Characterization of the Rocky Intertidal Ecological Communities Associated with Southern California Areas of Special Biological Significance: Phase II

Pete Raimondi

Southern California Coastal Water Research Project

Technical Report 818

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April 6, 2014

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EXECUTIVE SUMMARY

Two phases of sampling were done to characterize the biological communities at sites near to discharges in ASBS and at reference sites (considered to be unaffected by discharges). Sites were arranged in six geographic groups to account for biogeographical patterns in species composition. In phase 1, we concluded, “While there was no indication of a general and similar impact of discharges on biological communities there was an indication that specific locations might be affected by compromised water quality.” In fact, one of the motivations for phase II sampling was to determine if those sites that showed biological communities potentially affected by discharge showed the same pattern in the later sampling period. Using an analytical approach designed to assess site-specific effects, we found that there was no evidence of “persistent” effects and that the likely explanation was natural (or at least not related to discharge) variability in biological communities. None of the four sites that exceeded the prediction limits in phase I exceed them in phase II. Consistent with the idea of temporal variation, we found that three sites in phase II exceeded the prediction limits and none of the three exceeded them in phase 1 (note that one, Muddy Canyon was not evaluated in phase I). These results point to the strength of the phased assessment, particularly with respect to the possibility of an uninformed conclusion of discharge related effects. No matter how carefully a survey is designed, there is no way to completely control for the contributions of extraneous factors. In such situations it is often useful to examine if patterns hold over time – as was done here.

ACKNOWLEDGEMENTS

This project was only possible with the collaboration of the ASBS Planning Committee of the Southern California Bight Regional Marine Monitoring Program. The following individuals were instrumental in the implementation of the project: Maya George, Melissa Redfield, Nate Fletcher, Sara Worden, Kim Parisi, Laura Anderson, Rachael Williams, and Rani Gaddam from University of California Santa Cruz; Avrey Parsons-Field and Chris Teague from the University of California Santa Barbara; and Jessica Bredvik from the United States Navy. Also acknowledged are Isabelle Kay and Larry Jacklin.

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INTRODUCTION

The Regulatory Environment

The California Ocean Plan defines water quality objectives for State waters and is the basis of regulation of discharges to the 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 Resources Control Board (SWRCB) 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 (SWRCB 2005). 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, at least for southern California ASBS, coastal waters are no longer pristine. This is not simply due to discharges, as even if land based discharges were to be eliminated, aerial contaminants and pollutants carried by oceanic currents would influence water quality conditions.

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 SWRCB. In 2010, the ASBS Natural Water Quality Committee provided the SWRCB with its findings (Dickson et al. 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 et al. 2009) 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 2006, 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 *Balanu*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 the second phase of a project designed to: (1) characterize the ecological community living on rocky intertidal habitats near discharges inside southern 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 that may be due to water quality degradation within ASBS.

In phase 1 of the study, we found that four of the 21 sites surveyed, La Jolla Caves, Lechuza Point, Avalon Quarry and Crystal Cove, had biological communities that differed (>80% Prediction Limit) from what was expected. As part of the phase II assessment, we determined if this pattern was repeated or if it represented a single exception.

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: ASBS 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 to 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 30 m 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 30 m 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. In addition, for areas where only a single bench is available and it is not 30 m wide, we will adapt the protocol to a 20-m width.

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, which should be parallel to the upper baseline, was established farther down the shore. 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 insure that these lines were parallel, they should intersect the appropriate meter mark on the lower baseline. 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. It was noted where each transect crossed the lower baseline.

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 plots. Photographs were also taken that include prominent visual reef characteristics for orientation (e.g. a large crack). The distance and bearing between the baseline endbolts were measured. When possible, measurements were also taken between the endbolts and any pre-existing permanent plots. Other pertinent information, such as the compass heading of the vertical transects, the sampling interval, weather conditions, site complications, and problems with taxonomic identification, was also recorded. All such information was used to make the mapping of the site more spatially explicit.

In addition to the spatial information described above, we also collected information about the site including bench type, relief, slope, extent of habitat and characteristics of surrounding coast. We also collected a rock sample to characterize the geology. This information can be used to provide a 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. Hence, 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 and host were noted. Also recorded was whether the species under the point was in a pool, on cobble, or on boulders.

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 must fall within a circle centered over the point with a radius of half the length of the sampling interval. Note, as mentioned above, species that were not recorded directly under appoint were only used in depictions of species spatial distributions.

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, defined as the area below the mussel zone, the mid-zone (including mussels and rock weeds, and the high zone (usually dominated by barnacles and littorines). Within each zone, a quadrat was randomly placed on the transect, and all mobile species found within the quadrat were identified and counted. Sub-sampling was used when there was 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 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. These were taken back to the lab for identification.

Specific Hypotheses Tested

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

1) Species richness will not vary as a function of site type (ASBS, 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.

5) Those sites that differed from expectation in phase I will not differ in phase II.

For questions 1–3, two forcing (independent) variables were used in the statistical approaches. First, whether the site was considered to be an ASBS site (near to a discharge) or a reference site (that could also be in an ASBS). Second, we imposed a geographical group structure to match ASBS sites with appropriate reference sites. Point contact (mainly sessile or sedentary organisms) and quadrat data (mobile organisms) were evaluated using a PERMANOVA approach to compare communities between ASBS and reference sites after accounting for geography. 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 the sample is similar to a hypothetical typical sample, while large distances indicate samples are very different from the hypothetical typical sample. 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.

For hypothesis 5, we compared the results from hypothesis 4 in phase I to those from phase II.

RESULTS

Sites Sampled and Site Attributes

Sampling locations are shown in Figures 1A and 1B. Description of site metadata and site characteristics are in Tables 1 and 2, respectively.

Figure 1A. Map of sampling locations. Colors and numbers indicate geographic groups. Within each pointer, the symbol represents site type: Star = Discharge site in ASBS, Square = reference site.

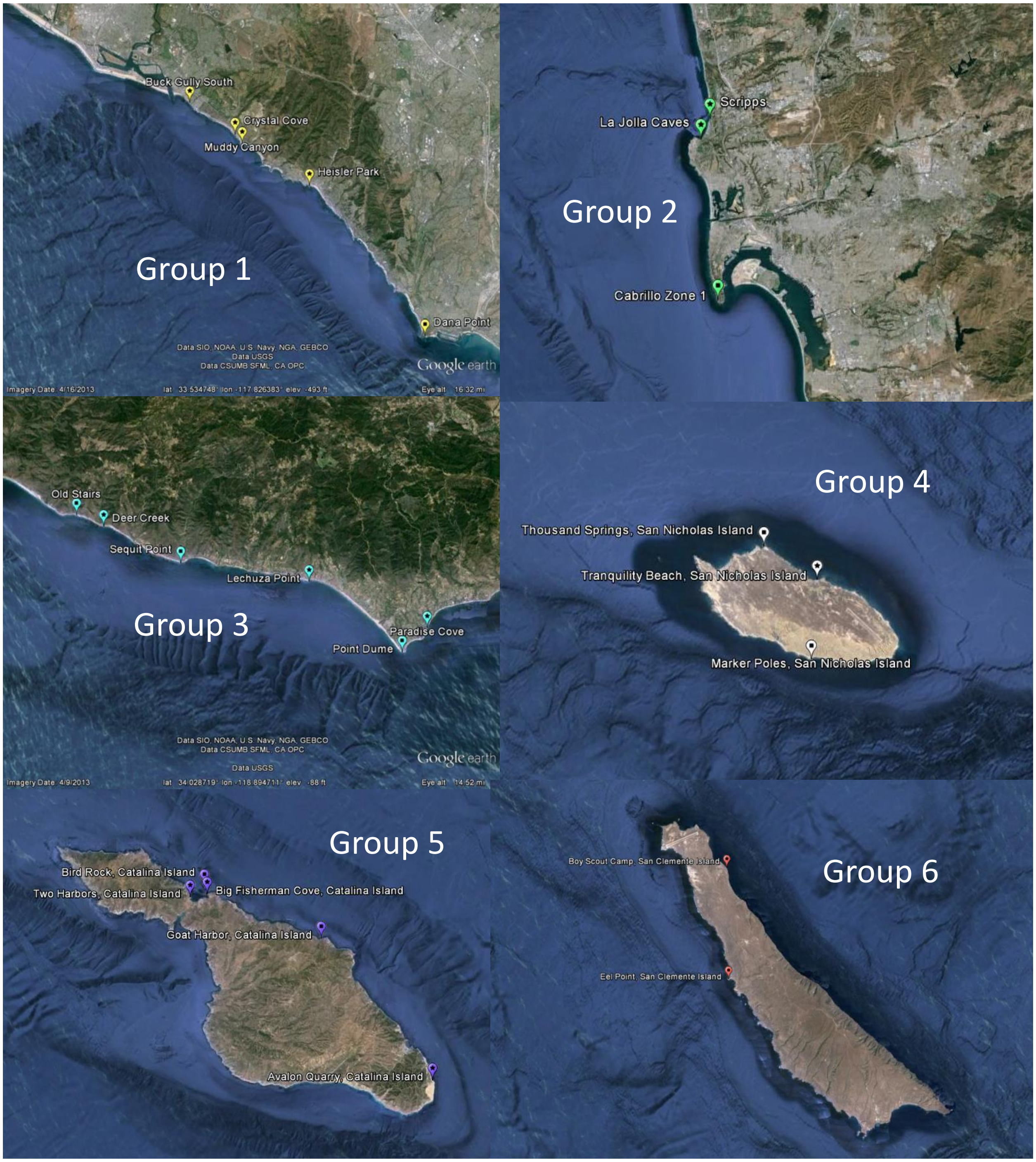

Figure 1B. detailed maps of the six geographic groups. Star = Discharge site in ASBS, Square = reference site.

