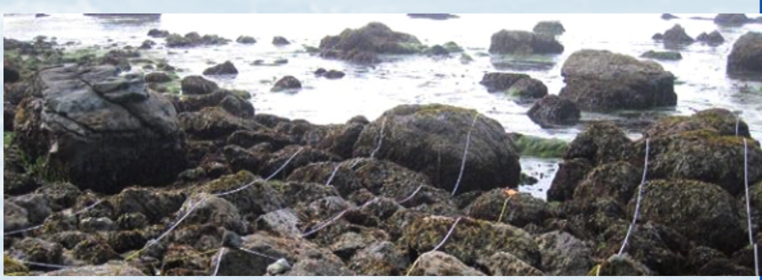
Characterization of the Rocky Intertidal Ecological Communities Associated with Northern California Areas of Special Biological Significance



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Southern California Coastal Water Research Project

SCCWRP Technical Report 855

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CONTENTS

INTRODUCTION

The regulatory environment

The California Ocean Plan defines water quality objectives for State waters and is the basis of regulation of discharges to marine environment. In 1972 there was recognition that certain areas had biological communities with ecological value or that were fragile. These areas were deemed to deserve enhanced protection to preserve and maintain natural (not affected by anthropogenic influences) water quality. These areas were designated Areas of Special Biological Significance (ASBS). As a result, regulations were enacted to prohibit discharges into ASBS as well as to any nearby waters that could affect the natural water quality in ASBS. In 1974 the State Water Board (SWB) designated 33 ASBS. An additional area was designated in 1975; there have been no subsequent designations.

ASBS have been designated to protect marine species or biological communities from an undesirable alteration in natural water quality. Furthermore ASBS provide intrinsic value or recognized value to man for scientific study, commercial use, recreational use, or esthetic reasons. Consistent with previous versions of the Ocean Plan, the 2009 Ocean Plan states: "Waste shall not be discharged to areas designated as being of special biological significance. Discharges shall be located a sufficient distance from such designated areas to assure maintenance of natural water quality conditions in these areas." This absolute waste discharge prohibition in the Ocean Plan stands, unless an "exception" is granted. The requirements for an exception are included in the Ocean Plan. When granting exceptions the State Water Board must determine that the public interest is served, and that protections of beneficial uses are not compromised. Despite the prohibition against waste discharges to ASBS, in 2003 there were approximately 1,658 outfalls to these marine water quality protected areas (SCCWRP 2003). As a result, the State Water Board has initiated regulatory actions, establishing special protections through the Ocean Plan's exception process.

The key attribute that underlies the ASBS water quality regulations is the standard of "natural water quality". The logic of the standard is that natural water quality is attainable using limited spatial regulations (prohibition of discharges in some areas) and essential for certain biological communities. Unfortunately for California ASBS, coastal waters may no longer pristine.

Since a definition of natural water quality did not exist, a committee of scientists, termed the ASBS Natural Water Quality Committee, was formed to provide such a definition for the State Water Board. In 2010 the ASBS Natural Water Quality Committee provided the State Water Board with its findings (Dickson 2010), including an operational definition of natural water quality with the following criteria. These criteria address the two tenets of ASBS protections.

1) It should be possible to define a *reference* area or areas for each ASBS that currently approximate *natural water quality* and that are expected to exhibit the likely natural variability that would be found in that ASBS.
2) Any detectable human influence on the water quality must not hinder the ability of marine life to respond to natural cycles and processes. Such criteria will ensure that the beneficial uses identified by the Ocean Plan are protected for future generations.

This operational definition of natural water quality allows for the assessment of biological impacts related to water quality in ASBS and it provides the basic design elements for the assessment. In particular the use of reference areas for each ASBS allows for control of natural and temporal variability in biological communities.

The ecological environment

Because most discharges are into intertidal areas (defined as that area between low and high tides), there has been concern that impacts would be primarily manifested in ecological communities in sandy beach and rocky intertidal systems. Ecological communities in sandy beach habitats are extraordinarily dynamic (McLachlan 1993, Defeo 2008) and attribution of change to anthropogenic causes is quite difficult, mainly due to low statistical power. Species associated with rocky intertidal areas are also dynamic, but much less so than those in or on sandy beaches. As a result, attribution of the cause of change is easier for species or communities associated with rocky intertidal habitats (Littler and Murray 1975, Minchinton and Raimondi 2005, Conway-Cranos and Raimondi 2007, Pinedo et al. 2007, Arevalo et al. 2007).

Within rocky intertidal communities, species have a variety of life histories that affect the assessment of potential causes of change. Shorter lived species like *Chthamalus*, *Ulva* and *Porphyra* often are associated with disturbance, while longer lived species like *Balanus*s, fucoid algae and mussels tend to be associated with more stable environments. Hence, communities with higher cover of the more ephemeral species are often considered to be indicative of recent or ongoing perturbation. Clearly, perturbations can be due to both natural and anthropogenic causes and hence the design of the sampling program is critical for separating these two general mechanisms of change.

Here we report on a project designed to: (1) characterize the ecological community living on rocky intertidal habitats near discharges inside northern California ASBS, and at reference areas far from discharges and, (2) use the comparison between ASBS discharge and reference areas as a means to assess the likelihood that differences in ecological community structure could be due to water quality degradation within ASBS. The methods used are consistent with those used in phase I and II assessments for ASBS in southern California (Raimondi et al. 2012, Raimondi 2014)

METHODS

Comprehensive sampling of ecological communities on rocky intertidal habitats was done using protocols developed by the coastal biodiversity surveys (www.pacificrockyintertidal.org). The general approach is described below.

Site selection: Discharge and Reference – Based on the operational definition of natural water quality described above, along with the regulations prohibiting discharge in ASBS, we selected sites as follows. Sites were selected within ASBS that (1) had sufficient rocky intertidal habitat to be suited for sampling (as described below) and, (2) were located near an active discharge. Reference sites were selected following guideline (1) but instead of requiring proximity to an active discharge, we only used sites that were not near an active discharge. In addition, we matched reference sites to discharge sites to control for spatial variance.

The sampling procedure used was identical to that used by the coastal biodiversity survey (CBS) program housed at UCSC and administered by Peter Raimondi. In order to be cost-efficient, data from sites previously sampled by the CBS program were used in the analyses. New sampling was done to supplement existing data.

Selecting an appropriate location within a site – Within a site, the ideal location to do a CBS is on a bench that 1) is at least 30m wide, 2) gently slopes from the high to low zone, and most importantly 3) contains a representative sample of the intertidal community of the entire site. If it is not possible to find a contiguous 30m stretch of coastline, the survey can be split between two adjacent benches. When this is done, the survey should be divided as evenly as possible between the two benches.

Set-Up – Once an appropriate area of shoreline was selected, it was sampled using a series of parallel transect lines extending from the high zone to the low zone. To facilitate the setup of these lines, two permanent 30m horizontal baselines (parallel to the ocean) were first established. The upper baseline was placed in the high zone above the upper limit of the organisms, while the lower baseline was placed in the mid-intertidal zone, parallel to the upper baseline. Depending on the amount of beach traffic or site regulations, the ends of these lines were permanently marked with either hex or carriage bolts.

Once these two baselines were established, parallel transect lines were run down the shore every three meters along the upper base line. To ensure that transect lines were parallel, samplers made sure to intersect upper and lower base lines at the same meter mark(e.g. transect began at the upper baseline at meter mark 6 and crossed the lower baseline at meter mark 6). In general the transect lines were allowed to follow the contours of the bench. When necessary, rocks were placed along the lines to prevent them from being shifted by heavy winds. To ensure repeatability of the layout of each parallel transect, the meter mark where each transect crossed the lower baseline was noted.

To facilitate resurveys of the site, a map was drawn of the site showing the location of the bolts relative to notable landmarks or other, pre-existing permanent plot markers. Photographs were also taken that included prominent visual reef characteristics for orientation (e.g. a large crack or tidepool). The distance and bearing between the baseline endbolts were measured. When possible, measurements were also taken between the endbolts and any pre-existing permanent plot markers. Other pertinent information, such as the compass heading of the vertical transects, the sampling interval along the transects, weather conditions, site complications, and challenges with taxonomic identification, was also recorded. All such information was used to make the mapping of the site more spatially explicit and repeatability more straightforward.

In addition to the spatial information described above, we recorded descriptive information about the site including bench rock type, relief, slope, extent of habitat and characteristics of surrounding coast. This information was used to provide spatial context for the site.

Point-Contact Surveys

Each vertical transect was sampled using the point intercept method. An average of 100 points were sampled on each transect line. For example the interval between points would be 20cm for a 20m long transect, and 10cm for a 10m long transect. The basis of this design was to ensure that there was a similar density of sampled points per vertical unit of tidal elevation for all sites. For each point, two types of data were collected: data that were used to determine relative abundance (% cover), and data that were used to describe spatial distributions. The relative abundance data were collected by identifying all taxa that fell directly under each point, including rock, sand, and tar. If there was layering of species, the taxa occupying the different layers were identified and assigned a letter; A for the top layer, B for the second layer, and C for the third. (Note: each layer must be a different taxa). If the point fell on an epibiont living on a host species, the epibiont was noted. Also recorded was whether the species under the point was in a pool, on cobble, or on boulders. A total of up to three taxa were identified under each point.

