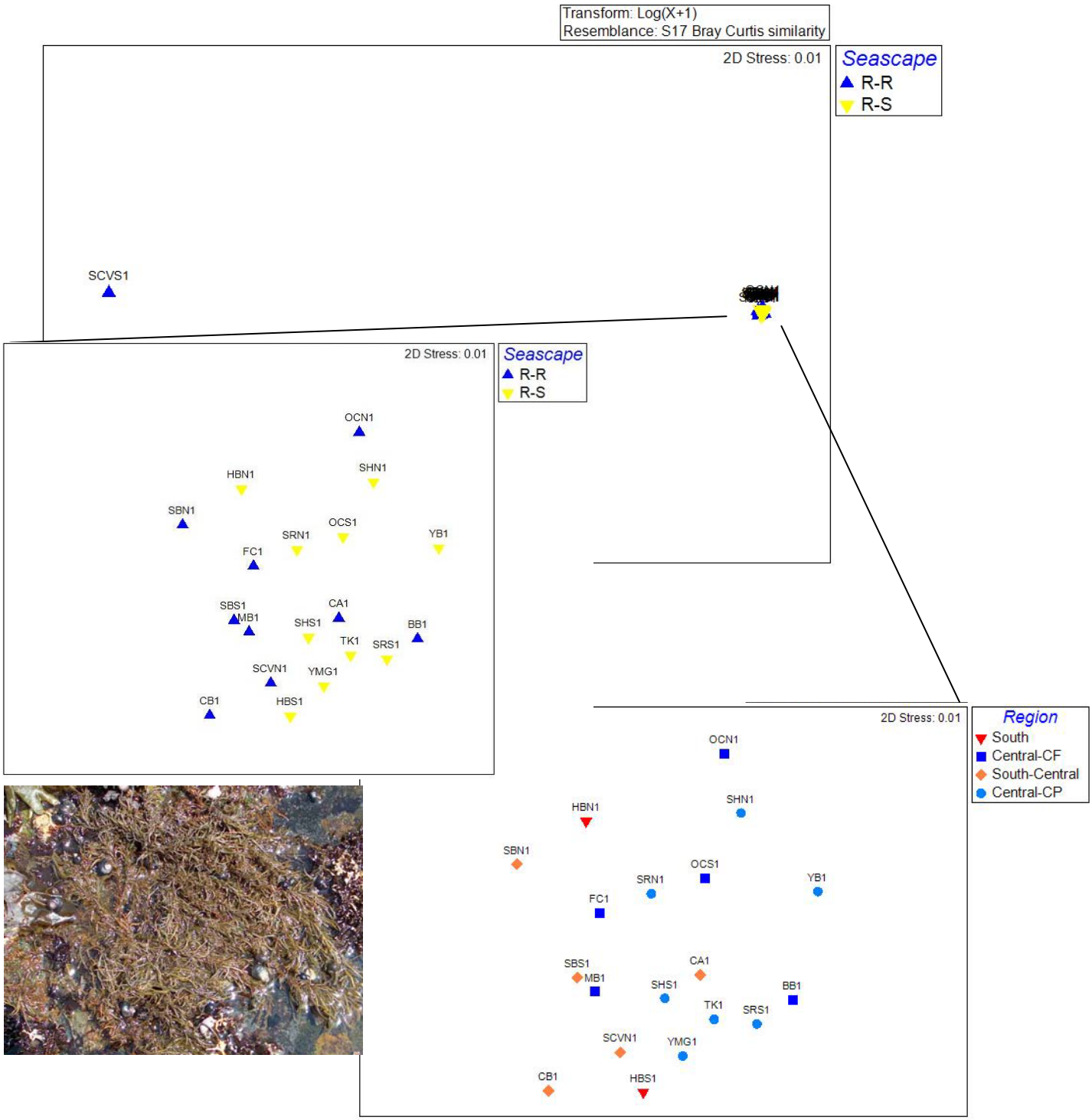


Mid shore patterns

The midshore results are more clustered (Fig. 6). The most intriguing pattern is the very distinctive community at South Cove South (indicated by an arrow on the MDS plot) that separates it from the rest of the sites so much that to be able to see the patterns at the rest of the sites we need to zoom-in (the two plots below). The South Cove South (SCVS1) site was 35-45% similar to the rest of the sites whereas the other sites were similar by around 60-80% among themselves. The species most responsible for these differences are as follows: mussels and the barnacle *Balanus glandula* were almost missing at the SCVS1 site as were the whelks *Nucella* spp., whereas the brown algae *Analipus japonicus* (see photo) was very abundant (~34% cover) at SCVS1 and almost absent everywhere else. Several more macroalgae were more abundant there than elsewhere, including mostly fucoids and *Mastocarpus*. This site also differed most last year (in the 2008 report it was coded as CAS1 but this year the site code name was replaced to better represent the site location: South Cove). The site is located inside the cove and has a very broad low and low-mid shore while the mid and high shore are bouldery in nature. We think that

these conditions (which probably are associated with lower wave action at the lower shore levels) may be responsible for this different community composition. In the zoomed-in plots we can see some separation by seascape and regions in the mid shore, but sites are still quite mixed.

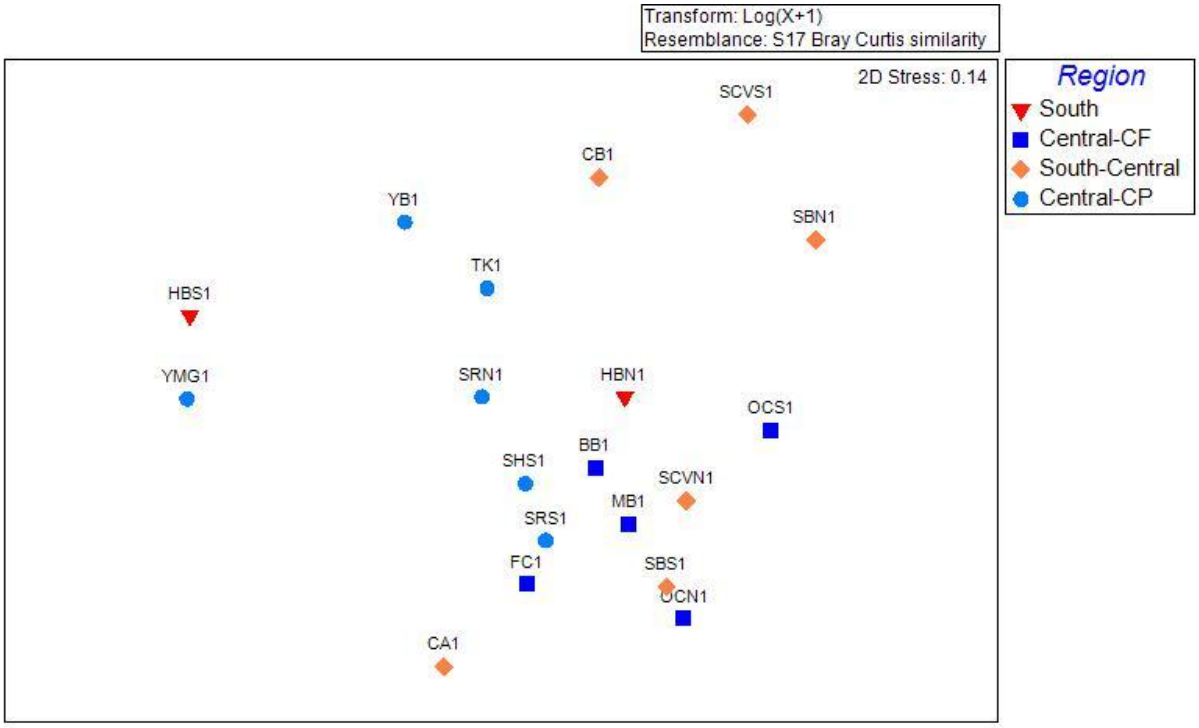
Fig. 6. MDS ordinations of the mid shore depicting the characterization of the sites by region and seascape. The photo is of *Analipus japonicas*.