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.

Group	Attributes of Site	Buck Gully South	Crystal Cove	Heisler Park	Dana Point	Muddy Canyon
1	Primary Bench Type	bedrock/boulders	bedrock	bedrock/sand	bedrock/boulders	bedrock/boulders/cobble/sand
	Slope	0-5 degrees	0-5 degrees	0-5 degrees	0-5 degrees	0-5 degrees
	Relief	moderate	low	moderate	moderate	moderate
	Extent	long	long	long	long	long
	Surrounding coast	bedrock/boulders/sand	bedrock/boulders/sand	bedrock/boulders/sand	bedrock/boulders/sand	bedrock/boulders/cobble/sand
	Species Richness	70(2010) , 64(2013)	81 (2001); 74 (2003); 75 (2004), 84(2013)	71 (2010), 71(2013)	71 (2001); 72 (2006); 73 (2010), 80(2013)	78 (2013)
	Species of Special Interest (P for present)					
	Haliotis spp					
	Lottia gigantea	P	P	P	P	P
	Phyllospadix spp		P	P	P	P
	Invasive species					
	Sargassum muticum	P	P	P	P	
	Sargassum agardhianum		P		P	
	Caulacanthus ustulatus	P	P	P	P	

Group	Attributes of Site	Scripps	La Jolla Caves	Cabrillo Zone I
2	Primary Bench Type	bedrock/boulders/sand	bedrock/boulders/sand	bedrock/boulders
	Slope	0-5 degrees	0-5 degrees	0-5 degrees
	Relief	moderate	low	moderate
	Extent	long	long	long
	Surrounding coast	boulders/sand	boulders/cobble/sand	bedrock/boulders/sand
	Species Richness	73 (2002); 83 (2006); 81 (2010), 71(2013)	59 (2010), 67 (2013)	69 (2002); 84 (2004); 76 (2009), 83(2013)
	Species of Special Interest (P for present)			
	Haliotis spp			
	Lottia gigantea	P		P
	Phyllospadix spp	P	P	P
	Invasive species			
	Sargassum muticum	P	P	P
	Sargassum agardhianum	P	P	
	Caulacanthus ustulatus	P	P	P

Group	Attributes of Site	Old Stairs	Sequit Pt	Lechuza Pt	Paradise Cove	Deer Creek	Point Dume
3	Primary Bench Type	bedrock/boulders/sand	bedrock	bedrock/sand	bedrock/sand	bedrock/sand	bedrock/boulders/sand
	Slope	5-15 degrees	0-5 degrees	5-15 degrees	5-15 degrees	0-5 degrees	0-5 degrees
	Relief	moderate	moderate	moderate	low	moderate	moderate
	Extent	long	long	long	intermediate	short	intermediate
	Surrounding coast	boulders/sand	bedrock/boulders/sand	bedrock/sand	sand	bedrock/boulders/sand	bedrock/boulders/sand
	Species Richness	49 (2001); 44 (2008), 47 (2013)	50 (2010), 47 (2013)	54 (2010), 51 (2013)	70 (2001); 61 (2006); 61 (2010), 62(2013)	43 (2013)	45 (2013)
	Species of Special Interest (P for present)						
	Haliotis spp						
	Lottia gigantea	P	P	P	P	P	P
	Phyllospadix spp			P	P		
	Invasive species						
	Sargassum muticum						
	Sargassum agardhianum						
	Caulacanthus ustulatus				P	P	

Table 2 (continued). Site characteristics. See Table 1 for attribute descriptions. P indicates presence.

Group	Attributes of Site	Thousand Springs SNI	Tranquility Beach SNI	Marker Poles SNI
4	Primary Bench Type	bedrock/boulders	bedrock	bedrock
	Slope	5-15 degrees	0-5 degrees	0-5 degrees
	Relief	moderate	moderate	moderate
	Extent	intermediate	long	long
	Surrounding coast	bedrock/boulders/sand	bedrock/boulders/sand	bedrock/sand
	Species Richness	65 (2003); 70 (2007), 66, (2013)	70 (2010), 74 (2013)	75 (2003); 69 (2007), 58 (2013)
	Species of Special Interest (P for present)			
	Haliotis spp	P		P
	Lottia gigantea	P		P
	Phyllospadix spp	P	P	P
	Invasive species			
	Sargassum muticum	P	P	
	Sargassum agardhianum			
	Caulacanthus ustulatus		P	

Group	Attributes of Site	Bird Rock CI	Big Fisherman Cove CI	Two Harbors CI	Goat Harbor CI	Avalon Quarry CI
5	Primary Bench Type	bedrock	bedrock	bedrock/boulders	bedrock/boulders	boulders
	Slope	5-15 degrees	5-15 degrees	5-15 degrees	5-15 degrees	5-15 degrees
	Relief	moderate	moderate	moderate	moderate	moderate
	Extent	intermediate	intermediate	intermediate	intermediate	intermediate
	Surrounding coast	bedrock/boulders	bedrock/boulders	bedrock/boulders/sand	bedrock/boulders/cobble	boulders
	Species Richness	60 (2002); 84 (2004); 75 (2007), 53 (2013)	68 (2010, 59 (2013)	75 (2010), 63 (2013)	50 (2010), 60 (2013)	53 (2010), 57 (2013)
	Species of Special Interest (P for present)					
	Haliotis spp			P		
	Lottia gigantea	P				
	Phyllospadix spp					
	Invasive species					
	Sargassum muticum	P	P	P		P
	Sargassum agardhianum	P	P			
	Caulacanthus ustulatus		P	P	P	

Group	Attributes of Site	Boy Scout Camp SCLI	Eel Pt. SCLI
6	Primary Bench Type	bedrock/boulders	bedrock
	Slope	5-15 degrees	5-15 degrees
	Relief	moderate	moderate
	Extent	intermediate	long
	Surrounding coast	bedrock/boulders	bedrock/boulders
	Species Richness	46 (2010), 49 (2013)	69 (2010), 67 (2013)
	Species of Special Interest (P for present)		
	Haliotis spp		
	Lottia gigantea		P
	Phyllospadix spp		P
	Invasive species		
	Sargassum muticum		P
	Sargassum agardhianum	P	
	Caulacanthus ustulatus		

Unless otherwise noted all results are for phase II.

Species Richness Analysis

For sessile species, there was no effect on species richness that was associated with geographic grouping, site type, or interaction between site type and geographic group indicating no difference between ASBS discharge and reference sites (Table 3, Figures 2 and 3).

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

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
Site Type	17.41206	1	17.41206	0.418569	**0.525009**
Group	74.95139	1	74.95139	1.801756	0.19454
Site Type*Group	26.27589	1	26.27589	0.631646	0.436083
Error	831.9814	20	41.59907		

For mobile species, there was no effect on species richness that was associated with site type or interaction between site type and geographic group indicating no difference between ASBS discharge and reference sites (Table 4, 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 of mobile species.

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
Site Type	2.192441	1	2.192441	0.101331	**0.753539**
Group	236.5938	1	236.5938	10.93494	0.003521
Site Type*Group	0.368683	1	0.368683	0.01704	0.897446
Error	432.7302	20	21.63651		

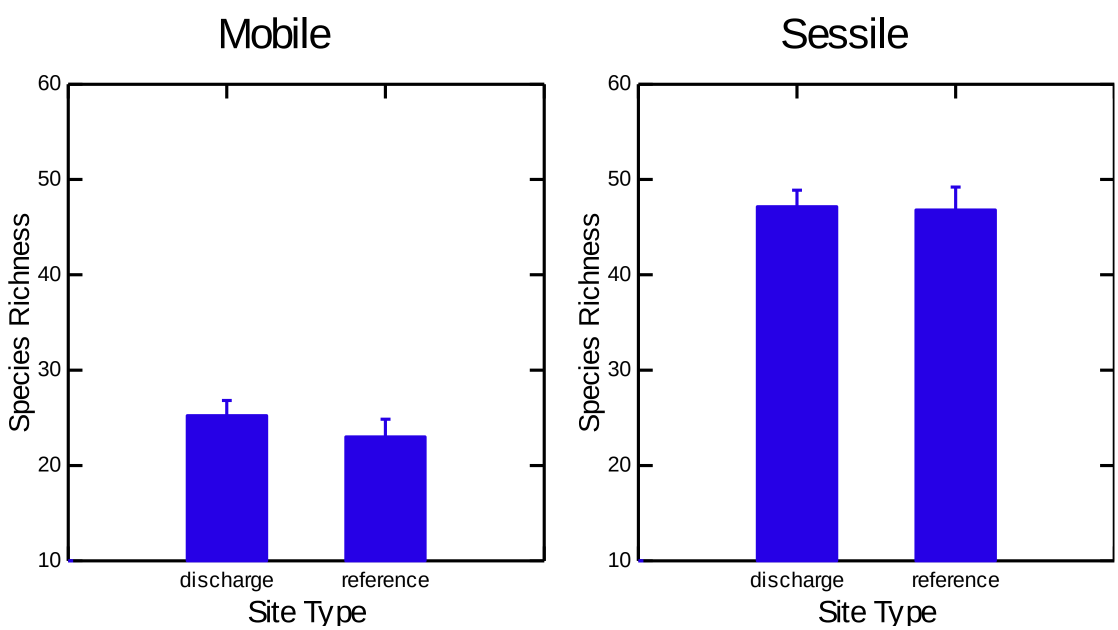

Figure 2. Species richness as a function of Site Type for Mobile and Sessile species. Error bars are one standard error.