If fewer than three taxa were recorded under a point, then the next one or two species closest to that point were also noted. These ‘nearby’ species had to differ from those found under the point, and had to occur within a circle centered over the point with a radius half the length of the sampling interval.

Mobile Invertebrate Surveys

Although point-contact surveys are good at determining the abundance of spatially common species, particularly sessile species, they do not sample rare or spatially uncommon species very well. Because most mobile species are not spatially common, their abundances were sampled in 50 x 50 cm quadrats placed at three locations along each transect. Each transect was first divided into three zones; the low zone (below the mussel and rockweed zone), the mid-zone (typically dominated by mussels and rockweeds, and the high zone (above mussels/rockweeds, usually dominated by barnacles and littorines). Within each zone a quadrat was randomly placed adjacent to the transect, and all mobile species found within the quadrat were identified and counted. Sub-sampling was used when there were more than one hundred individuals of one species in a quadrat. If a quadrat landed in a deep pool or in an area dominated by sand, a new location within the defined zone was randomly selected.

Vouchers

We collected field vouchers for all species that could not be identified in the field. Voucher samples were labeled with the date, site, name of sampler, and transect line on which it was found.

Specific Hypotheses Tested

The general goal of this project was to compare the ecological communities in discharge and reference locations. To do this we developed the following specific (null) hypotheses

1) Species richness will not vary as function of site type (Discharge, Reference)
2) Community composition of sessile species will not vary as a function of site type
3) Community composition of mobile species will not vary as a function of site type
4) An integrated assessment of both mobile and sessile species will not identify particular sites as being substantially different from the expectation based on all sites. This is a way to look at specific sites rather than site types.

For questions 1-3 our model looked at the relationship between type of ASBS site (near to a discharge) or a reference site (that could also be in an ASBS) and the response variable (species richness or community composition). Point contact (mainly sessile or sedentary organisms) and Quadrat data (mobile organisms) were evaluated using a PERMANOVA approach to compare communities between discharge and reference sites. Species richness was assessed using ANOVA. For hypotheses 1-3 we set the critical p-value at 0.05 (null hypothesis not rejected unless $p<0.05$).

For hypothesis 4 we generated site similarity matrices (using Bray Curtis values) then calculated Mahalanobis distances using values from the two matrices. Mahalanobis distances are the distance from a multivariate centroid accounting for the covariance structure among variables. Small values indicate that a given site is similar to a hypothetical typical site, while large distances indicate sites very different from the hypothetical typical site. Prediction limits (of the Mahalanobis distance) were used to assess the likelihood of inclusion of samples. For example, an 80% prediction limit would contain 80% of samples drawn from a pool of samples coming from the same population. This differs from confidence limits, which are used to assess the inclusion likelihood of means of samples from a population.

RESULTS

Sites sampled and site attributes

Sampling locations are shown in Figure 1. Description of site metadata and site characteristics are in tables 1 and 2 respectively. Also see Appendix for detailed site descriptions.

Figure 1: Map of sampling locations. Color of symbol represents site type: Red = Discharge site in ASBS, Blue = reference site.

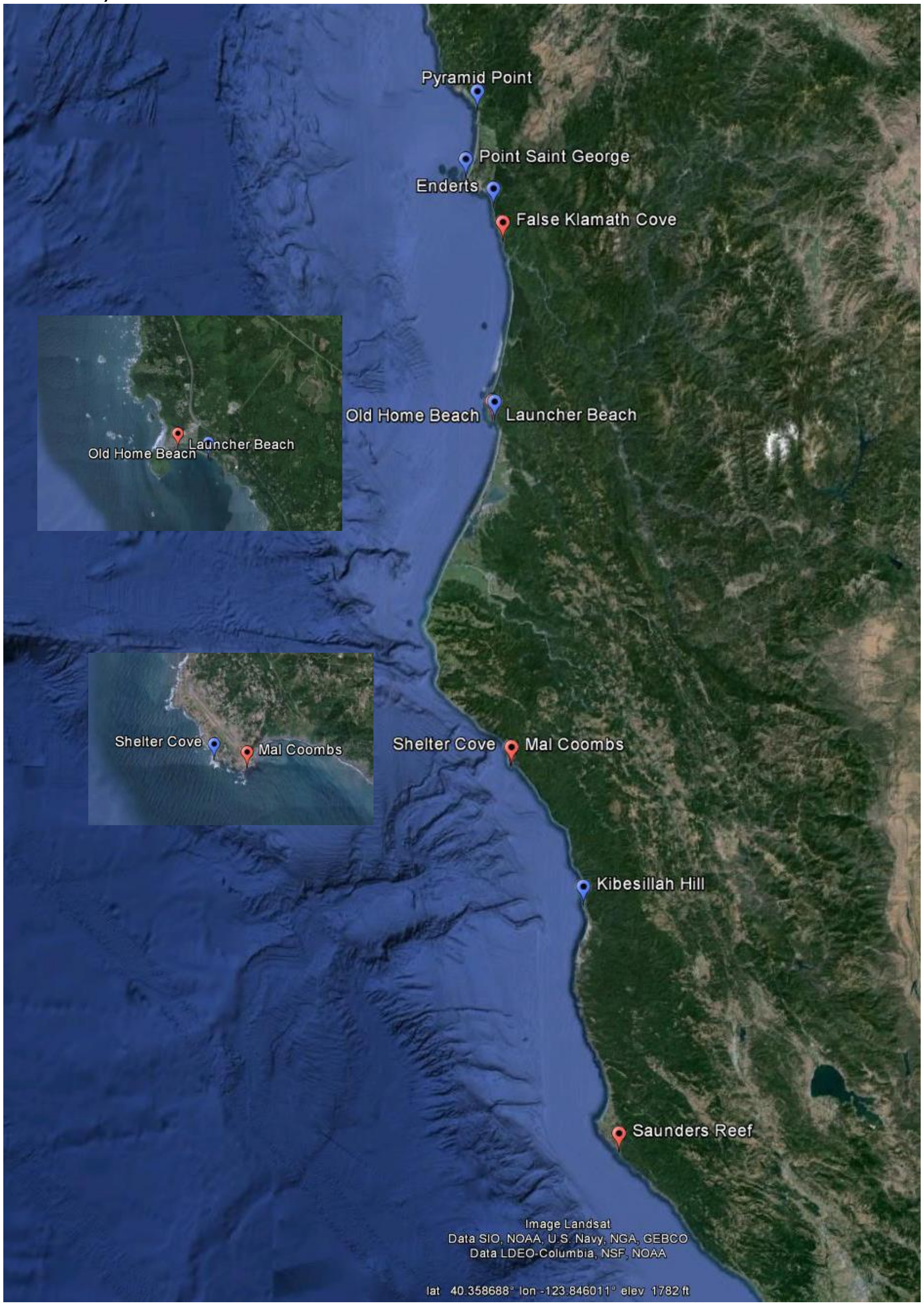


Table 1: Metadata for site attributes.

1. **Primary Bench Type:** describes the dominant geology of the site
   a. **bedrock:** the primary bench type is consolidated bedrock at this site
   b. **bedrock/boulders:** the primary bench type is a mixture of consolidated bedrock and boulder fields at this site
   c. **bedrock/sand:** the primary bench type is a mixture of consolidated bedrock and sandy beach at this site
   d. **bedrock/boulders/sand:** the primary bench type is a mixture of consolidated bedrock, boulder fields, and sandy beach at this site
   e. **boulders:** the primary bench type is boulder fields at this site
2. **Slope:** describes the slope of the coastline at the site
   a. **0-5 degrees:** the slope of this site is between 0-5 degrees
   b. **5-15 degrees** the slope of this site is between 5-15 degrees
3. **Relief:** describes the rugosity of the site
   a. **high:** the relief of the site consists of extremely uneven terrain, containing many deep cracks and folds, such as in some mixed consolidated bedrock and boulder fields
   b. **moderate:** the relief of the site consists of moderately uneven terrain, containing few cracks and folds, such as in boulder or cobble fields and some consolidated bedrock
   c. **low:** the relief of the site consists of flat terrain, such as a sandy beach
4. **Extent:** describes the length of the intertidal area at the site, from the land to the ocean
   a. **long:** the extent of the site is greater than 15 meters
   b. **intermediate:** the extent of the site is between 5-15 meters
   c. **short:** the extent of the site is less than 5 meters
5. **Surrounding Coast:** describes the geology of the area surrounding the site
   a. **bedrock:** the surrounding coast is consolidated bedrock at this site
   b. **bedrock/boulders:** the surrounding coast is a mixture of consolidated bedrock and boulder fields at this site
   c. **bedrock/sand:** the surrounding coast is a mixture of consolidated bedrock and sandy beach at this site
   d. **bedrock/boulders/sand:** the surrounding coast is a mixture of consolidated bedrock, boulder fields, and sandy beach at this site
   e. **bedrock/boulders/cobble:** the surrounding coast is a mixture of consolidated bedrock, boulder fields, and cobble beach at this site
   f. **boulders/sand:** the surrounding coast is a mixture of boulder fields and sandy beach at this site
   g. **boulders/cobble/sand:** the surrounding coast is a mixture of boulder fields, cobble beach, and sandy beach at this site
   h. **boulders:** the surrounding coast is boulder fields at this site
   i. **sand:** the surrounding coast is sandy beach at this site
6. **Species Richness:** a count of the total number of species found at a given site, using existing protocols.