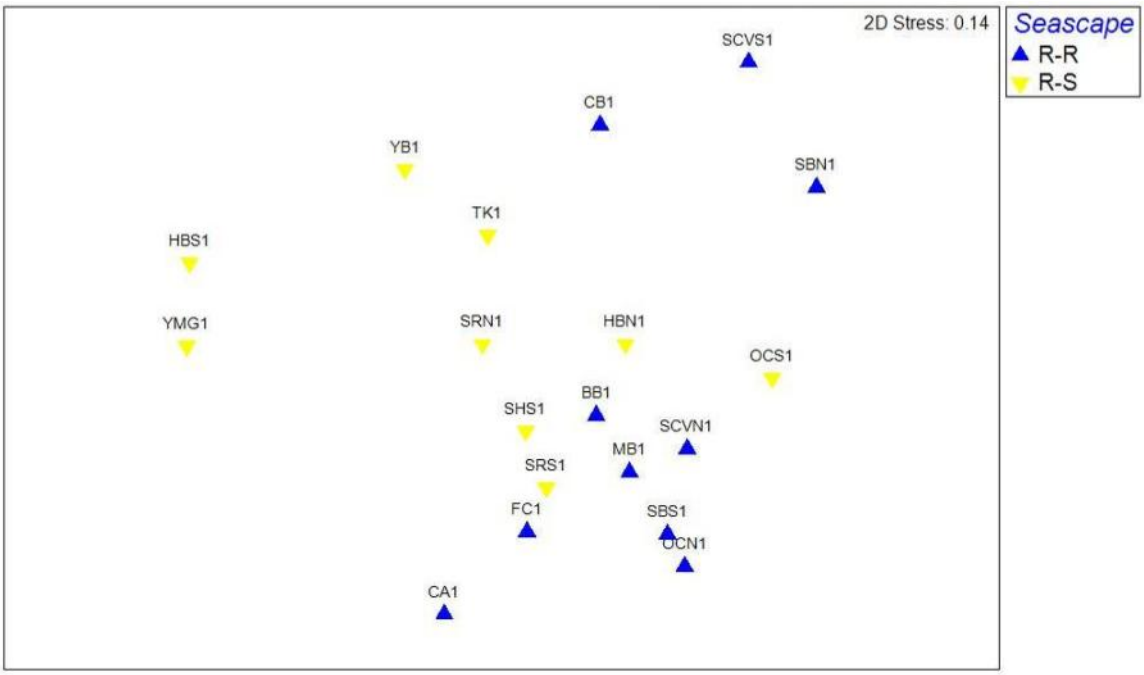


Low-mid shore patterns

At the low-mid shore level there appears to be some clustering on a regional level within the "cloud" of sites, but the South-Central and South sites are very scattered compared to the two central Oregon capes (Fig. 7). Harris Beach South appears to be most similar to the Yachats Marine Garden site and both are quite distinct from the other sites. Tube worms that were near absent in all sites in the past few years, and were shown in the past to have boom and bust dynamics, appeared in patches in many sites along the coast and contributed up to 10% in mean cover at some sites (Fig. 8).

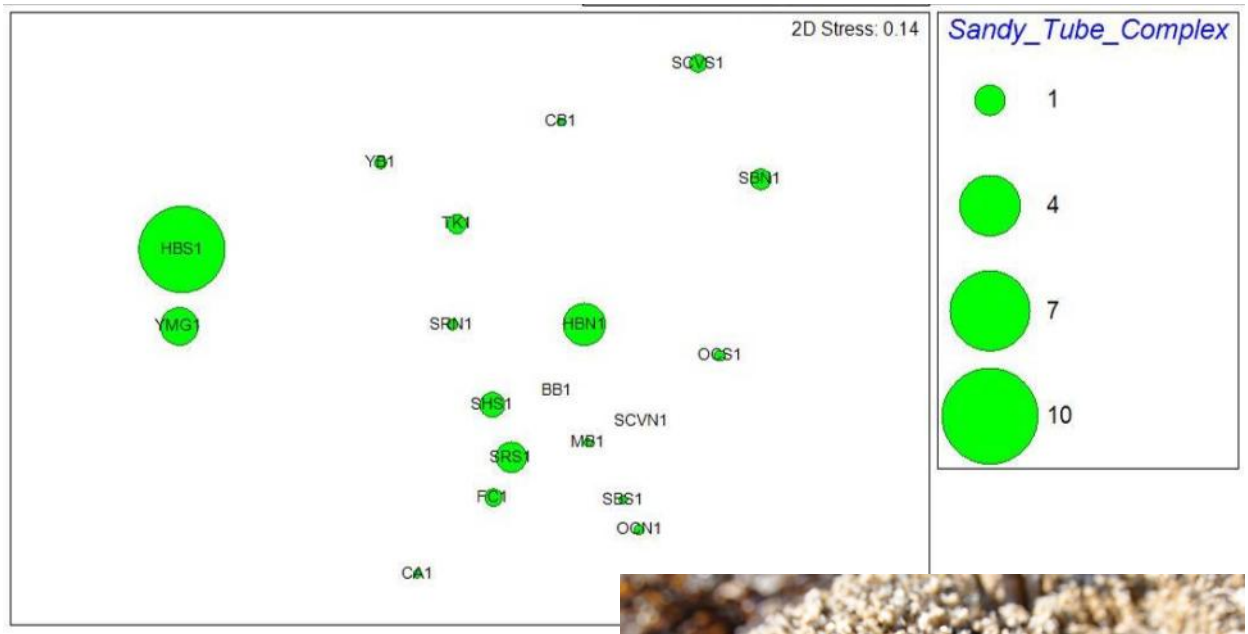
Fig. 7. MDS ordinations of the low-mid shore depicting the characterization of the sites by region and seascape





Tube worms were most abundant at the southern sites of Harris Beach but appeared in lower numbers in several other sites to the north too, mostly in R-S sites.

Fig. 8. The abundance (percent cover) of sandy tube worms is shown with bubbles overlaid on the MDS ordinations of the low-mid shore level. The legend shows the scale of the bubbles in percent cover.