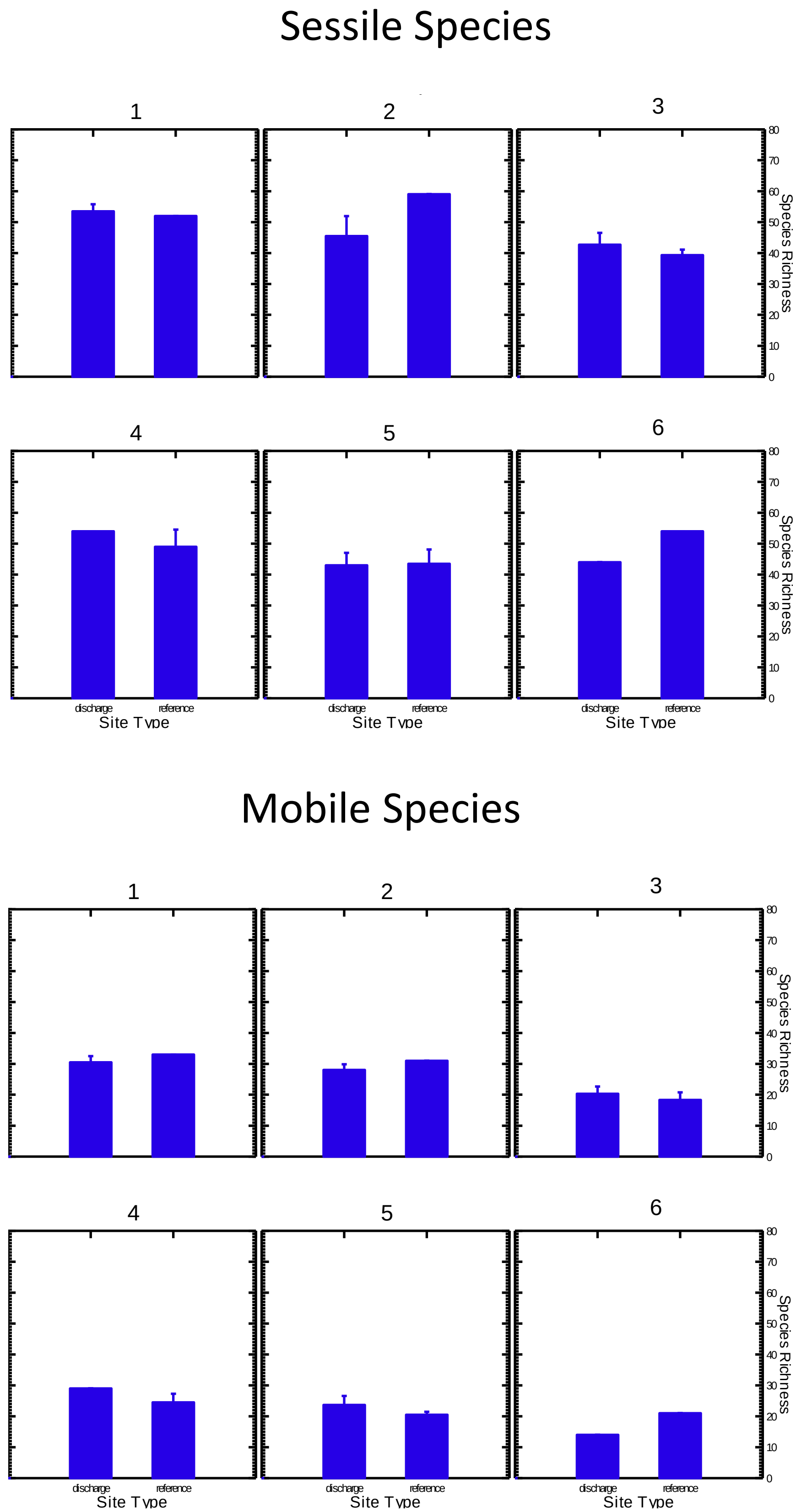

Figure 3. Species richness for Sessile (top panels) and Mobile (bottom panels) species as a function of geographic group (1-6) and Site Type. Error bars are one standard error.

Community Composition of Sessile Species

There was a large effect of geographic group, which reflects the biogeography of the bight. There was no significant effect of either site type or any evidence of an interaction between site type and group, 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.

Table 5. PERMANOVA table for effect of site type and geographic group on the community composition of sessile species.

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Group	5	16012	3202.3	2.5552	0.001	998
ASBS_site_type	1	1233.3	1233.3	0.98406	**0.467**	999
GroupxASBS_site_type	5	5634.9	1127	0.89925	0.614	998
Res	12	15039	1253.3			
Total	23	38882				

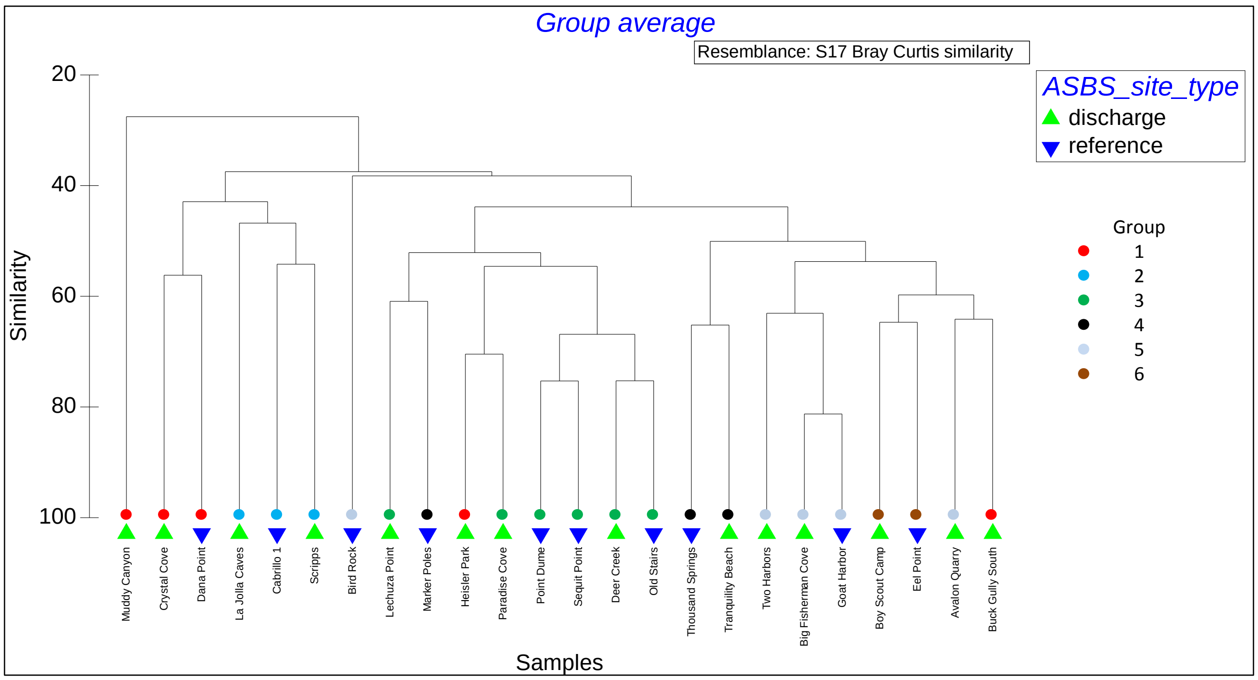

Figure 4. Cluster diagram for sessile species community composition. Site type and geographic group are indicated.

Community Composition of Mobile Species

There was a large effect of geographic group, which reflects the biogeography of the bight. There was no significant effect of either Site Type or any evidence of an interaction between Site Type and Group, 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.

Table 6. PERMANOVA results table for effect of site type and geographic group on the community composition of mobile species.