Table 2: Site characteristics. See Table 1 for attribute descriptions. P indicates presence.

Attributes of Site	**Pyramid Point**	**Point Saint George**	**Enderts**	**False Klamath Cove**
Primary Bench Type	boulders/cobble/sand	bedrock/boulders/cobble/sand	bedrock	bedrock/boulders/cobble/sand
Slope	0-5 degrees	0-5 degrees	greater than 15 degrees	5-15 degrees
Relief	high	moderate	moderate	high
Extent	long	long	intermediate	intermediate
Surrounding coast	bedrock/boulders/cobble/sand	bedrock/boulders/cobble/sand	bedrock/boulders/cobble/sand	bedrock/boulders/cobble/sand
Species Richness	35	59	72	76
Species of Special Interest (P for present)				
Haliotis spp				
Lottia gigantea				
Phyllospadix spp		P	P	P
Invasive species				
Sargassum muticum				
Sargassum agardhianum				
Caulacanthus ustulatus				

Attributes of Site	**Launcher Beach**	**Old Home Beach**	**Shelter Cove**
Primary Bench Type	boulders/cobble/sand	bedrock/boulders/cobble/sand	bedrock
Slope	5-15 degrees	5-15 degrees	5-15 degrees
Relief	high	high	high
Extent	intermediate	long	long
Surrounding coast	boulders/cobble/sand	boulders/cobble/sand	bedrock/boulders
Species Richness	50	66	88
Species of Special Interest (P for present)			
Haliotis spp			P
Lottia gigantea			P
Phyllospadix spp	P	P	P
Invasive species			
Sargassum muticum			
Sargassum agardhianum			
Caulacanthus ustulatus			

Attributes of Site	**Mal Coombs**	**Kibesillah Hill**	**Saunders Reef**
Primary Bench Type	bedrock/boulders/cobble/sand	bedrock	bedrock/boulders
Slope	0-5 degrees	0-5 degrees	0-5 degrees
Relief	moderate	moderate	moderate
Extent	long	long	long
Surrounding coast	bedrock/boulders/cobble/sand	bedrock	bedrock/boulders/sand
Species Richness	70	86	65
Species of Special Interest (P for present)			
Haliotis spp			
Lottia gigantea			
Phyllospadix spp	P	P	P
Invasive species			
Sargassum muticum			
Sargassum agardhianum			
Caulacanthus ustulatus			

Species Richness Analysis

For sessile species, there was no effect on species richness that was associated with Site Type indicating no difference between ASBS discharge and reference sites (Table 3 and Figures 2 and 3).

Table 3: ANOVA results for species richness: sessile species.

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Site Type	1	1.66667	1.6667	0.0169	0.8999
Error	8	790.33333	98.7917		
C. Total	9	792			

For mobile species, there was no effect on species richness that was associated with Site Type indicating no difference between ASBS discharge and reference sites (Table 4 and Figures 2 and 3). There was a significant effect of geographic groups indicating a spatial pattern in species richness.

Table 4: ANOVA results for species richness: mobile species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Site Type	1	5.4	5.4	0.0714	0.7961
Error	8	605	75.625		
C. Total	9	610.4			

Figure 2: Species richness as a function of Site Type for Mobile and Sessile species. Error bars are +- 1 standard error of the mean.

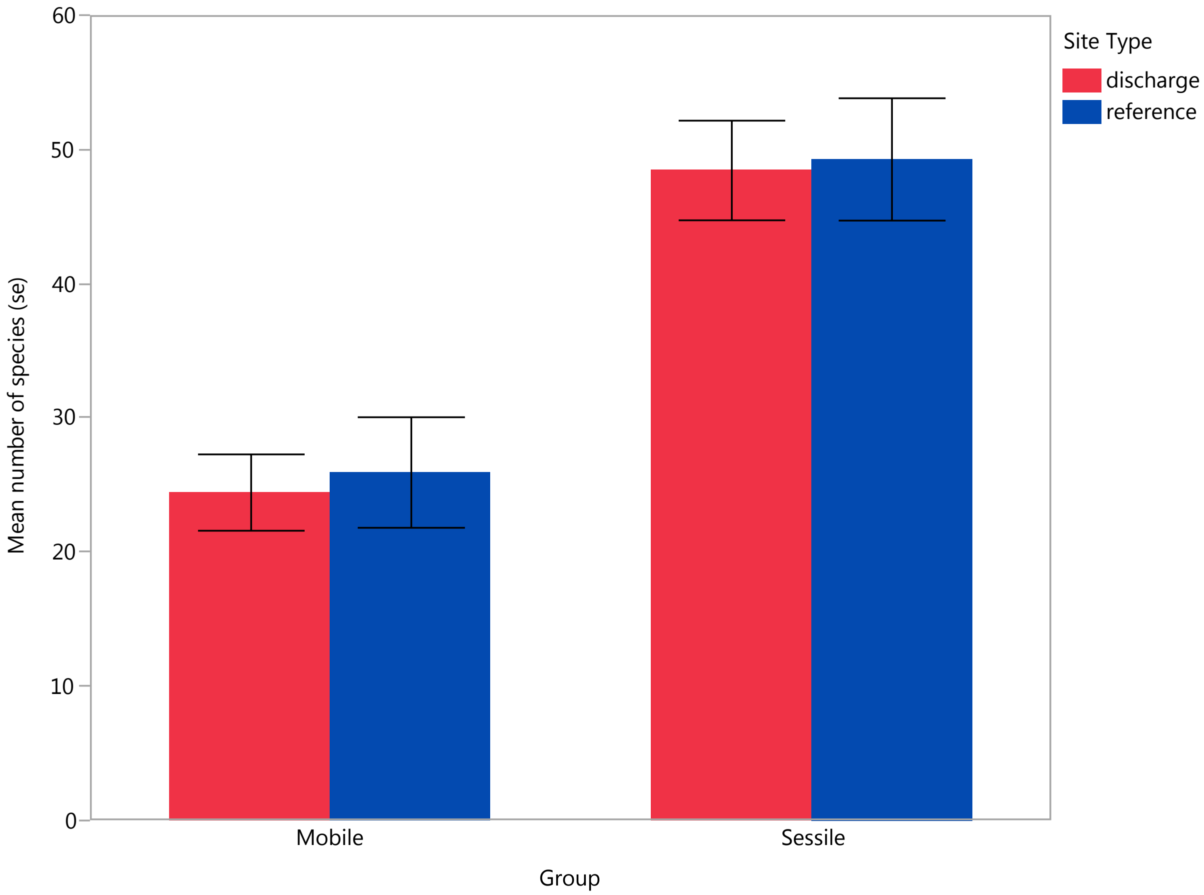
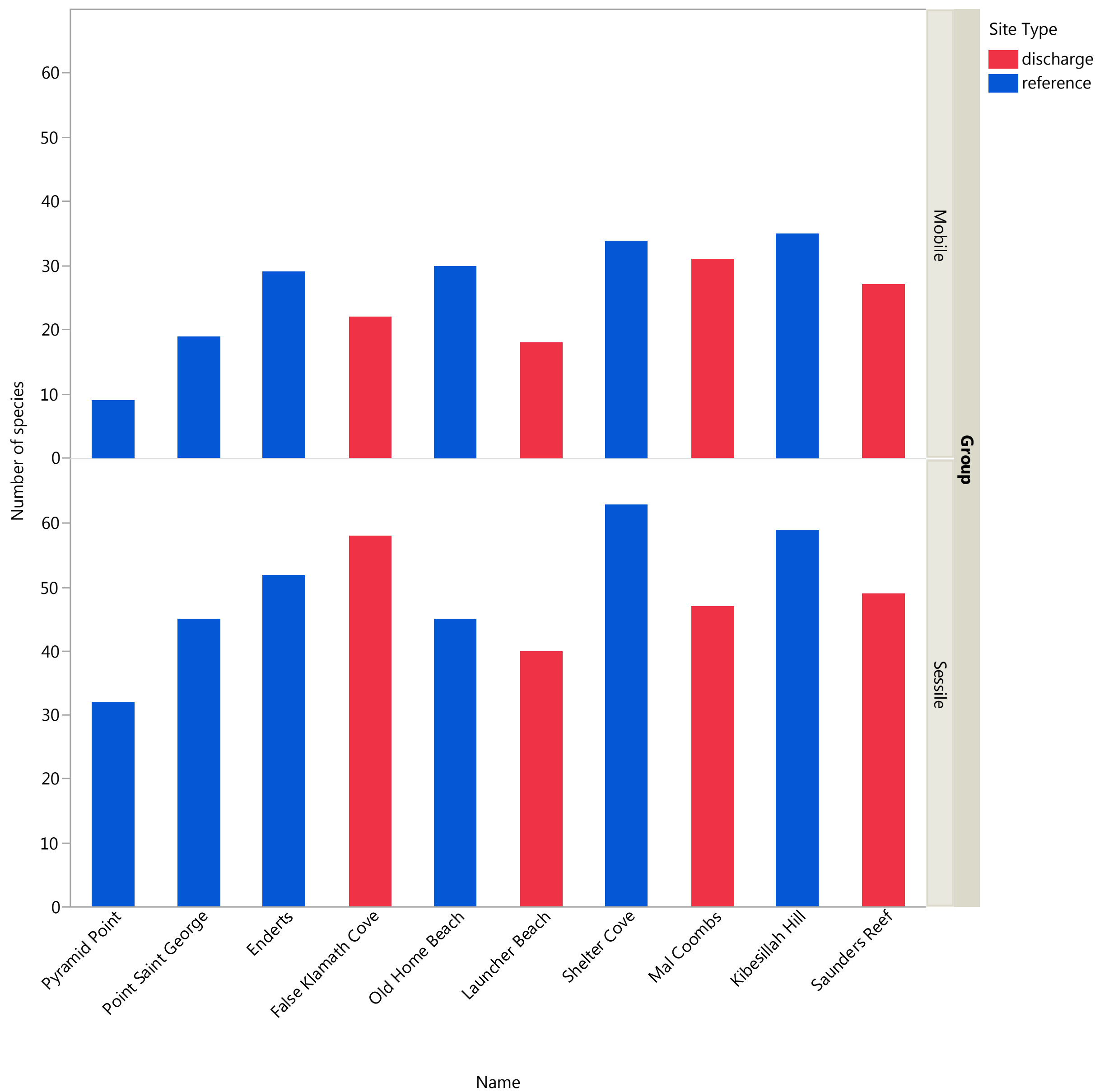