Tube worm patch

Low shore patterns

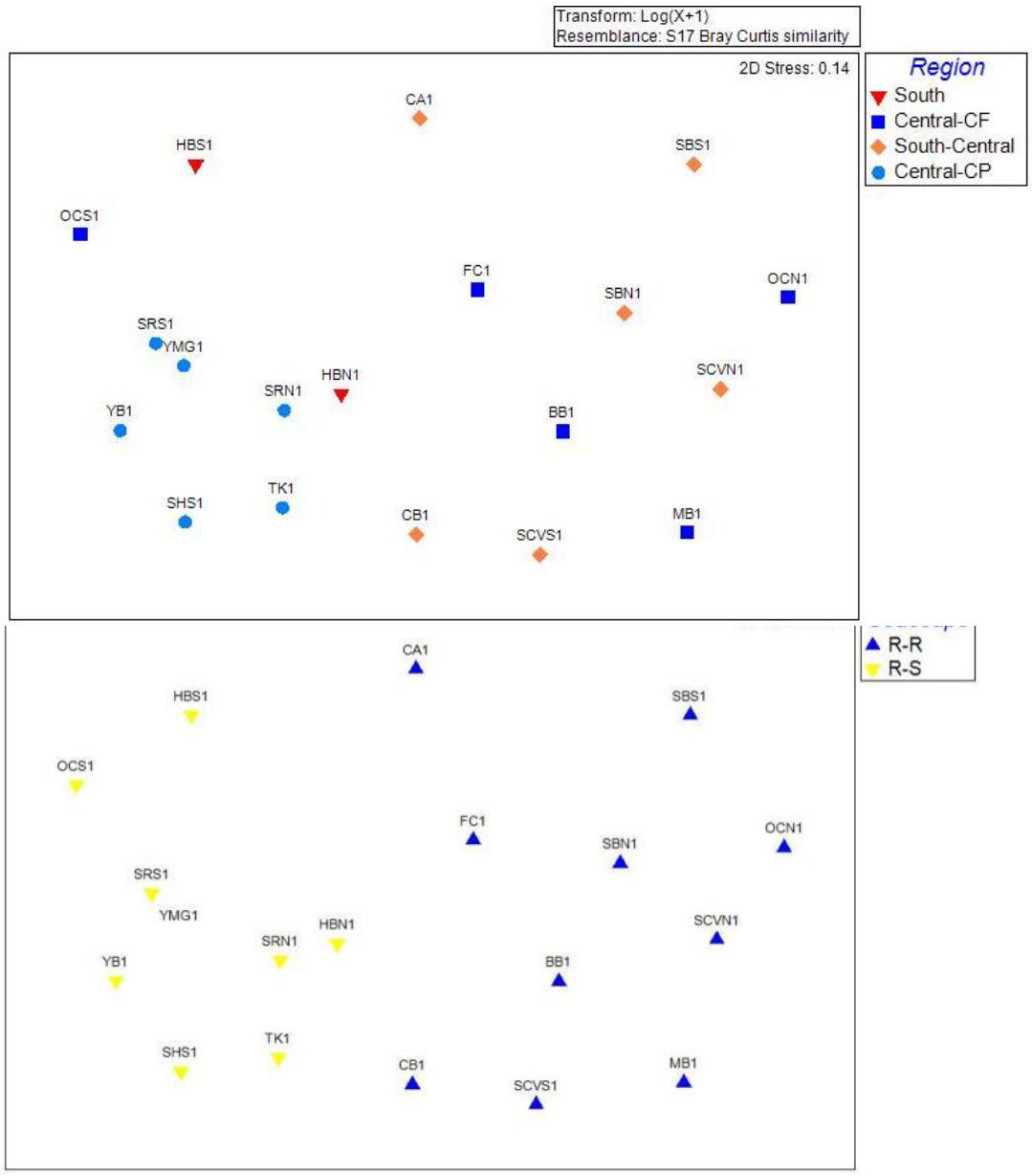
As in previous years, the communities at low shore level were the most clustered ones in both the region and seascape categories (Fig. 9). The CP sites were the most clustered ones whereas the other sites were less organized by region, including the Harris Beach sites. However, the Harris Beach sites mapped well with the rest of the R-S sites indicating that seascape has a larger effect than region on the structure of rocky intertidal communities found at the low shore level. Table 1 shows the 6 taxa most contributing to the dissimilarity between R-R and R-S sites based on the log-transformed data. This analysis indicates that *Laminaria* is scarce at R-R sites and abundant at R-S sites whereas sea urchins (*Strongylocentratus purpuratus*) are absent at R-S sites, probably because they are sensitive to sand and perhaps also because of scarcity of their favorite food. Limpets (*Lottia*), that are also important herbivores in the rocky intertidal, on the

other hand, were more abundant in the low shore of R-S sites, perhaps because of reduced competition for food or exclusion of the competitors of their food by sand abrasion.

Table 1. The average abundance (log scale) and relative contribution of the five species contributing most to the dissimilarly between R-R and R-S site as calculated in the SIMPER analysis.

	R-R sites	R-S sites		
Species	Average Abundance	Average Abundance	% Contribution	Cumulative contribution %
Laminaria sp.	0.53	3.33	6.5	6.5
Strongylocentratus purpuratus	2.53	0	5.77	12.27
Diatoms	1.86	0.37	4.17	16.44
Odonthalia Complex	1.72	0.15	3.71	20.15
Phyllospadix sp.	1.41	0.78	3.56	23.71
Lottia Complex	0.96	1.83	3.17	26.88

Fig. 9. MDS ordinations of the low shore depicting the characterization of the sites by region and seascape.



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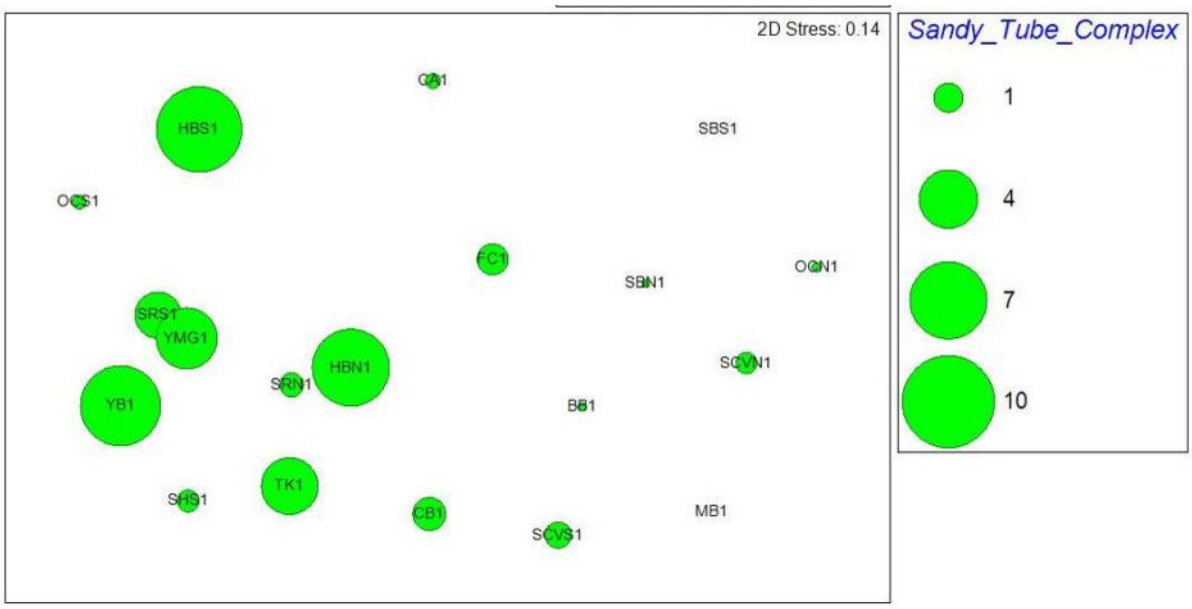
Tube worms were more abundant at more sites in the low shore than the low-mid shore but the general patterns of distribution are similar to the low-mid shore (Fig. 10). Their affiliation with R-S sites is more pronounced in this zone.

Fig. 10. The abundance (percent cover) of sandy tube worms is shown with bubbles overlaid on the MDS ordinations of the low shore level. The legend shows the scale of the bubbles in percent cover.



Temporal patterns

We examined change over time using one core PISCO site (Boiler Bay) that has been surveyed almost continuously from 1999, and one of the State Park sites where we have 3 years of data (Otter Crest). Temporal trends are most structured (and thus probably less stochastic) at the low shore level and therefore are only shown for that level. At Boiler Bay, a large shift in community structure is evident over the past 11 years. In fact, we see two main shifts, from 1999 to 2000 and then from 2007 to 2008 and 2009, as indicated by the arrows in Fig. 10. The species most contributing to those major shifts are given in Table 2.

Fig. 11. Temporal change in community structure at one of the PISCO core sites, Boiler Bay is shown on an MDS plain. Arrows depict the major shifts.