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Group	5	12017	2403.5	3.6435	0.001	999
ASBS_site_type	1	374.75	374.75	0.56809	0.772	998
GroupxASBS_site_type	5	2478.6	495.72	0.75148	0.816	997
Res	12	7915.9	659.66			
Total	23	22310				

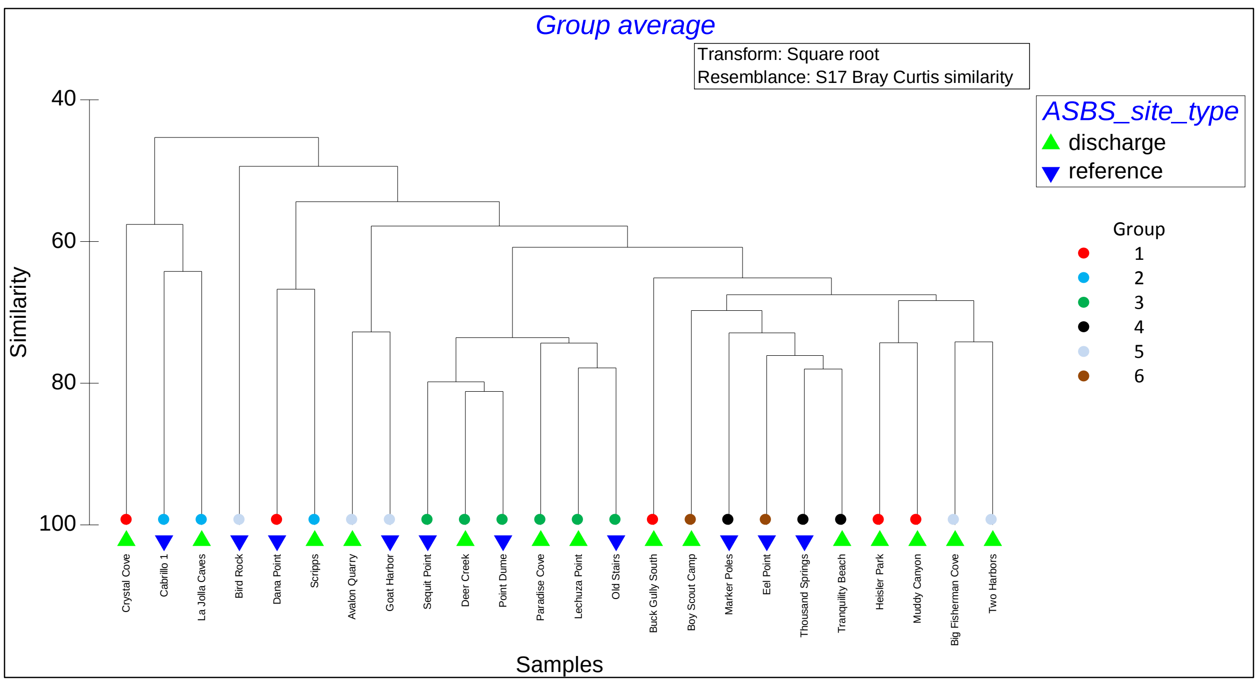

Figure 5. Cluster diagram for mobile species community composition. Site type and geographic group are indicated.

While the PERMANOVA and Cluster analysis results are useful in a statistical assessment of the effect of discharges on intertidal communities, they do not convey information about the communities. Figures and tables showing species abundances are in Appendices 1 and 2.

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 6). The results of phase I and phase II sampling are presented. Two prediction limits are shown: 80 and 95%. No sites that exceeded the 80 or 95% prediction limit in phase I exceed either of those limits in phase II. Note that some values for the first survey have changed from the first survey report as a result of some analytical changes in the second survey. Avalon Quarry exceeded the prediction limit in phase I, but using the new analytical approach it no longer does. By contrast, Sequit Point was below the prediction limit in phase I, but using the new analytical approach it is now above. However, the key result is that no site that exceeded the prediction limit in phase I exceeded it in phase II. That is, of the 21 sites that were surveyed twice, none exceeded the prediction limit in both phases. Temporal variation is likely to explain this pattern. As an example, Lechuza Point was considered to be a compromised site from the phase I study largely because of evidence of sand scour, but this dramatically improved in phase II and showed lower sand levels and very little current evidence of scour at the time of sampling.

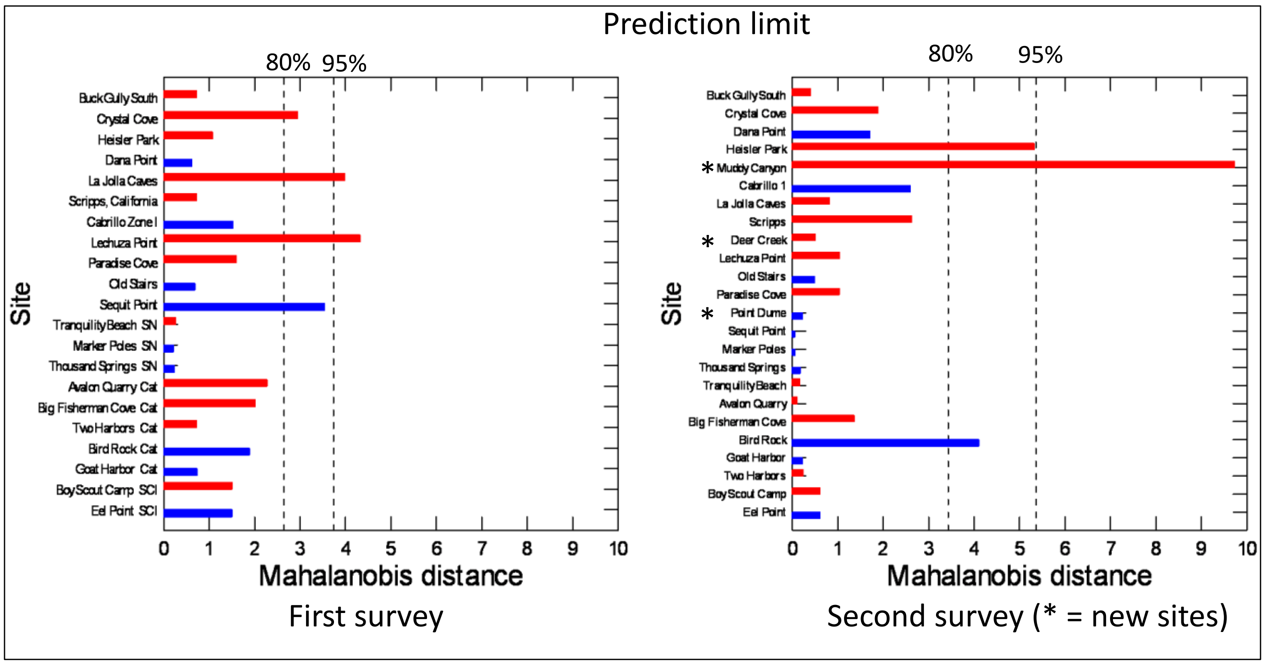

Figure 6. Mahalanobis distances for all sample sites. 80% and 95% prediction limits are shown.

One of the three new sites, Muddy Canyon, was very different from expected. There is no way to specifically attribute the differences at this site to the effects of the discharge, however, these results clearly indicate that the biological communities at this site are different from that expected based on the regional analysis. Further analysis and field assays may help clarify the cause of these differences. In the figures shown below (Figures 7 and 8), the source of the differences can be seen. In these figures, the biological communities at Muddy Canyon are compared to the "expected" biological community, represented by the average across all sites.

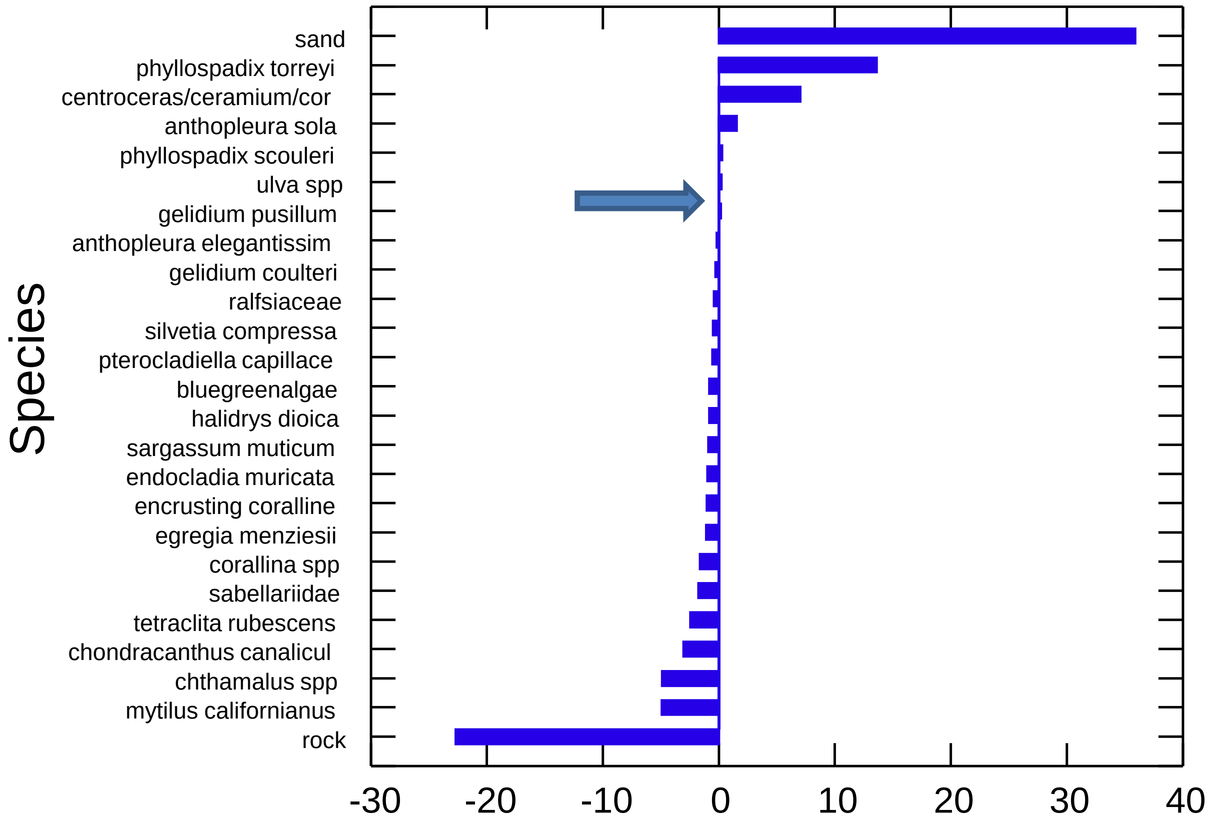

Figure 7. Differences in percent cover of sessile species between Muddy Canyon and expected values based on averages across all sites. Arrow indicates the transition between positive and negative differences.