Figure 3: Species richness for mobile (top panels) and sessile species (bottom panels) as a function of site. Sites are arranged from north to south.



Community composition of sessile species

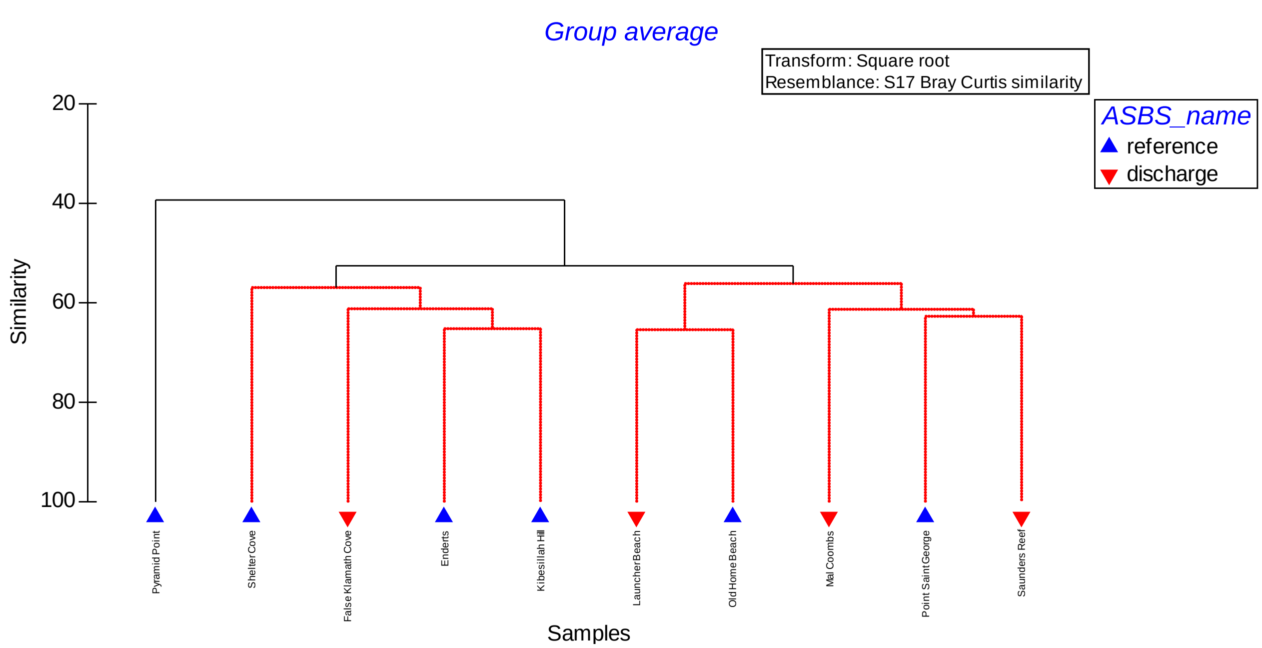
There was no significant effect of Site Type indicating no difference between ASBS discharge and reference sites (Table 5, Figure 4). The results are shown below in the PERMANOVA table and cluster diagram. There are clear (significant) clusters but both major clusters contain both discharge and reference sites. In addition, there is no evidence of a geographic signature in the clustering. This is consistent with previous assessment done during the California MPA design process.

Table 5: PERMANOVA table for effect of site type on the community composition of sessile species

PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
ASBS_name	1	1148.8	1148.8	0.97363	**0.501**	209
Res	8	9439.5	1179.9			
Total	9	10588				

Figure 4: Cluster diagram for sessile species community composition. Site types are indicated by symbol. Clusters connected by black lines are distinct at the P<0.05 level.



Community composition of mobile species

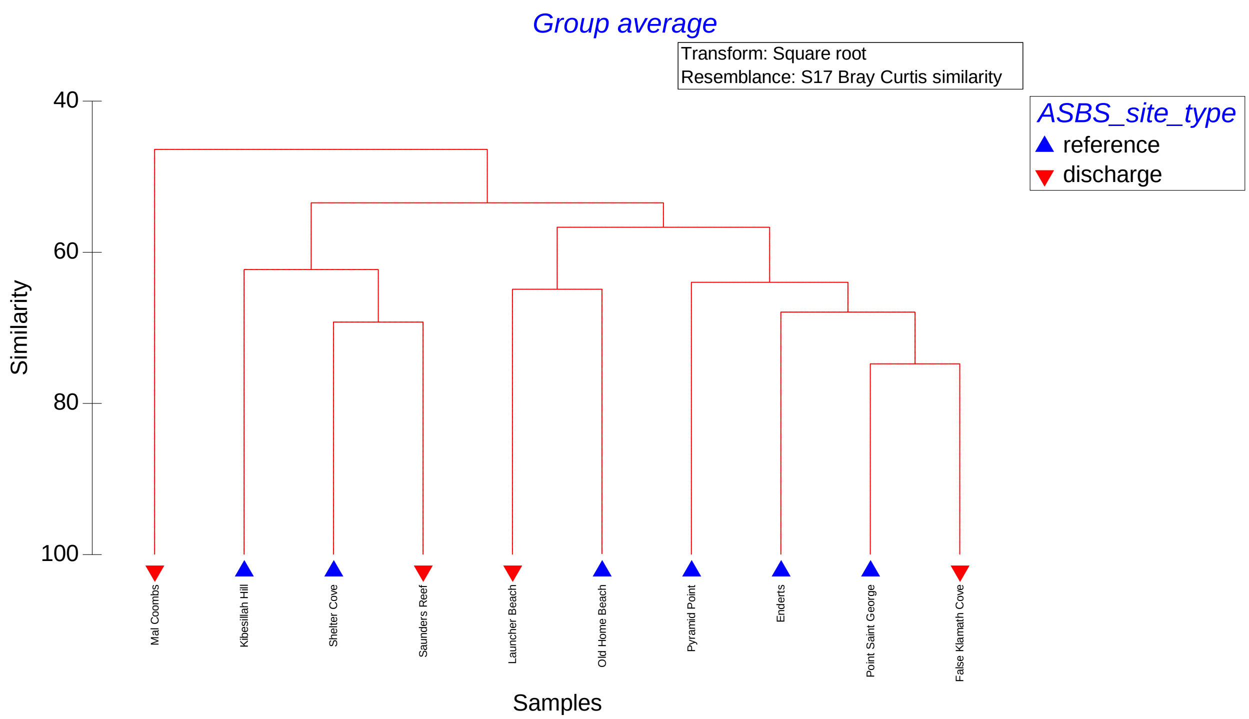
There was no significant effect of Site Type indicating no difference between ASBS discharge and reference sites (Table 6, Figure 5). The results are shown below in the PERMANOVA table and cluster diagram. There are no clear (significant) clusters. The results of the comparison of the diversity of mobile species between discharge and reference sites showed that Pyramid Point had unusually low diversity. We were concerned that this site could affect the results of the community comparison between discharge and references sites by adding variability to reference sites that might be attributable to the specific geomorphology of Pyramid Point. Too test this we ran the same Permanova test without after removing Pyramid Point from the analysis. The conclusion that there was no difference between reference and discharge sties was still support. Indeed the p-value increased from 0.847 to 0.931. As for the sessile species there was also no evidence of a geographic signature in the clustering. This is consistent with previous assessment done during the California MPA design process.