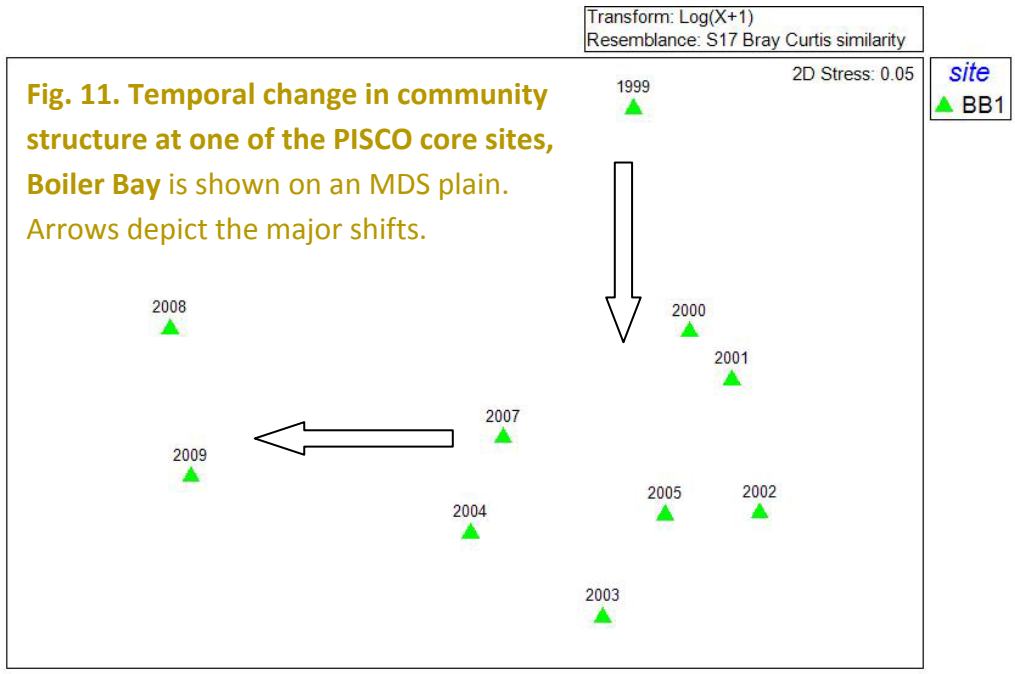
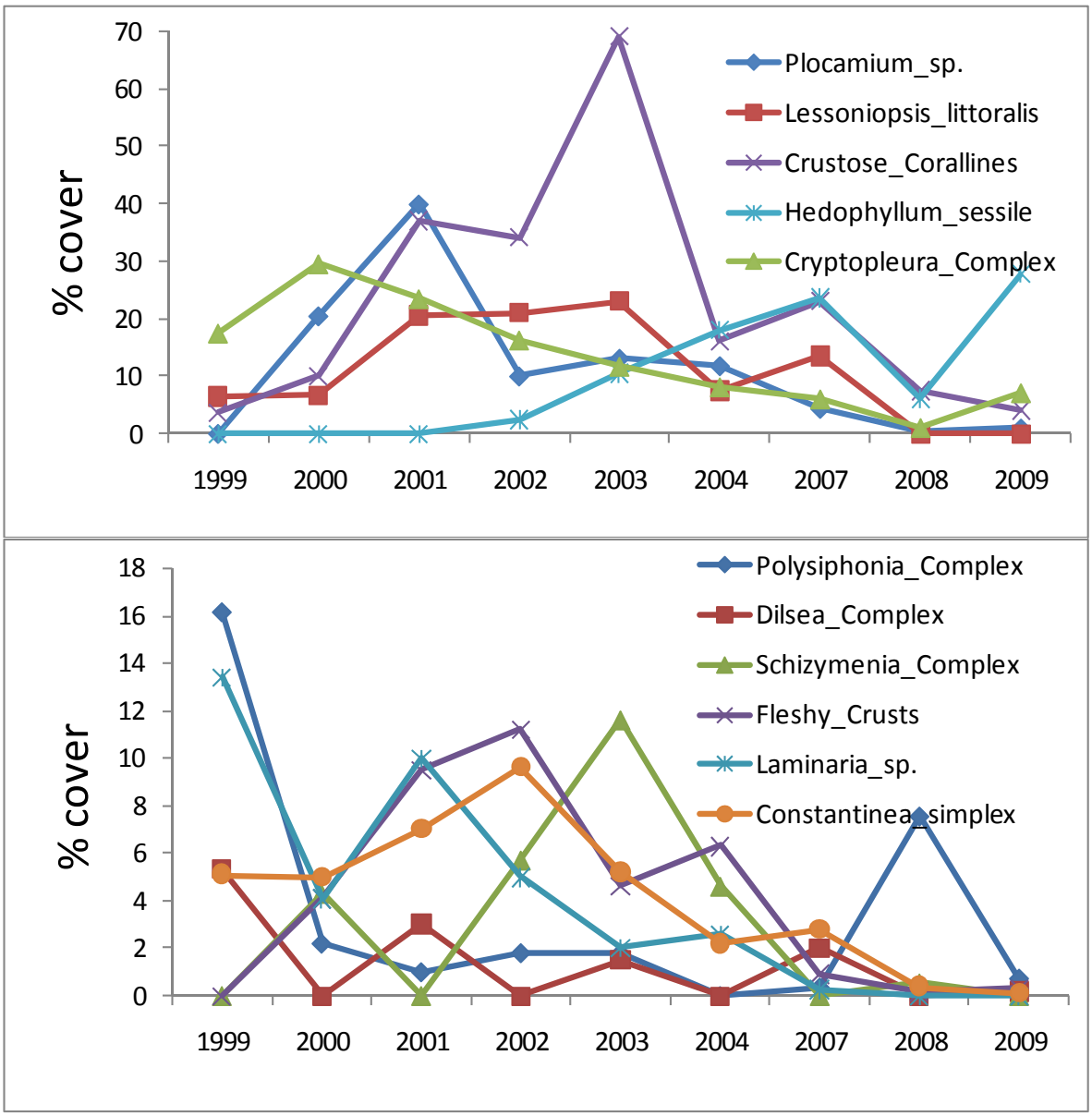


Table 2 shows the species most contributing to the dissimilarity between the years 1999 and 2000 and 2007 and 2008 at Boiler Bay. Abundances are in log scale. Most of these species are macroalgae.

1999 vs. 2000				
Average dissimilarity = 34.61				
	1999	2000		
Species	Average Abundance	Average Abundance	% Contribution	Cumulative contribution %
Plocamium_sp.	0	3.07	13.53	13.53
Dilsea_Complex	1.84	0	8.12	21.65
Polysiphonia_Complex	2.84	1.16	7.39	29.04
Schizymenia_Complex	0	1.67	7.35	36.39
Fleshy_Crusts	0	1.63	7.18	43.58
Large_Red_Blade_Complex	1.59	0	7.01	50.59
Isopod_Complex	1.2	0	5.31	55.89
Laminaria_sp.	2.67	1.63	4.58	60.47
Crustose_Corallines	1.55	2.4	3.75	64.22
2007 vs. 2008				
Average dissimilarity = 45.18				
	2007	2008		
Species	Average Abundance	Average Abundance	% Contribution	Cumulative contribution %
Lessoniopsis_littoralis	2.68	0	8.71	8.71
Polysiphonia_Complex	0.31	2.14	5.97	14.68
Odonthalia_Complex	1.16	2.6	4.69	19.37
Plocamium_sp.	1.68	0.29	4.53	23.9
Cryptopleura_Complex	1.95	0.69	4.07	27.97
Hedophyllum_sessile	3.2	1.97	4	31.97
Egregia_menziesii	0	1.22	3.98	35.95
Dilsea_Complex	1.1	0	3.57	39.53
Crustose_Corallines	3.18	2.14	3.39	42.91
Constantinea_simplex	1.34	0.34	3.26	46.18
Neorhodomela_Complex	0	0.93	3.02	49.19