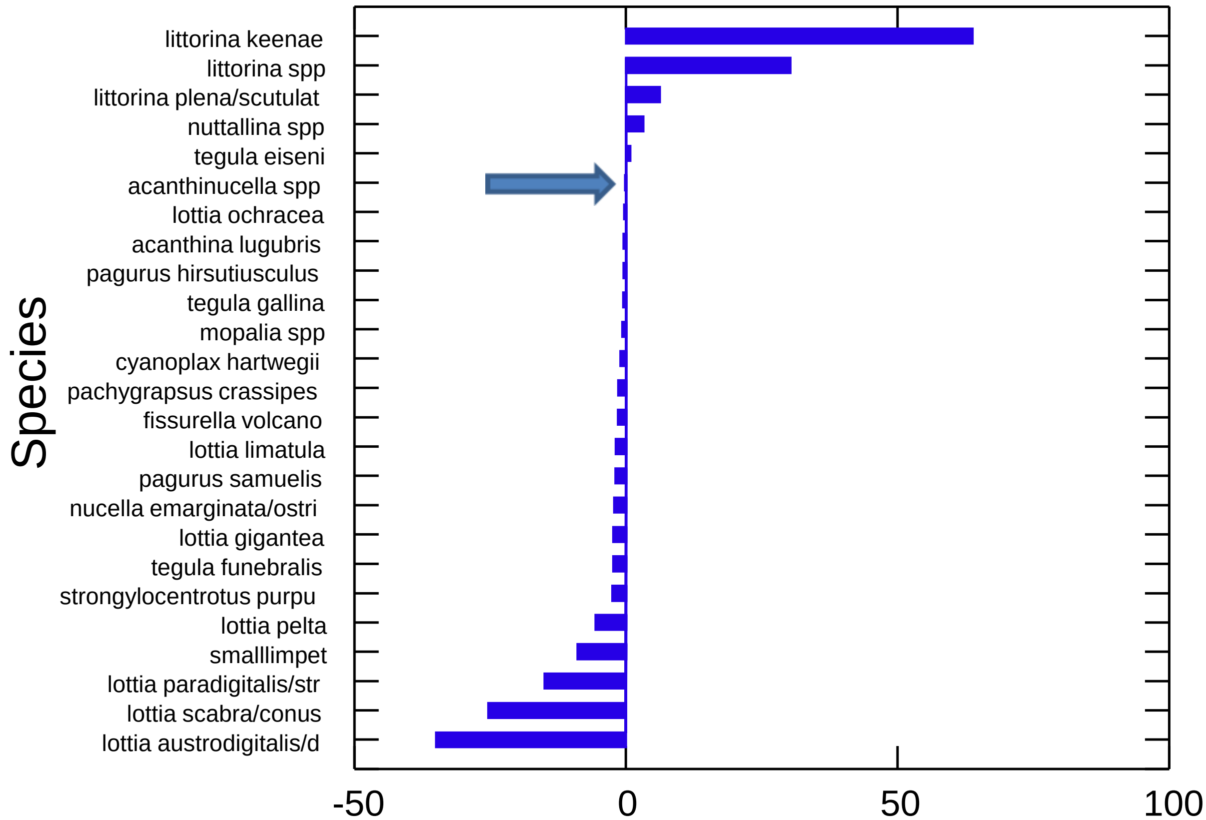

Figure 8. Differences in density per quad of mobile species between Muddy Canyon and expected values based on averages across all sites. Arrow indicates the transition between positive and negative differences.

Two general points for Muddy Canyon can be made based on these results:

1) For sessile and mobile species, more have below average than above average abundances.

2) The biological community is characteristic of a sand influenced site with intermittent emergent rock. Indeed, notes from the site support this result.

"Site is heavily sand influenced and was set up at a time when the sand was partially in."
"Much of the site beyond 4 m is a mix of low zone pools, sand, and rocky outcrops with mid-zone species assemblages."

Differences Potentially Due to Low Rainfall in 2013

There was clear difference in rainfall between the phase I and phase II surveys. Based on Los Angeles records, rainfall in phase I (2009–2010) was slightly greater than normal and in phase II (2013–2014) it has been much less than normal to date. This difference may have led to a difference in response to discharge between the two periods. Here the idea was that the relationship between reference sites should not vary because of rainfall but that the relationship between discharge and reference sites would if rainfall affected the communities. To examine this, we used an analysis of covariance approach to compare the relationship between discharge and reference sites in phase I and phase II for both sessile and mobile organisms. The covariate, pair type, in the model was binary: pairs of sites were either the same (both discharge or both reference) or mixed (one discharge and one reference). The independent variable was the similarity between a pair of sites in phase I. The dependent variable was the similarity between pairs of sites in phase II. The ANCOVA tested was whether the slopes of the relationship between phase I and phase I varied by pair type.

There was no evidence that rainfall affected the results for either sessile or mobile species ($P = 0.974$ for sessile species and $P = 0.586$ for mobile species). Given that the slopes did not differ for either species we test the direct relationship between phase I and phase II irrespective of pair type. For both sessile and mobile species, phase I results were highly predictive of phase II results ($P < 0.000001$ for both sessile and mobile species).

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. This was also true when accounting for biogeographic differences present in the southern California Bight. These results strongly support the idea that there is no common impact associated with discharges. In part, this is consistent with earlier work, which showed considerable spatial variability in the biological communities in this region. The site-specific figures (www.pacificrockyintertidal.org) also show the tremendous spatial variability among biological communities.

In phase 1, we concluded, "While there was no indication of a general and similar impact of discharges on biological communities there was an indication that specific locations might be affected by compromised water quality." In fact, one of the motivations for phase II sampling was to determine if those sites that showed biological communities potentially affected by discharge showed the same pattern in the later sampling period. Using an analytical approach designed to assess site-specific effects, we found that there was no evidence of "persistent" effects and that the likely explanation was natural (or at least not related to discharge) variability in biological communities. None of the four sites that exceeded the prediction limits in phase I exceed them in phase II. Consistent with the idea of temporal variation, we found that three sites in phase II exceeded the prediction limits and none of the three exceeded them in phase 1 (note that one, Muddy Canyon was not evaluated in phase I). These results point to the strength of the phased assessment, particularly with respect to the possibility of an uninformed conclusion of discharge related effects. No matter how carefully a survey is designed, there is no way to completely control for the contributions of extraneous factors. In such situations it is often useful to examine if patterns hold over time – as was done here.

In this study, we looked at whether the 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 question is whether and how the biological community is affected by discharge of water and associated components. Given a difference, 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 compared to reference areas. This was not the case for any site sampled twice.

2) Communities characterized by disturbance-associated species. This was not the case for any site sampled twice but was true for Muddy Canyon.

3) Of those communities characterized by disturbance-associated species, there should be no other obvious pattern of species. Muddy Canyon has considerable sand influence, which is a clear driver of disturbance-associated communities.

In addition to biological information collected from discharge and reference sites, water quality has been recently sampled as part of an ongoing program at The Southern California Coastal Water Research

Project (SCCWRP). Results of this sampling relevant to this study should be used to assess the potential for discharge related impacts at Muddy Canyon and Heisler Park. In addition, following the sampling protocol established in phase I, there should be an additional assessment for Muddy Canyon (and perhaps for Heisler Park) to determine if the departure from expected species composition found in phase II is chronic.

In summary, this project (phases I and II) provided the first condition report for the rocky intertidal zone in Southern 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, www.pacificrockyintertidal.org) allows the results of earlier sampling to be incorporated in the study (because the monitoring uses identical methodologies) and gives context for the ASBS sampling. When combined with the new two-phase approach, it yields a powerful tool for impact assessment.