Table 6: PERMANOVA table for effect of site type on the community composition of mobile species.

PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
ASBS site type	1	626.84	626.84	0.57647	**0.847**	209
Residual	8	8699	1087.4			
Total	9	9325.8				

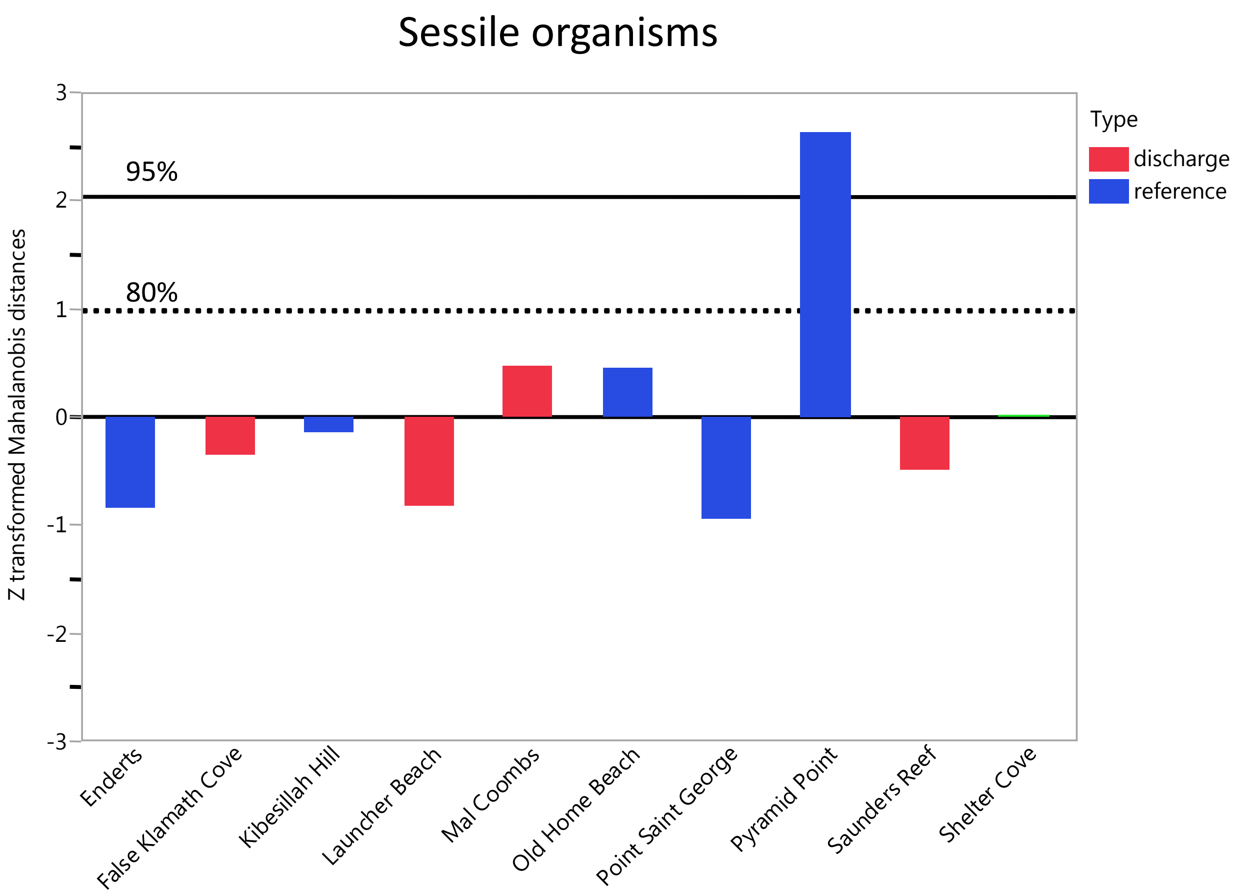
Figure 5: Cluster diagram for mobile species community composition. Site types are indicated by symbol.



An integrated assessment of both mobile and sessile species

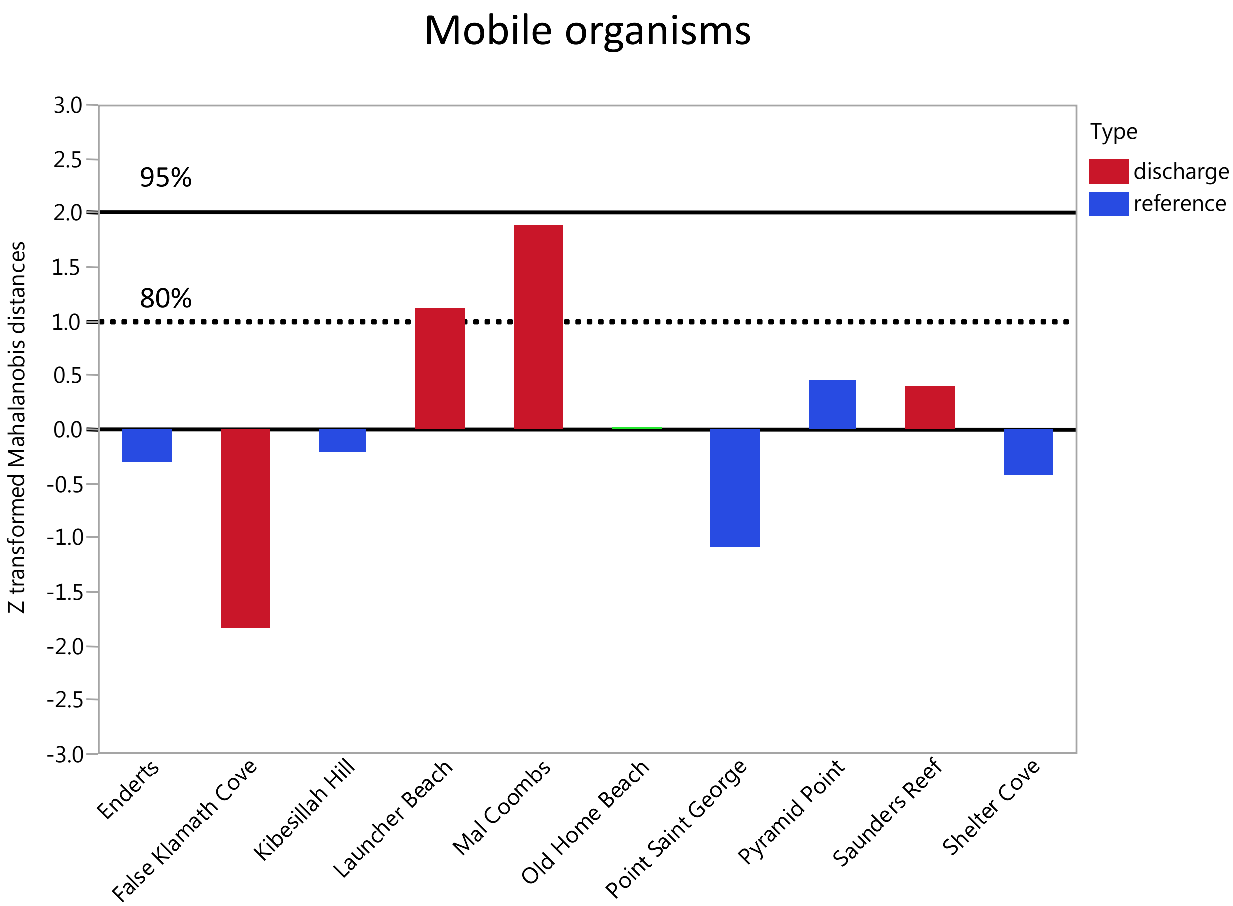
In order to assess the relationships among sites when mobile and sedentary species were jointly considered, we calculated the prediction limit on site specific Mahalanobis distances (Figure 6a and 6b). Two prediction limits are shown: 80 and 95%. Values beyond these limits indicate communities that differ from expected (at the 80 or 95% level).

Figure 6a: Mahalanobis distances (sessile species) for all sample sites. 80% and 95% prediction limits are also shown.