Figure 12 shows the change in percent cover of most of these species or species complexes (when plants cannot be identified at the species level) over 11 years of monitoring at BB. Some species (e.g., crustose corallines, *Plocamium* sp.) were almost absent in 1999, peaked (to almost 70 and 40 percent, respectively) and then declined to almost 1999 levels in 2009. Other species (e.g., *Cryptopleura* complex, *Laminaria* sp., *Constantinea simplex, Polysiphonia complex*) generally decreased in abundance over the monitoring period, whereas one species

generally increased (*Hedophyllum sessile*). We do not know yet the reasons for those temporal changes however it should be noted that 1998, the year before the monitoring started was an El Niño year. There are indications that warmer water can adversely affect some algae species, mostly red algae. The near absence of some of these species during 1999 may have been a result of the El Niño conditions (warmer surface waters). Thus the pattern that we see may indicate the recovery of some affected species that was followed by a decrease. Why other species showed an overall decrease in abundance over the monitoring period is unknown. It may be related to more long-term cycles or to climate change effects. More knowledge on the physiology and



ecology of these species is needed to be able to explain some of these patterns.

Fig. 12. Temporal change in macro algae abundance (percent cover) over 11 years.

Studies near power plants, where water is discharged back to sea at temperatures higher than the ambient ones, showed dramatic impacts on species composition. This was illustrated in the benthic community structure near the thermal outfall of a power generating station on the rocky coast of California (Schiel et al. 2004). There, communities were greatly altered in apparently cascading responses to reduced abundances of habitat-forming species like subtidal kelps and intertidal red algae(Schiel et al. 2004). In contrast, grazers showed positive response to temperature, attributed by the authors to physiological tolerances, trophic responses, space availability and recruitment dynamics (Schiel et al. 2004).

The other example of temporal change in community structure is from one of the State Park areas, Otter Crest in Cape Foulweather (Fig. 13). Change was greater at OCS, the R-S site, than at OCN, the R-R site. The greater shift was between 2007 and 2008 at OCS. Table 3 shows that the dissimilarly between 2007 and 2008 at this site is very large, near 55%. The taxa most contributing to the dissimilarity between years were *Odonthalia*, *Littorina* and *Lottia* that decreased sharply in numbers whereas *Plocamium* increased in numbers.

Fig. 13. Temporal change in community structure at the Otter Crest sites is shown on the MDS plain.

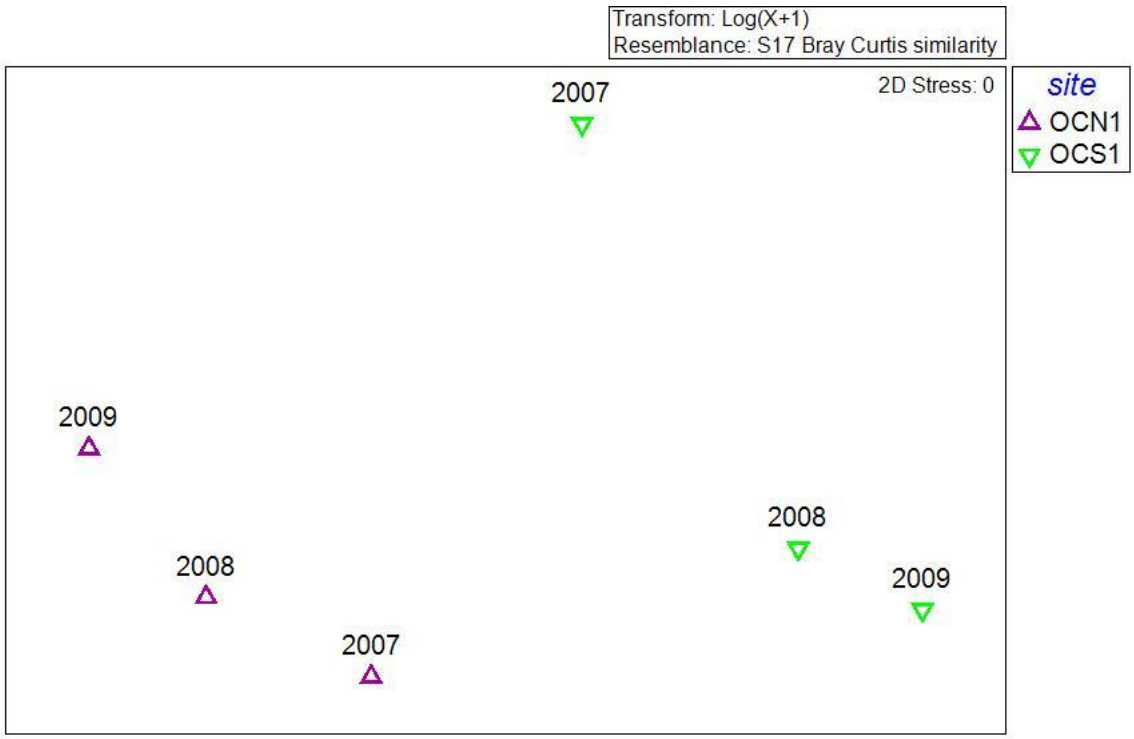


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Table 3. Species most contributing to the dissimilarity between years at OCS.

OCS				
Years 2007 & 2008				
Dissimilarity = 55.84%				
	2007	2008		
Species	Average Abundance	Average Abundance	% Contribution	Cumulative contribution %
Odonthalia_Complex	3.59	0	10.95	10.95
Plocamium_sp.	0	3.56	10.84	21.79
Littorina_Complex	3.9	0.61	10.04	31.83
Lottia_Complex	3.12	0	9.5	41.33
Laminaria_sp.	1.22	3.43	6.75	48.08
Diatoms	0	1.95	5.93	54.01
Phaeostrophion_irregulare	0	1.77	5.39	59.4
Mastocarpus_Complex	1.77	0.18	4.84	64.25
Ptilota_Complex	0	1.57	4.78	69.03
Codium_setchellii	0.32	1.47	3.48	72.51
Years 2008 & 2009				
Dissimilarity = 37.51%				
	2008	2009		
Species	Average Abundance	Average Abundance	% Contribution	Cumulative contribution %
Cryptopleura_Complex	0	2.24	11.6	11.6
Diatoms	1.95	0	10.06	21.66
Phaeostrophion_irregulare	1.77	0	9.15	30.81
Littorina_Complex	0.61	2.26	8.52	39.33
Ptilota_Complex	1.57	0	8.11	47.44
Crustose_Corallines	2.24	0.8	7.46	54.9
Ulva_Complex	1.08	0.2	4.53	59.43
Codium_setchellii	1.47	0.75	3.72	63.15
Bryozoan_Complex	0.69	0	3.58	66.73

At Otter Crest North most taxa contributing to temporal change are different than at OCS. Interestingly, the only species that appears high on the list of both sites, *Plocamium*, declined in abundance between 2007 and 2008 (opposite to the trend in OCS), suggesting that some of these changes may be related to very local processes and may be dependent on the seascape.