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APPENDIX A: ADDITIONAL FIGURES

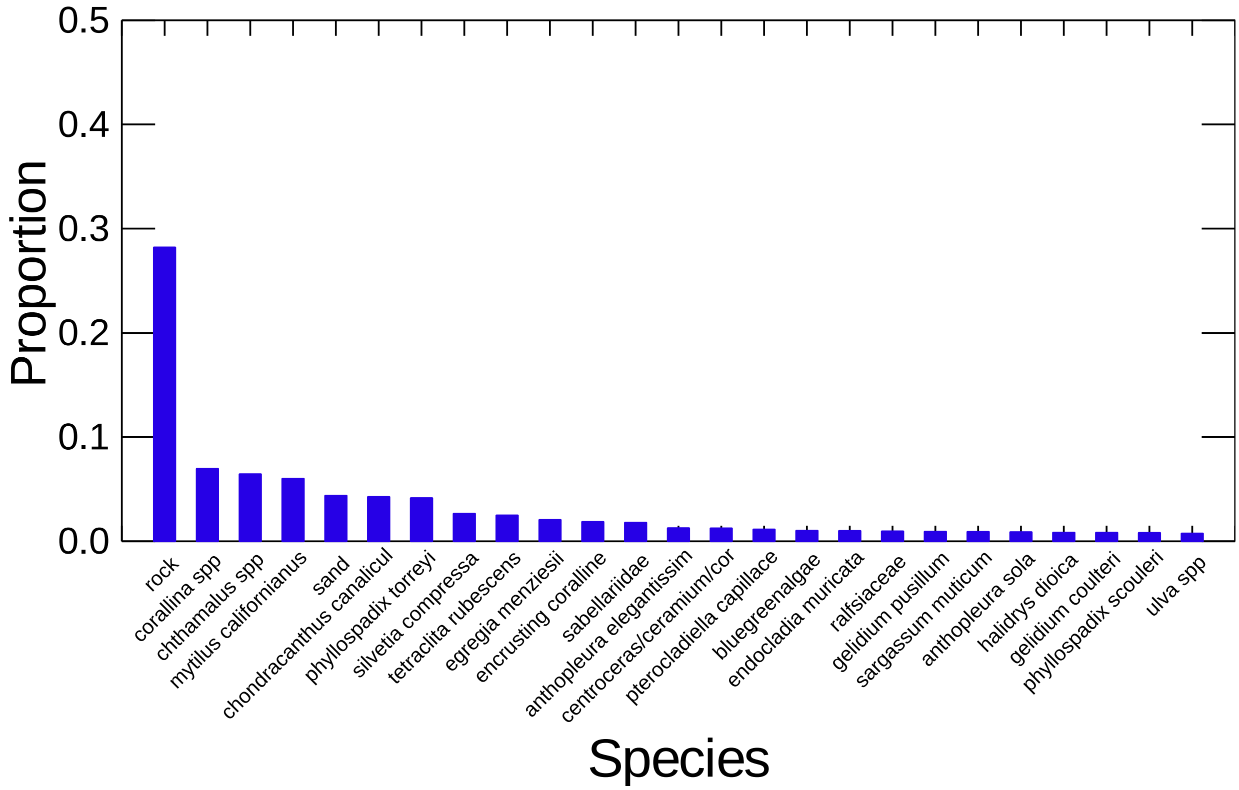


Figure A-1. Proportion of most common sessile species at all sites.

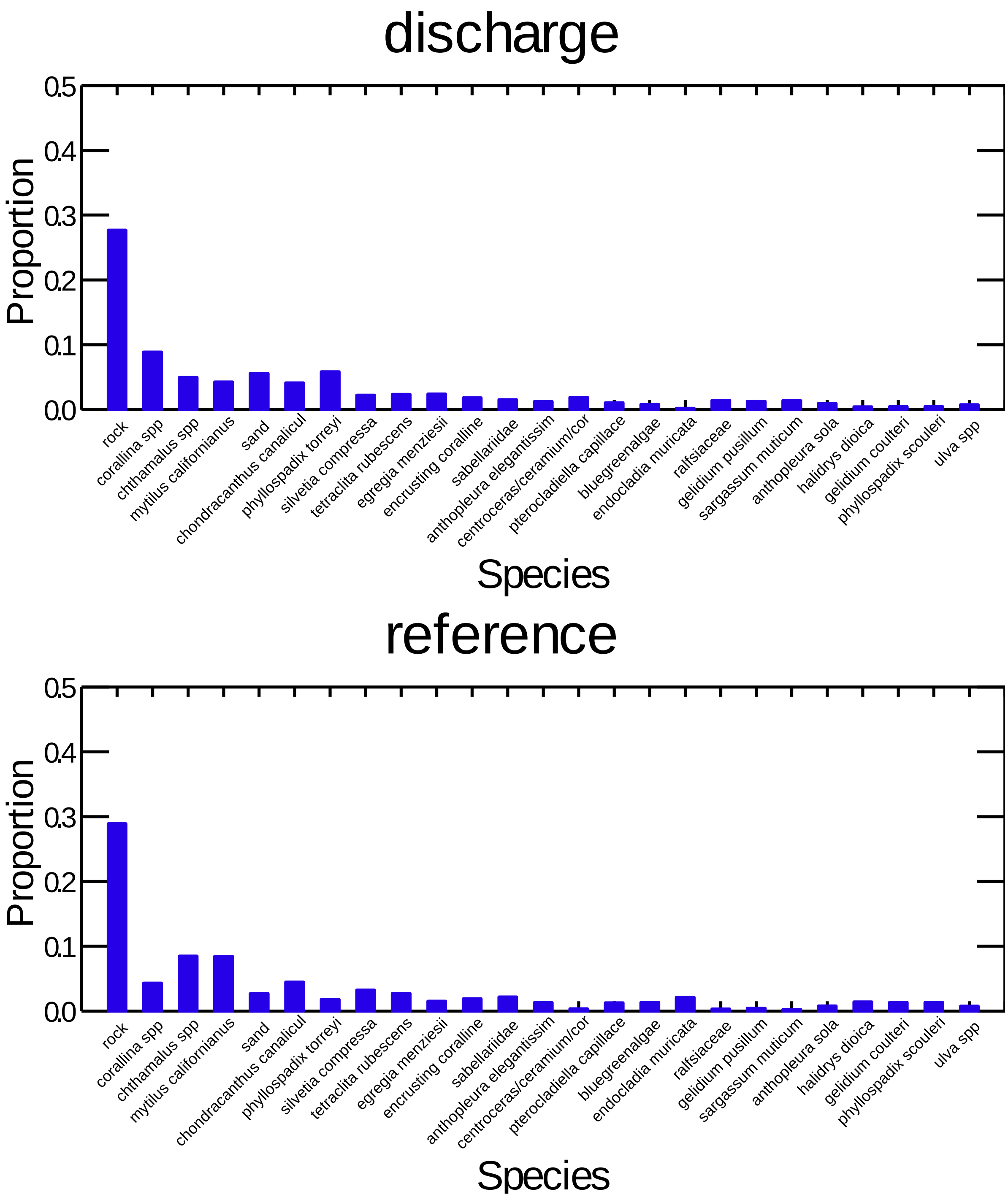


Figure A-2. Proportion of most common sessile species at discharge versus reference sites.

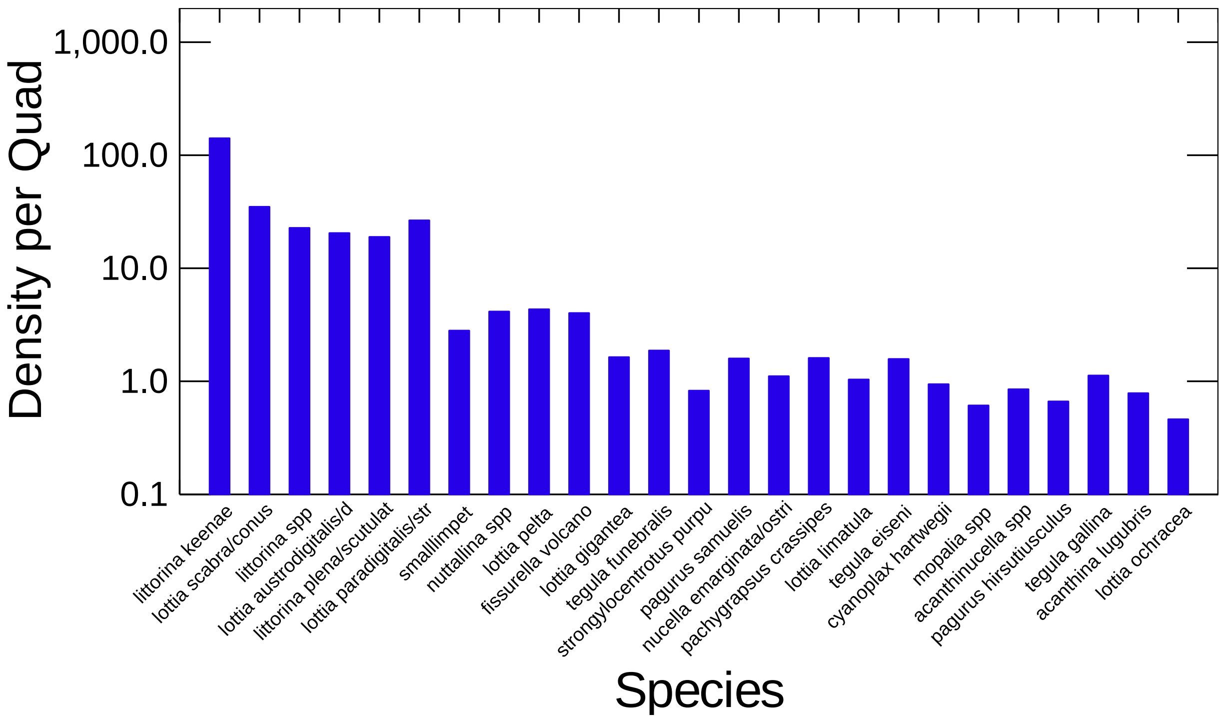
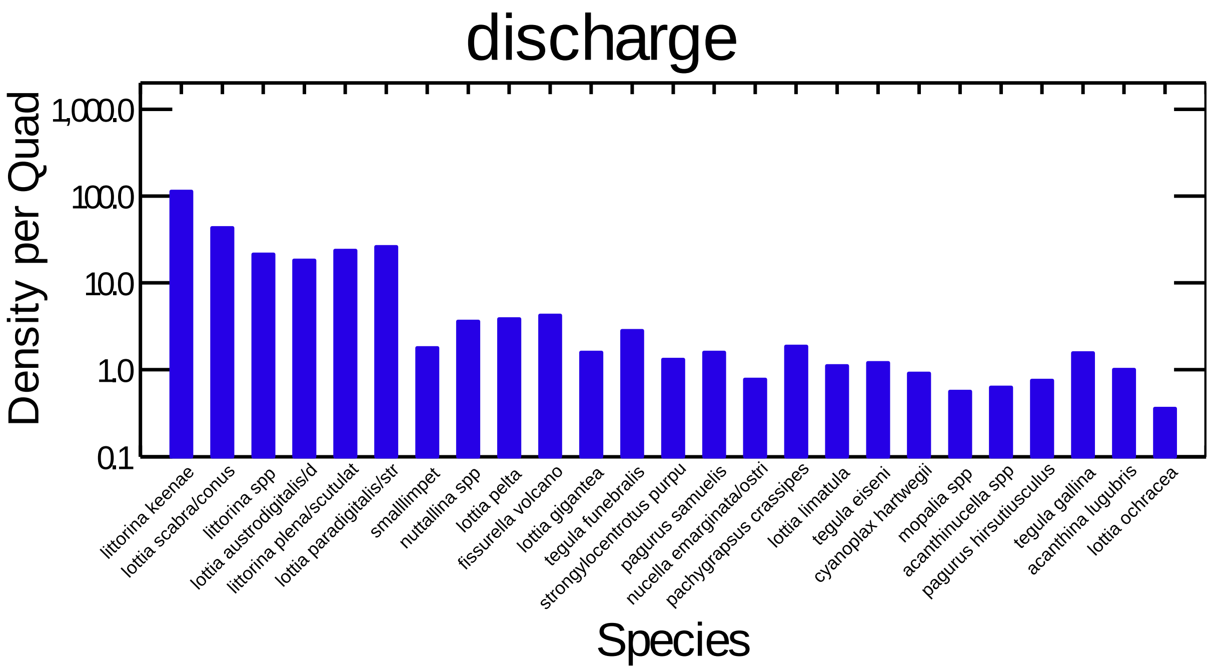