For sessile species the only site that exceeds the prediction is Pyramid point, which is a reference site. A tornado graph showing the differences in percent cover for all species between reference and discharge sites is shown in figure 7. The null expectation is that many species will show differences but no bias in the pattern of differences.

Figure 6b: Mahalanobis distances (mobile species) for all sample sites. 80% and 95% prediction limits are also shown.



A tornado graph showing the differences in counts for all species between reference and discharge sites is shown in figure 7. The null expectation is that many species will show differences but no bias in the pattern of differences. For mobile species, both Launcher and Mal Coombs communities differ from expected and warrant further assessment (e.g. a second sample). The differences can be seen in figure 8B.

Figure 7: Differences in percent cover of sessile species between reference and discharge locations. There is no evidence of a pattern in the differences. Positive values indicate more of a given species at reference sites as compared to discharge sites; negative values indicate less of a given species at reference sites as compared to discharge sites.

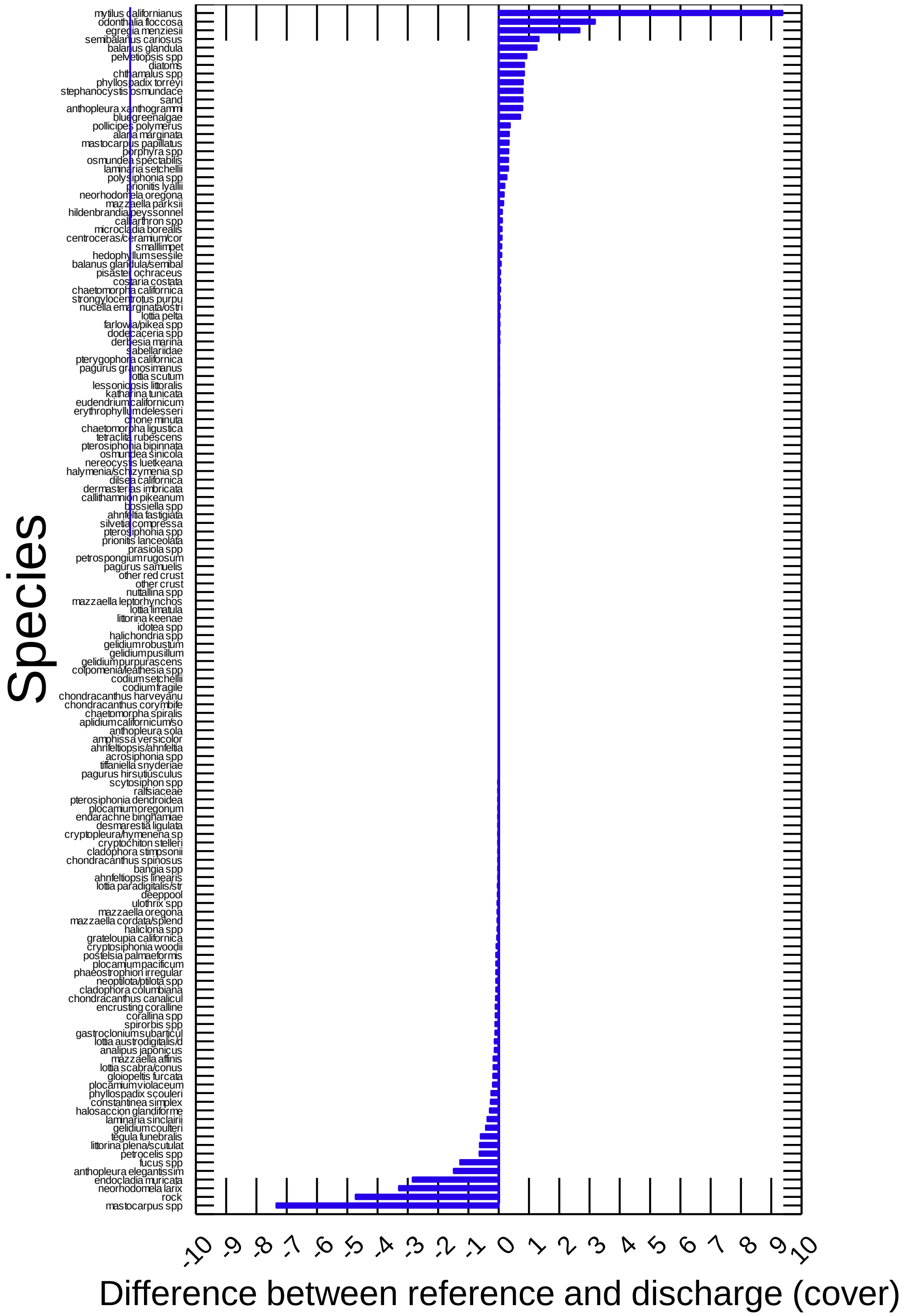


Figure 8: Differences in density of mobile species between discharge and reference locations. There is no evidence of a pattern in the differences. Positive values indicate more of a given species at reference sites as compared to discharge sites; negative values indicate less of a given species at reference sites as compared to discharge sites.

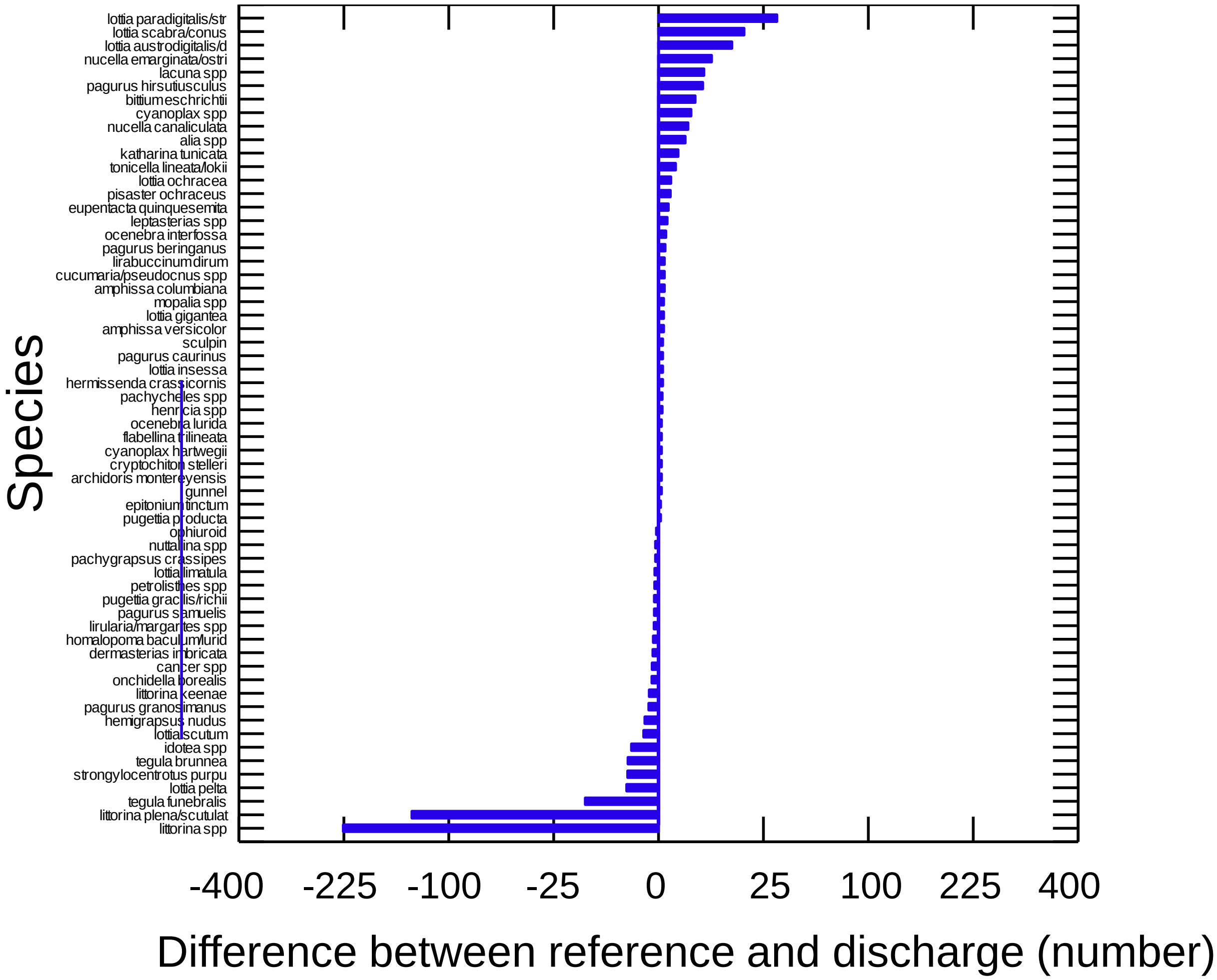
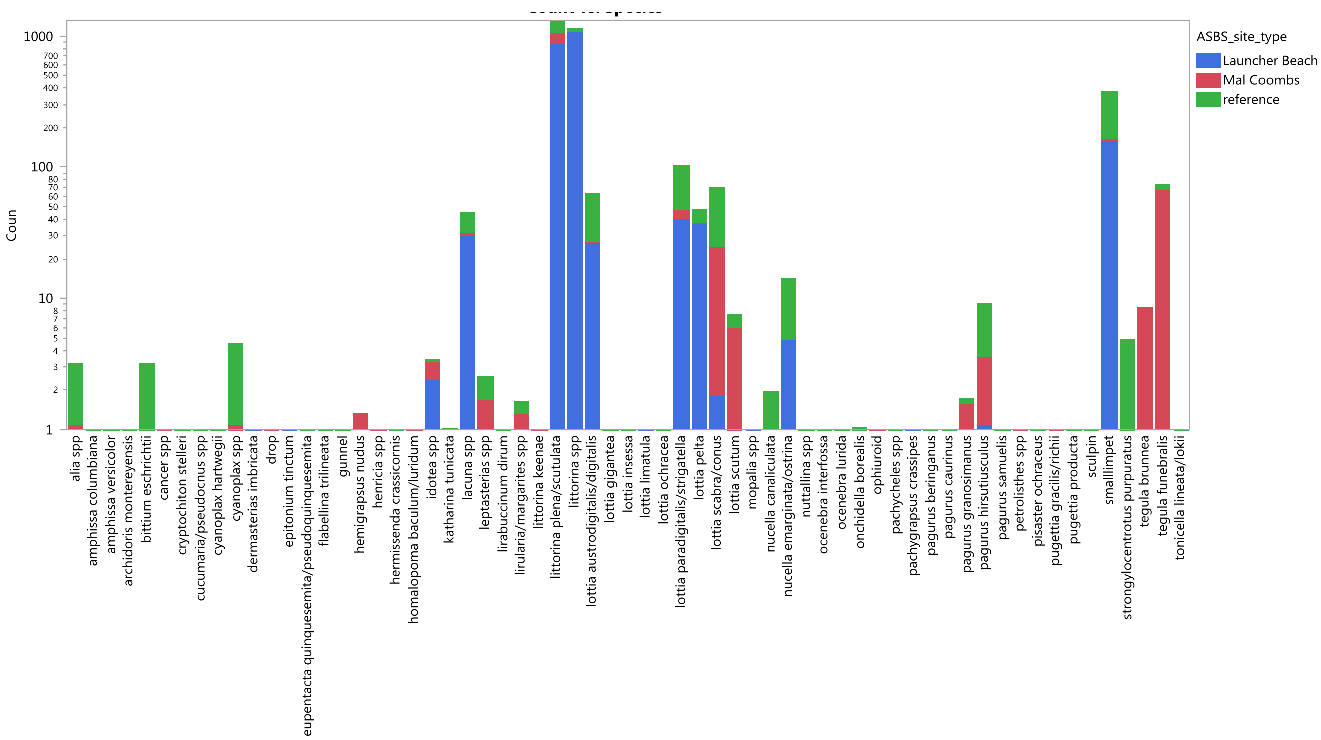