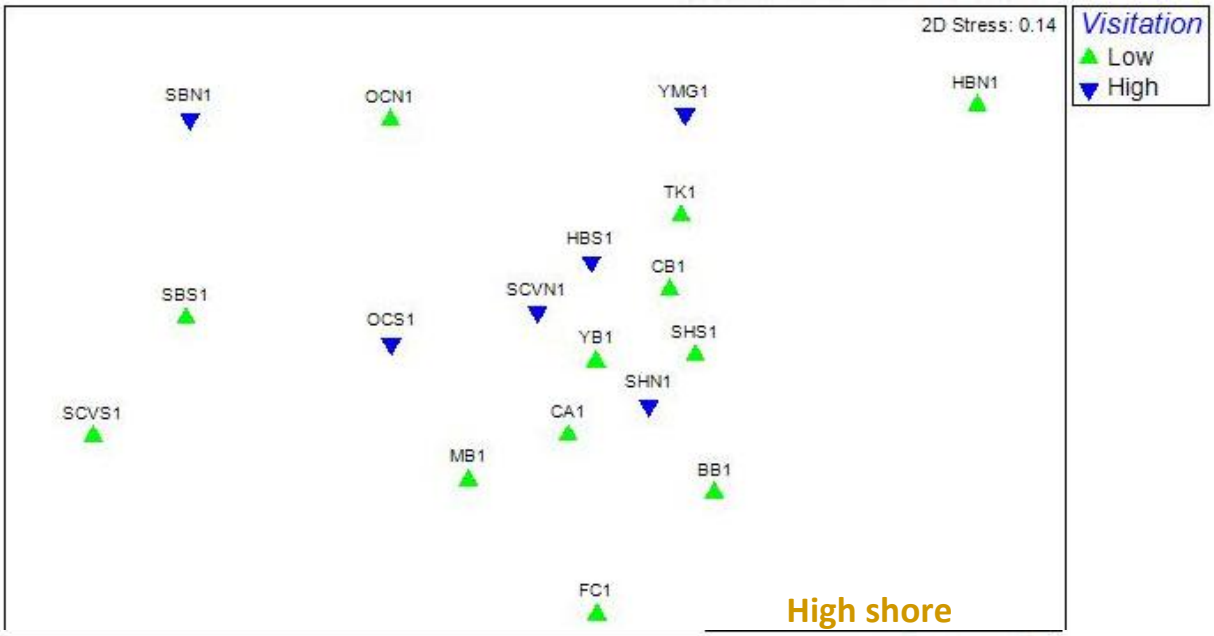
Table 4. Species most contributing to the dissimilarity between years at OCN.

OCN				
Years 2007 & 2008				
Dissimilarity = 37.52%				
	2007	2008		
Species	Average Abundance	Average Abundance	% Contribution	Cumulative contribution %
Plocamium_sp.	2.19	0	8.46	8.46
Microcladia_coulteri	0	1.88	7.28	15.74
Alaria_marginata	0.08	1.96	7.26	23
Neorhodomela_Complex	1.79	0	6.93	29.93
Unidentified_Branched	0	1.67	6.44	36.37
Mastocarpus_Complex	1.52	0	5.88	42.25
Callithamnion_sp	0.51	1.79	4.94	47.2
Years 2008 & 2009				
Dissimilarity = 42.61%				
	2008	2009		
Species	Average Abundance	Average Abundance	% Contribution	Cumulative contribution %
Polysiphonia_Complex	2.93	0.34	9.86	9.86
Alaria_marginata	1.96	0	7.42	17.28
Microcladia_coulteri	1.88	0	7.15	24.43
Cryptopleura_Complex	1.87	0	7.11	31.54
Callithamnion_sp	1.79	0	6.8	38.34
Unidentified_Branched	1.67	0	6.32	44.66
Erect_Corallines	1.86	0.59	4.83	49.49
Anthopleura_elegantissima	0.07	1.13	4.04	53.53
Acrosiphonia_sp.	0.07	0.88	3.07	56.6
Anthopleura_xanthogrammica	0	0.79	2.99	59.59
Fleshy_Crusts	0.76	0	2.89	62.48

Visitation effects

At none of the shore levels were high visitation sites all clustered together, although some within-region clustering of some sites is visible on the MDS plots (Fig. 14). This result suggests that human impacts have lower effects on community structure than other structuring forces such as biogeography or seascape. As mentioned above, in some regions even on the same beach the high and low visitation sites also differ in their seascape (e.g., R-R vs. R-S at Otter Crest) or finer structure (e.g., vertical walls vs. boulders at the low shore level at Harris Beach), making it hard to have true, controlled estimations of the effect of human impacts although they may exist.

Fig. 14. MDS ordinations of the four shore levels depicting the characterization of the sites by human visitation levels.