Figure A-3. Density of most common mobile species at all sites.



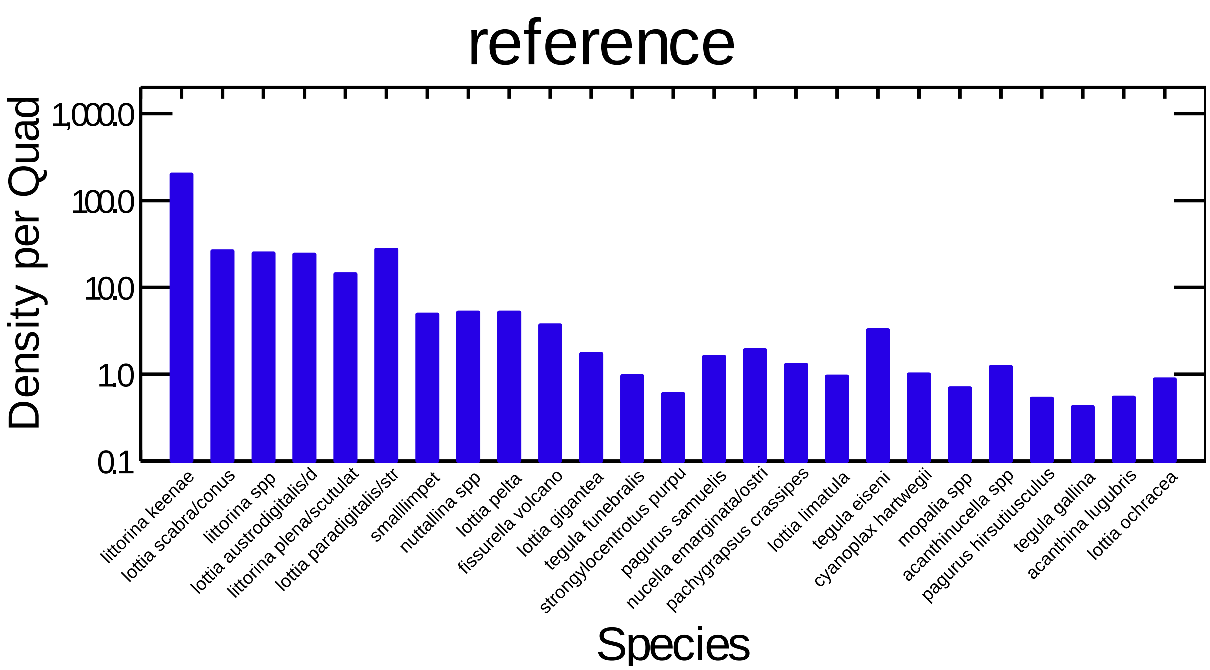


Figure A-4. Density of most common mobile species at all sites.

APPENDIX B: SITE LOCATIONS, DESCRIPTIONS, PICTURES AND SITE-SPECIFIC COVER AND DENSITY OF SPECIES

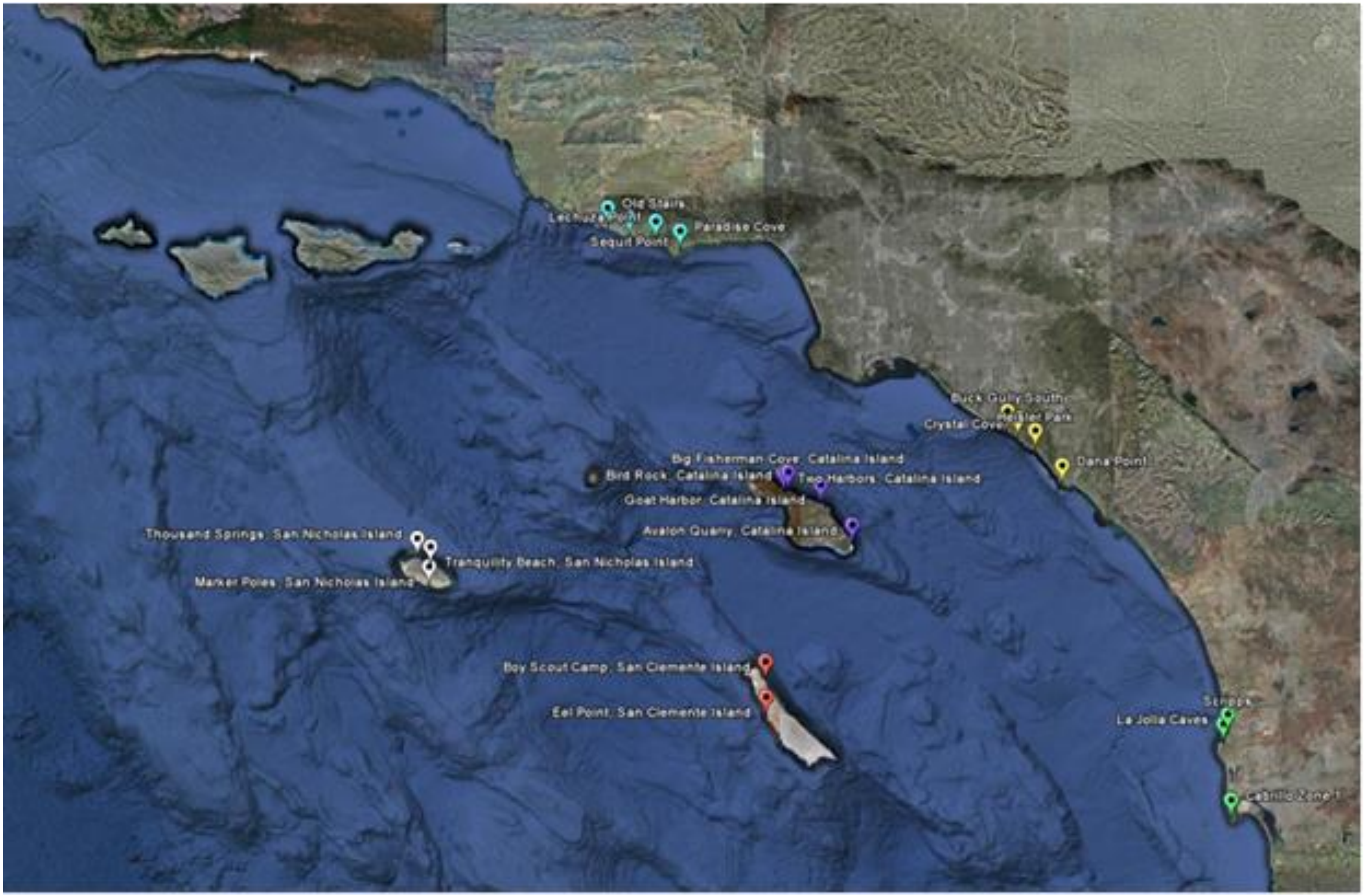
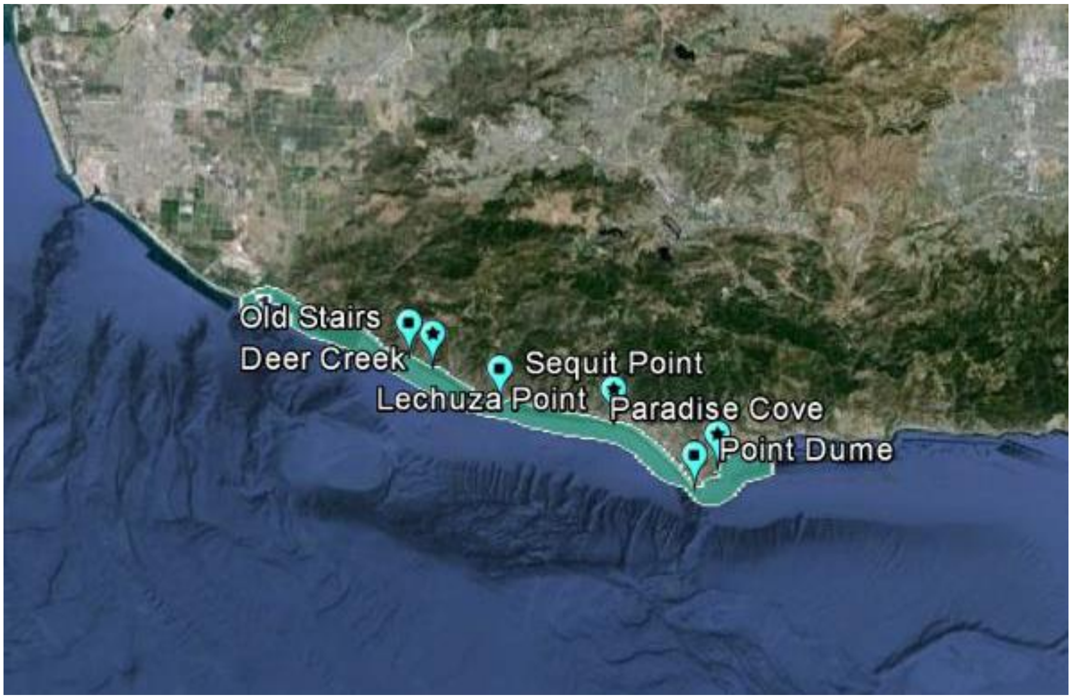