Figure 8B: Comparison of Mal Coombs and Launcher Beach to expected values for reference sites.



DISCUSSION

There are many natural local (site scale) drivers of community structure including rock type, bedding orientation, sand influence, orientation of the rock surface to the prevailing swell direction, local swell height and period and upwelling. There are also many local human-induced drivers of community structure that do not involve discharges. These include collecting, trampling and non-point source pollution. The integration of these factors is the background driver of community structure against which the effect of discharge is measured. In this study we used a sampling program designed to minimize this integrated driver. We found that there was no general difference in species richness or biological communities at discharge versus reference sites.

In this study we examined whether actual species composition differed from the expected species composition and if such deviation was associated with whether the site was near or far from a discharge. The general questions are whether the biological community is affected by discharge of water and associated components, and if so, in what way? If a difference is found, then specific expectations need to be evaluated. Here, the specific expectations consistent with an impact due to compromised water quality are (Arevelo et al. 2007, Pineda et al. 2007):

1) Generally decreased abundance of species at discharge sites compared to reference sites. This was not the case for any site sampled twice.
2) Communities at discharge sites are characterized by disturbance-associated species. There is not strong support for this general prediction.
    a. There is support for the idea that specific sites that have been identified as being outlier sites (especially Launcher Beach) are characterized by disturbance associated species (Figure 8B)

In summary, this project provides the first comprehensive condition report for the rocky intertidal zone in northern California Areas of Special Biological Significance and serves as a good basis and trigger for focused additional work. The use of standardized sampling consistent with the primary intertidal monitoring program along the West Coast (PISCO/MARINe see www.pacificrockyintertidal.org) allows the results of earlier sampling to be incorporated into the study (because the monitoring uses identical methodologies) and gives context for the ASBS sampling. This approach was used previously in the southern California ASBS assessments, which was a two phase approach (Raimondi et al. 2012, Raimondi 2014). Phase 1 was identical to the current northern California assessment. In southern California, there was a second phase where all sites were evaluated a second time. If those discharge sites that showed differences from expected communities (here the sites are Launcher Beach and Mal Coombs) in phase 1 did not show those differences in phase 2, they were deemed not to differ from expected.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

- Based on the results of these analyses there is no support that discharges in the North Coast generate regionwide impacts to diversity or community composition in the nearby rocky intertidal sites. This does not mean that there are no impacts to species in the communities. Other attributes such as individual growth and reproduction could be affected with no subsequent impact to diversity or composition.
- Some sites stood out as differing substantially from what was expected for biological communities in the region. Pyramid Point, a reference site, had much lower species richness of mobile taxa than other sites. It also was the one site that was an outlier with respect to sessile species composition. Mal Coombs and Launcher Beach, both discharge sites, were outliers with respect mobile species composition. Launcher Beach, in particular, was characterized by more disturbance associated (likely sediment) than other sites.

Recommendations

- The protocols used in this ASBS assessment are identical to those used in Southern and Central California. Because the analytical approach used for these assessments can incorporate geographic effects on community composition (e.g. biogeography), it would be possible to conduct a comprehensive statewide meta-assessment that could be much more powerful (able to detect impacts) than regionally-based assessments.
- With respect to the North Coast Assessment, two discharge sites were outliers in community composition relative to reference sites: Launcher Beach and Mal Coombs. A second year of sampling was used in southern California to confirm impacted sites and increase confidence in statements about deviations in natural water quality. In southern California, discharge sites originally deemed as outliers in year 1 were free from such patterns in year 2. A second year of sampling could be equally beneficial in the North Coast.

REFERENCES

Arevalo R, S. Pinedo, E. Ballesteros. 2007. Changes in the composition and structure of Mediterranean rocky-shore communities following a gradient of nutrient enrichment: Descriptive study and test of proposed methods to assess water quality regarding macroalgae, Marine Pollution Bulletin, Volume 55, Issues 1-6. Pages 104-113

Conway-Cranos and Raimondi. 2007. Spatial and temporal variation in recruitment to rocky shores: Relationship to recovery rates of intertidal communities. Coastal Research Center, Marine Science Institute, University of California, Santa Barbara, California. MMS Cooperative Agreement Number 14-35-0001-30758

Defeo O. , A McLachlan, D. Schoeman, T Schlacher, J Dugan, A Jones, M Lastra, F Scapin. 2009. Threats to sandy beach ecosystems: A review. Estuarine, Coastal and Shelf Science, Volume 81, Issue 1, Pages 1-12

Dickson A, R. Gossett, D. Gregorio, B. Jones, S. Murray, B. Posthumus and K. Schiff. 2010 Summation of Findings Natural Water Quality Committee 2006-2009. Technical Report 625. Southern California Coastal Water Research Project, Costa Mesa, CA

Littler, M and S. Murray. 1975. Impact of sewage on the distribution, abundance and community structure of rocky intertidal macro-organisms. Marine Biology ,Volume 30, Number 4, 277-291.

McLachlan, A. 1993. Sandy beach macrofauna communities and their control by the physical environment: a geographical comparison. Journal of Coastal Research 15: 27-38

Minchinton T. and P. Raimondi. 2007. Effect of Temporal and Spatial Separation of Samples on Estimation of Impacts. MMS OCS Study 2005-002. Coastal Research Center, Marine Science Institute, University of California, Santa Barbara, California. MMS Cooperative Agreement number 14-35-0001-30758. 85 pages.