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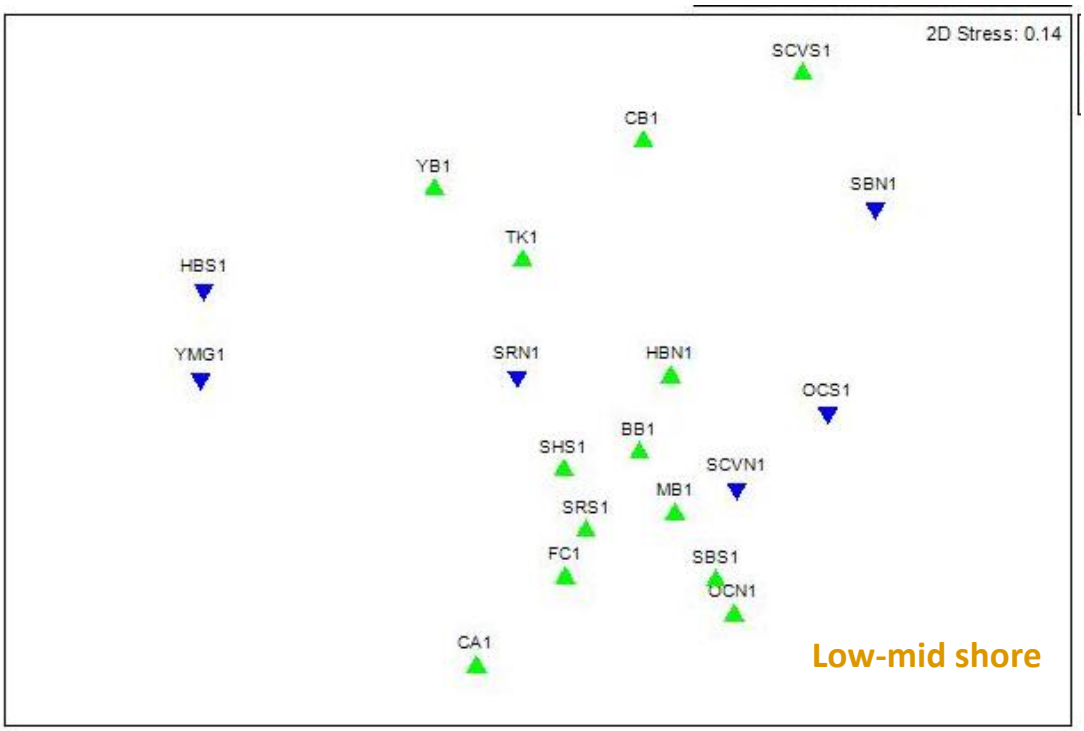
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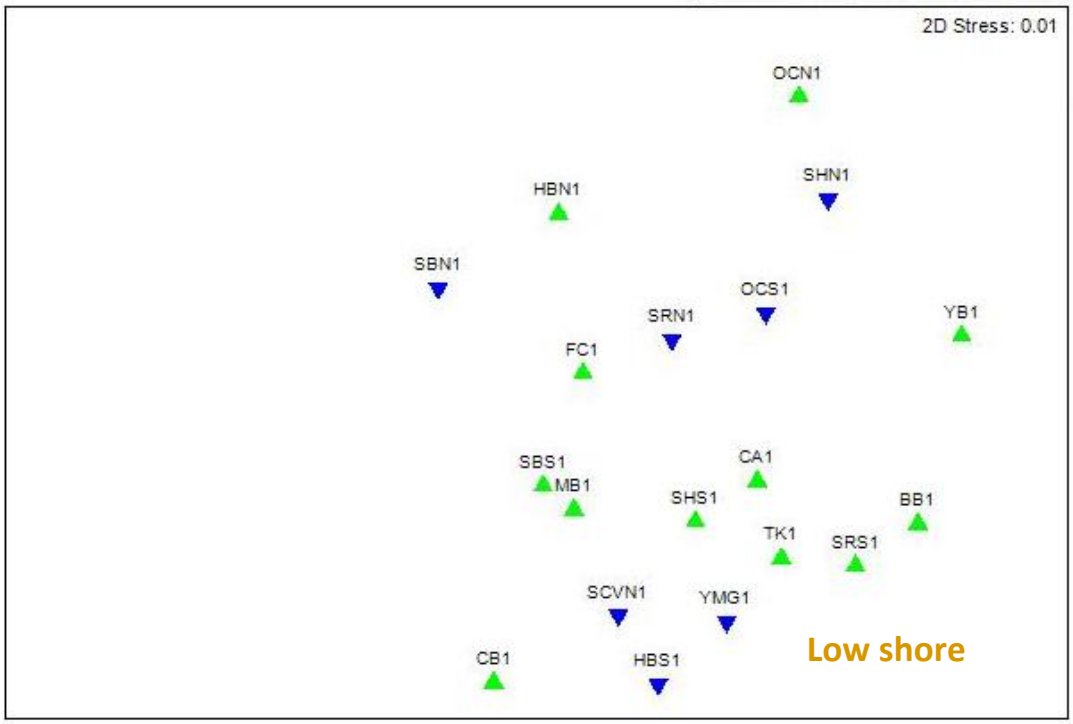
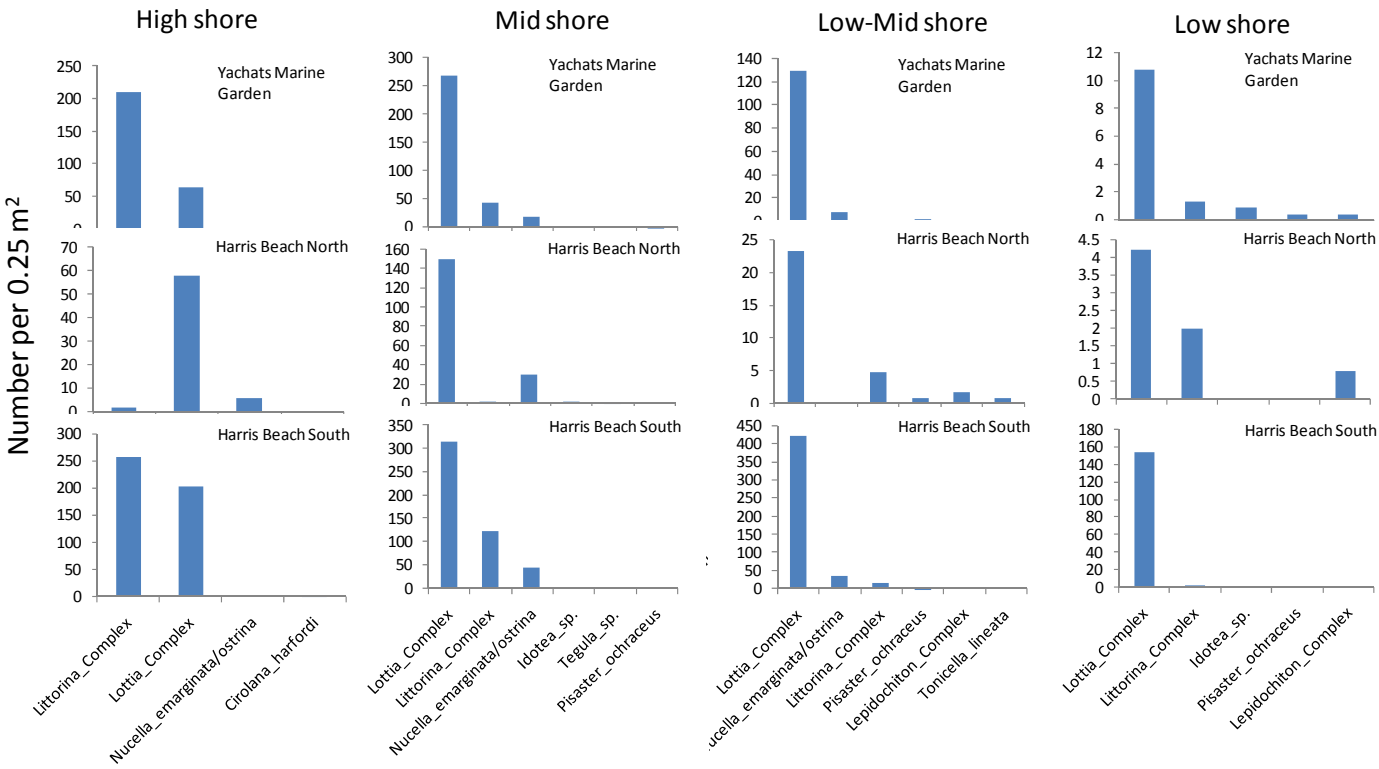
CB1
YB1
SBN1
TK1
HBS1
YMG1
SRN1
HBN1
OCS1
BB1
SHS1
SCVN1
MB1
SRS1
FC1
SBS1
OCN1
CA1
Low-mid shore


2D Stress: 0.01
OCN1
SHN1
HBN1
SBN1
OCS1
SRN1
YB1
FC1
SBS1
CA1
MB1
SHS1
BB1
TK1
SRS1
SCVN1
YMG1
CB1
HBS1
Low shore

Species abundances in the new sites

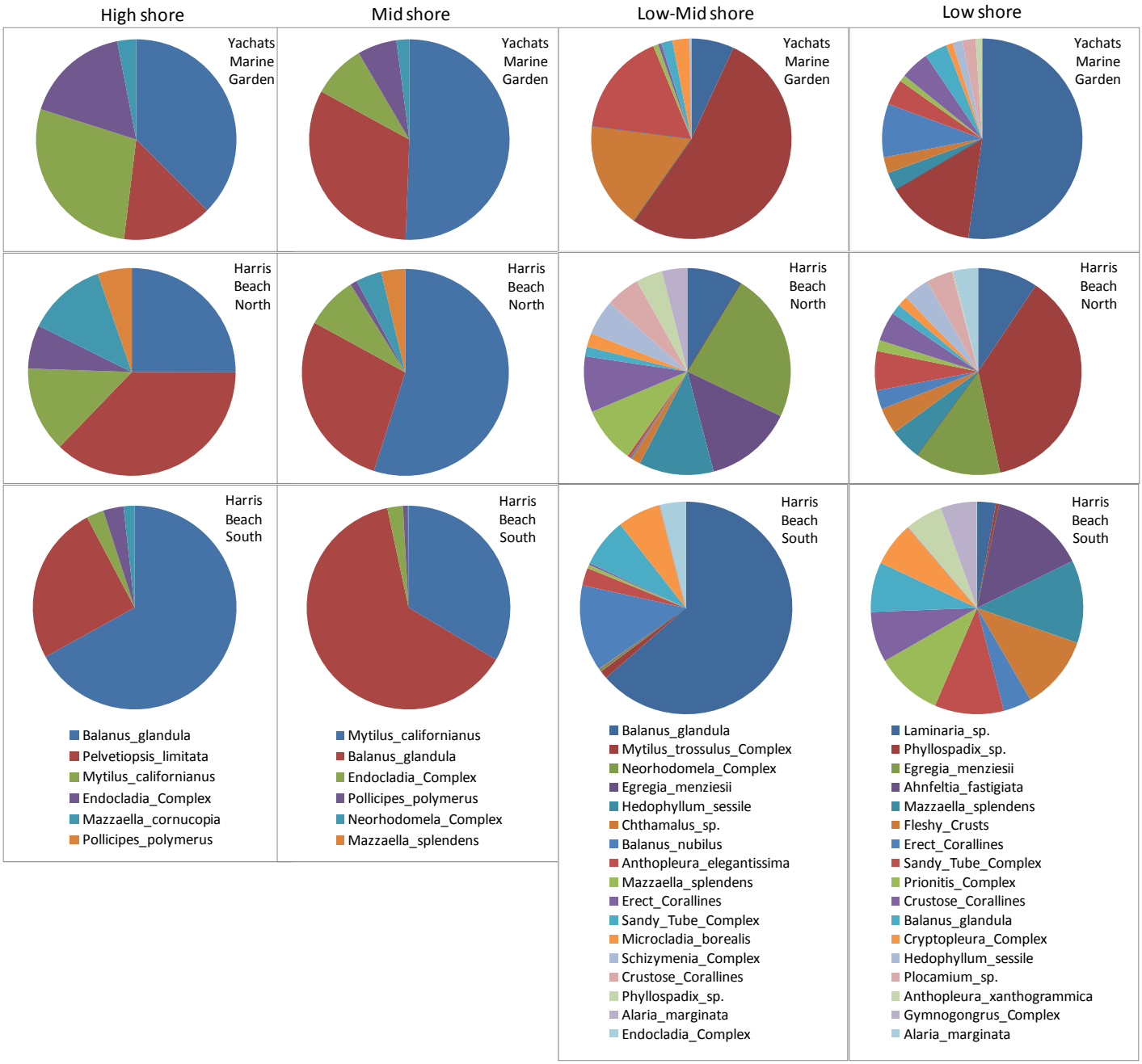
The average abundaces of the most abundance species in each zone is presented for the 3 new survey sties in the next two figures. The most abundant mobile species at all zones were periwinkles (Littorina complex) and limpets (Lottia complex, Fig. 15). Interestingly, periwinkles were almost absent in the high shore at Harris Beach North.

Fig. 15. Average abundance of mobile invertebrates at the three new survey sites.



Percent cover of macroalgae and sessile invertebrates at all shore levels is shown in Fig. 16. The two lower shore levels at the three sites have very different species composition, which is probably related to the small scale topography although all three are R-S sites. Yachats Marine Garden has flat bedrock at these shore levels; Harris Beach North is bouldery whereas Harris Beach South has vertical walls at these levels.

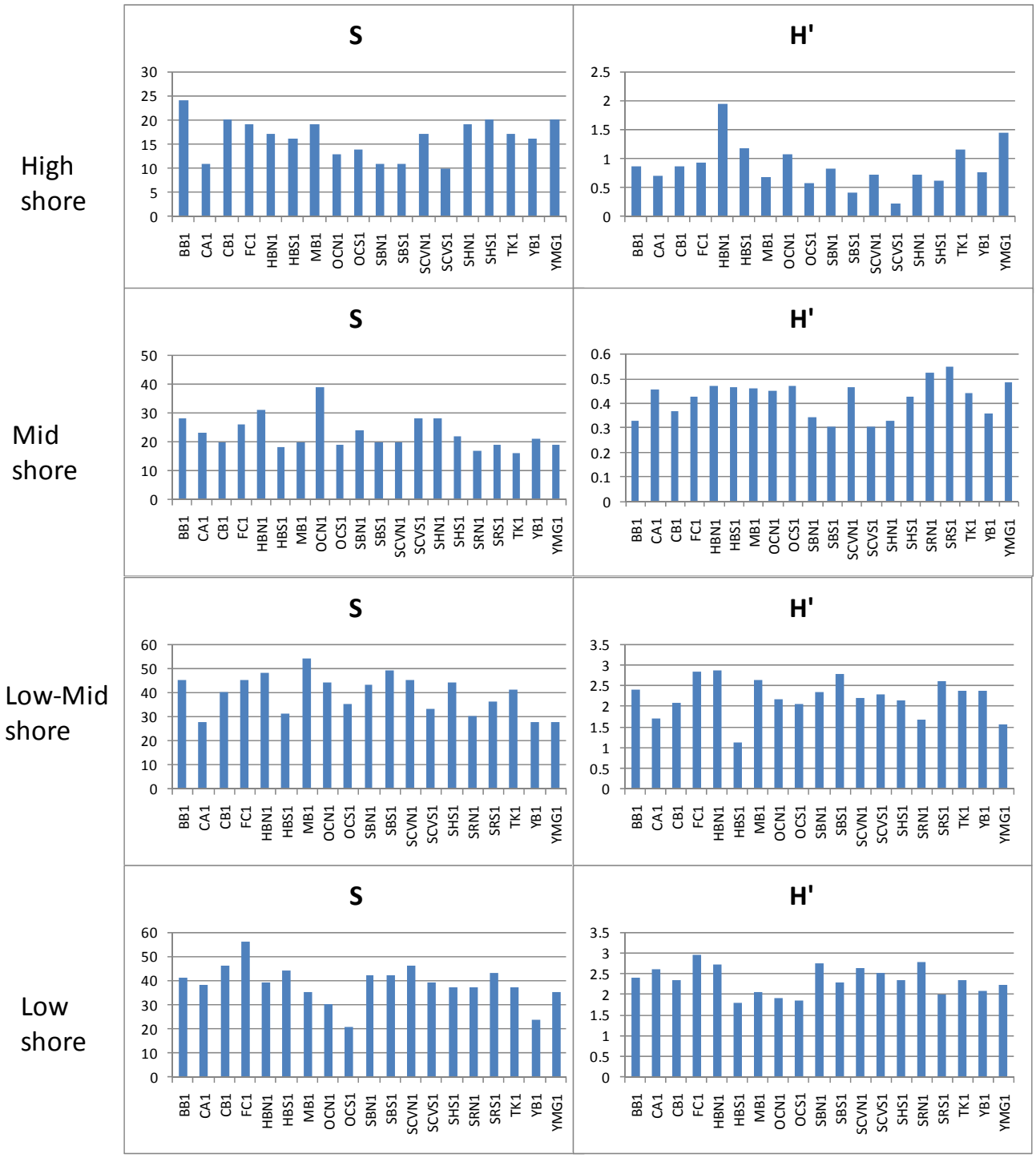
Fig. 16. Average percent cover of macroalgae and sessile invertebrates at the three new survey sites.



Species diversity

Fig. 17 shows biodiversity values (species richness, S, and Shannon-Winner species diversity index, H') for all 2009 survey sites at the four shore levels.

Fig. 17. Species diversity indexes for all study sites surveyed in 2009.



Summary

The results that emerge from the 2009 biodiversity survey along the Oregon coast reveal similar spatial patterns of community structure to the ones in previous years, with both regional and seascape effects on community composition. This is most pronounced on the low shore level. The new sites fall within both regional and especially seascape categories. In 2009, we also demonstrated the extensive temporal variability in biodiversity patterns by looking at both long-term patterns in one of the core PISCO sites and shorter-term patterns at one of the State Parks. We see striking shifts in community structure at both scales. Some of these patterns may be related to large-scale climatic events and other to local, possibly stochastic dynamics. In the first report of 2007 where we compared only the 3 surveyed central Oregon State Park sites, and again in the more extensive 2008 report, we suggested that human impacts may be affecting intertidal communities in Oregon, mostly at the higher shore levels that are more accessible to humans. The more comprehensive analysis of all the study sites surveyed along the coast during 2009 suggests that though human visitation impacts on rocky intertidal communities may occur on the Oregon coast, it is hard to distinguish between them and other structuring mechanisms of the ecological community on the rocks. Also, ecological processes on the rocky shore are very dynamic, and thus recovery from impact may be rapid and mask some of the local impacts visitors (e.g., trampling or collection) may have on the organisms on the shore. This situation may change if other, stronger, human stressors, such as massive coastal development, pollution or global climate change become more important or visitation increase considerably to become the dominant structuring force.

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