Raimondi P, K Schiff, D. Gregorio. 2012. Characterization of the rocky intertidal ecological communities associated with southern California Areas of Special Biological Significance. SCCWRP Technical Report. 80 pages

Raimondi, PT. 2014. Characterization of the Rocky Intertidal Ecological Communities Associated with Southern California Areas of Special Biological Significance: Phase II

Pinedo S, M Garcia, M Paola Satta, M de Torres, E Ballesteros. 2007. Rocky-shore communities as indicators of water quality: A case study in the Northwestern Mediterranean, Marine Pollution Bulletin, Volume 55, Issues 1-6. Pages 126-135,

Southern California Coastal Water Research Project. 2005. California Ocean Plan. Sacramento, CA

APPENDIX

Site locations, descriptions, pictures and site specific cover and density of species

Pyramid Point

Pyramid Point is located in the North Coast region of California within the Pyramid Point State Marine Conservation Area and is part of the Smith River Rancheria. The site is highly sand influenced with sand levels varying greatly throughout the year. This gently sloping site consists of extremely uneven terrain, containing many deep cracks and folds.

Pyramid Point is dominated by a mixture of boulder fields (Franciscan mélange/Soapstone/serpentinite), cobble, and sandy beach, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder fields, and sandy beach. The primary coastal orientation of this site is west/southwest.

The Biodiversity Survey grid encompasses one section that is approximately 20 meters (along shore) x 33 meters (seaward).

Point Saint George

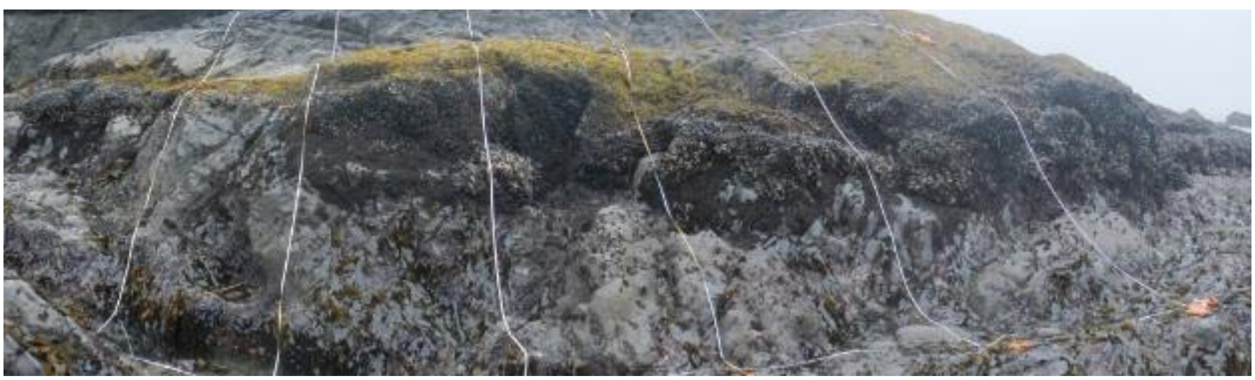
Point Saint George is located in the North Coast region of California and is part of the Smith River Rancheria. This site is near the Point Saint George Mussel Watch site. This site is located on the northern end of Crescent City and is easily accessible from the parking lot at Point St. George. It receives moderate visitation from school groups and tide poolers. This gently sloping site consists of moderately uneven terrain, containing few cracks and folds.

Point Saint George is dominated by a mixture of consolidated bedrock, boulder fields, and cobble and sandy beach, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder fields, and sandy beach. The primary coastal orientation of this site is west.

The Biodiversity Survey grid encompasses one section that is approximately 29 meters (along shore) x 50 meters (seaward).

Enderts

Enderts is located in the North Coast region of California, within Redwood National and State Parks. This site is located in an Area of Special Biological Significance (Redwood National Park ASBS). Visitation is relatively low due to obstructed access through a cave. This steep site consists of moderately uneven terrain, containing few cracks and folds.



Enderts is dominated by consolidated bedrock (greywacke mudstone/sandstone with calcite intrusions), and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder fields, and sandy beach. The coastal orientation of this site is both north and south.

The Biodiversity Survey grid encompasses two sections that are approximately 10 meters (along shore) x 10 meters (seaward), and 8 meters (along shore) x 15 meters (seaward).

False Klamath Cove

False Klamath Cove is located in the North Coast region of California, within Redwood National and State Parks. This site is located in an Area of Special Biological Significance (Redwood National Park ASBS) and is part of the Yurok Tribal Territory. This site is easily accessible from Highway 101 and receives moderate visitation from tide poolers and fishers. This moderately sloping site consists of extremely uneven terrain, containing many deep cracks and folds.

False Klamath Cove is dominated by a mixture of consolidated bedrock, boulder fields, and cobble and sandy beach, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder fields, and sandy beach. This site is a peninsula and consists of a boulder field with some bedrock. The primary coastal orientation of this site is west.

The Biodiversity Survey grid encompasses two sections that are approximately 12 meters (along shore) x 10 meters (seaward), and 15 meters (along shore) x 20 meters (seaward).

Launcher Beach

Launcher Beach is located in the North Coast region of California. This site is located in an Area of Special Biological Significance (Trinidad Head ASBS) and is near the Flint Rock Head Mussel Watch site. This site is part of the Trinidad Rancheria and Yurok Tribal Territory, and receives relatively high visitation due to easy access and being near the Trinidad boat launch. This moderately sloping site consists of extremely uneven terrain, containing many deep cracks and folds.

Launcher Beach is dominated by a mixture of boulder fields, cobble, and sandy beach, and the area surrounding the site is comprised of a mixture of boulder fields, cobble beach, and sandy beach. The primary coastal orientation of this site is southwest.

The Biodiversity Survey grid encompasses one section that is approximately 20 meters (along shore) x 15 meters (seaward).

Old Home Beach

Old Home Beach is located in the North Coast region of California and is part of the Yurok Tribal Territory. This site is located at the southern end of Old Home Beach and receives moderate visitation by tide poolers. This moderately sloping site consists of extremely uneven terrain, containing many deep cracks and folds.

Old Home Beach is dominated by a mixture of consolidated bedrock, boulder fields, and cobble beach, and the area surrounding the site is comprised of a mixture of boulder fields, cobble beach, and sandy beach. The primary coastal orientation of this site is south/southwest/southeast.

Biodiversity Survey grid encompasses two sections that are approximately 8 meters (along shore) x 20 meters (seaward), and 10 meters (along shore) x 20 meters (seaward).

Shelter Cove

Shelter Cove is located in the North Coast region of California. This site is located in an Area of Special Biological Significance (King Range NCA ASBS) and is near the Point Delgada/Shelter Cove Mussel Watch site. This site receives moderate visitation by abalone divers, fishermen, and tide poolers. This moderately sloping site consists of extremely uneven terrain, containing many deep cracks and folds.

Shelter Cove is dominated by consolidated bedrock, and the area surrounding the site is comprised of a mixture of consolidated bedrock and boulders. The primary coastal orientation of this site is west/southwest.

The Biodiversity Survey grid encompasses one section that is approximately 30 meters (along shore) x 50 meters (seaward).

Mal Coombs

Mal Coombs is located in the North Coast region of California, within the King Range National Conservation Area. This site is located in an Area of Special Biological Significance (King Range NCA ASBS) and is near the Point Delgada/Shelter Cove Mussel Watch site. . This site receives relatively high visitation by tide poolers due to nearby parking and steps leading down to the intertidal. It is also about a quarter mile upcoast of the Shelter Cove boat launch. This gently sloping site consists of moderately uneven terrain, containing few cracks and folds.

Mal Coombs is dominated by a mixture of consolidated bedrock, boulder fields, and cobble beach, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder fields, and sandy beach. The primary coastal orientation of this site is southeast.

The Biodiversity Survey grid encompasses one section that is approximately 20 meters (along shore) x 50 meters (seaward).

Kibesillah Hill

Kibesillah Hill is located in the North Coast region of California. Kibesillah Hill is one of 6 sites where Kinnetic Laboratories did experimental clearings (1m x 2m) in 1985 in the *Endocladia*, *Mastocarpus* and *Mytilus* zones to look at recovery rates within these assemblages. This site receives low visitation by fisherman and tide poolers. This gently sloping site consists of moderately uneven terrain, containing few cracks and folds.

Kibesillah Hill is dominated by consolidated bedrock, and the area surrounding the site is comprised of consolidated bedrock. The primary coastal orientation of this site is north/northwest.

The Biodiversity Survey grid encompasses one section that is approximately 30 meters (along shore) x 80 meters (seaward).

Saunders Reef

Saunders Reef is located in the North Central Coast region of California, within the Saunders Reef State Marine Conservation Area. This site is near the Saunders Landing/Saunders Reef Mussel Watch site. This site receives low visitation by abalone divers, fisherman, and tide poolers. This gently sloping site consists of moderately uneven terrain, containing few cracks and folds.

Saunders Reef is dominated by a mixture of consolidated bedrock (mudstone) and boulders, and the area surrounding the site is comprised of a mixture of consolidated bedrock (mudstone), boulder fields, and sandy beach. The primary coastal orientation of this site is west.

The Biodiversity Survey grid encompasses one section that is approximately 30 meters (along shore) x 80 meters (seaward). Click here to view Biodiversity Survey findings at this site.