Figure B-1. Locations of ASBS and reference sites.



■ Reference Site
★ Discharge site in ASBS

Figure B-2. Coastal segment from Mugu Lagoon to Latigo Point.

Figure B-3. Old Stairs is comprised of bedrock, boulders and sand with moderate relief. The surrounding coast is made up of boulders and sand. The survey area is divided into two sections.

Figure B-4. The upcoast section of Old Stairs is 6 meters wide and 20meters long. The downcoast section is 21 meters wide and 20 meters long.

Figure B-5. Deer Creek is comprised of bedrock and sand with moderate relief. The surrounding coast is made up of bedrock, boulders and sand. The survey area is 20 meters wide and 5 meters long.

Figure B-6. The nearest outfall (MUG022) to Deer Creek is approximately 126 meters upcoast of the survey bolt OT1.

Figure B-7. Sequit Point is comprised of bedrock with moderate relief. The surrounding coast is made up of bedrock, boulders and sand. The survey area is 20 meters wide and 25 meters long.

Figure B-8. Lechuza Point is comprised of bedrock and sand with moderate relief. The surrounding coast is made up of bedrock and sand. The survey area is divided into two sections. The upcoast section is 14 meters wide and 45 meters long. The biological community at this site differs from that expected based on other sites in the region. It is likely that this is due to the influence of sand burial and scour at the site.

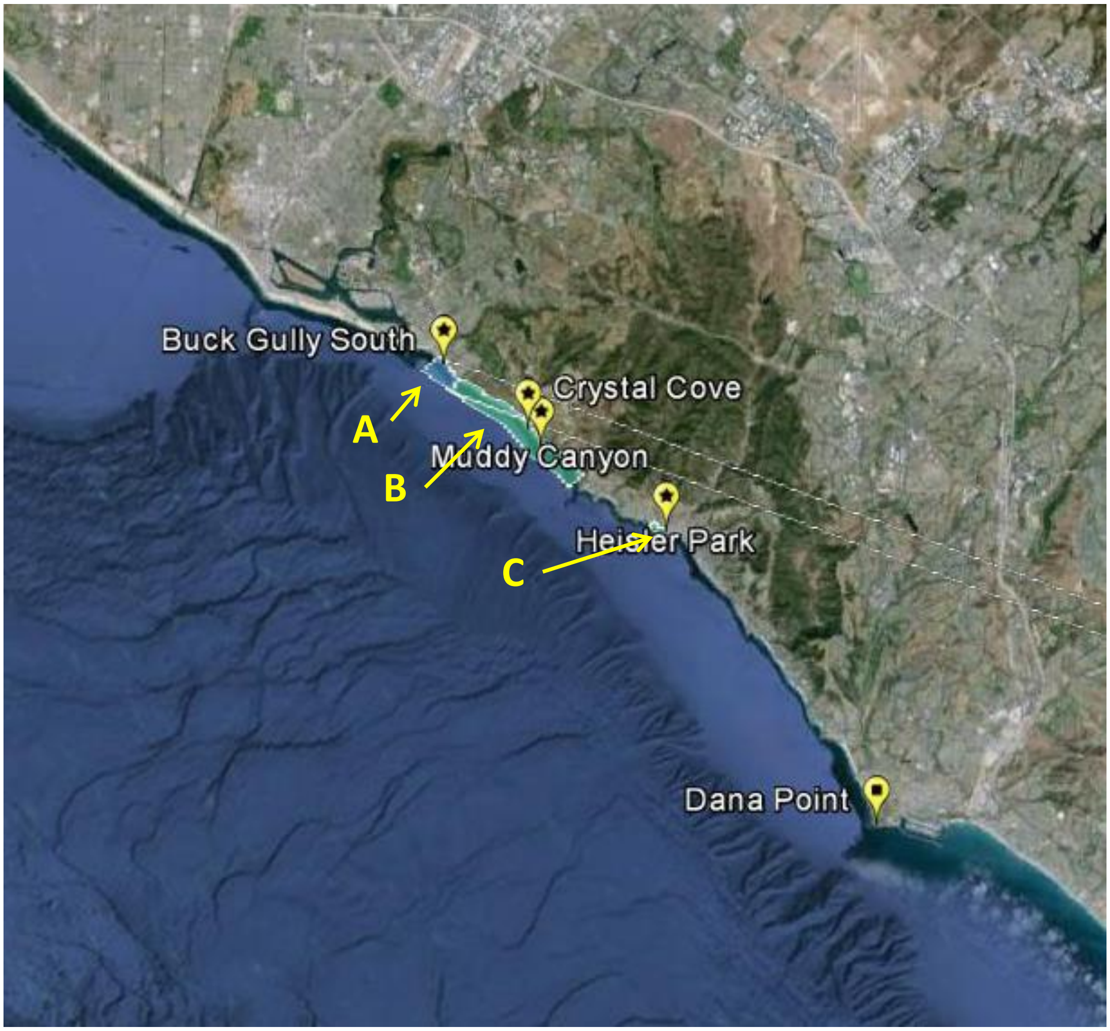
Figure B-9. The downcoast section of Lechuza Point is 4 meters wide and 30 meters long.

Figure B-10. The nearest storm water discharge pipe to Lechuza Point is 25 meters from survey bolt OT1.

Figure B-11. Point Dume is comprised of bedrock, boulders, and sand with moderate relief. The surrounding coast is made up of bedrock, boulders and sand. The survey area is 20 meters wide and 10 meters long. This site is very exposed and the sand levels can vary greatly. Point Dume is a reference site (no outfall).

Figure B-12. Paradise Cove is comprised of bedrock and sand with low relief. The surrounding coast is made up of sand. The survey area is divided into two sections. The upcoast section is 12 meters wide and 10 meters long. The downcoast section is 15 meters wide and 10 meters long.

Figure B-13. The nearest discharge (MUG379) to Paradise Cove is approximately 20 meters from survey bolt R2.



■ Reference Site

★ Discharge site in ASBS

Figure B-14. Location of Newport Beach marine life refuge (A), Irvine Coast marine life refuge (B), and Heisler Park ecological reserve (C).

Figure B-15. Buck Gully South is comprised of bedrock and boulders with moderate relief. The surrounding coast is made up of bedrock, boulders and sand. The survey area is 30 meters wide and 35 meters long.

Figure B-16. The nearest storm water discharge pipe (NEW016) to Buck Gully South is 5 meters from survey bolt OT2.

Figure B-17. Crystal Cove is comprised of bedrock with low relief. The surrounding coast is made up of bedrock, boulders and sand. The survey area is 30 meters wide and 35 meters long. There is some sand influence at this site. The biological community, and in particular mobile species, differed considerably from that expected based on other sites in the region.

Figure B-18. Muddy Canyon is comprised of bedrock, boulders, cobble, and sand with moderate relief. The surrounding coast is made up of bedrock, boulders, cobble, and sand. The survey area is 20 meters wide and ~45 meters long. This site is heavily sand influenced.

Figure B-19. The nearest outfall (IRV009) to Muddy Canyon is approximately 207 meters downcoast of the survey bolt OT2.

Figure B-20. Heisler Park is comprised of bedrock and sand with moderate relief. The surrounding coast is made up of bedrock, boulders and sand. The survey area is 20 meters wide and 35 meters long.

Figure B-21. The nearest storm water discharge pipe (HSL013) to Heisler Park is 52 meters from survey bolt OT1.

Figure B-22. Dana Point is comprised of bedrock and boulders with moderate relief. The surrounding coast is made up of bedrock, boulders and sand. The survey area is 30 meters wide and 29 meters long.

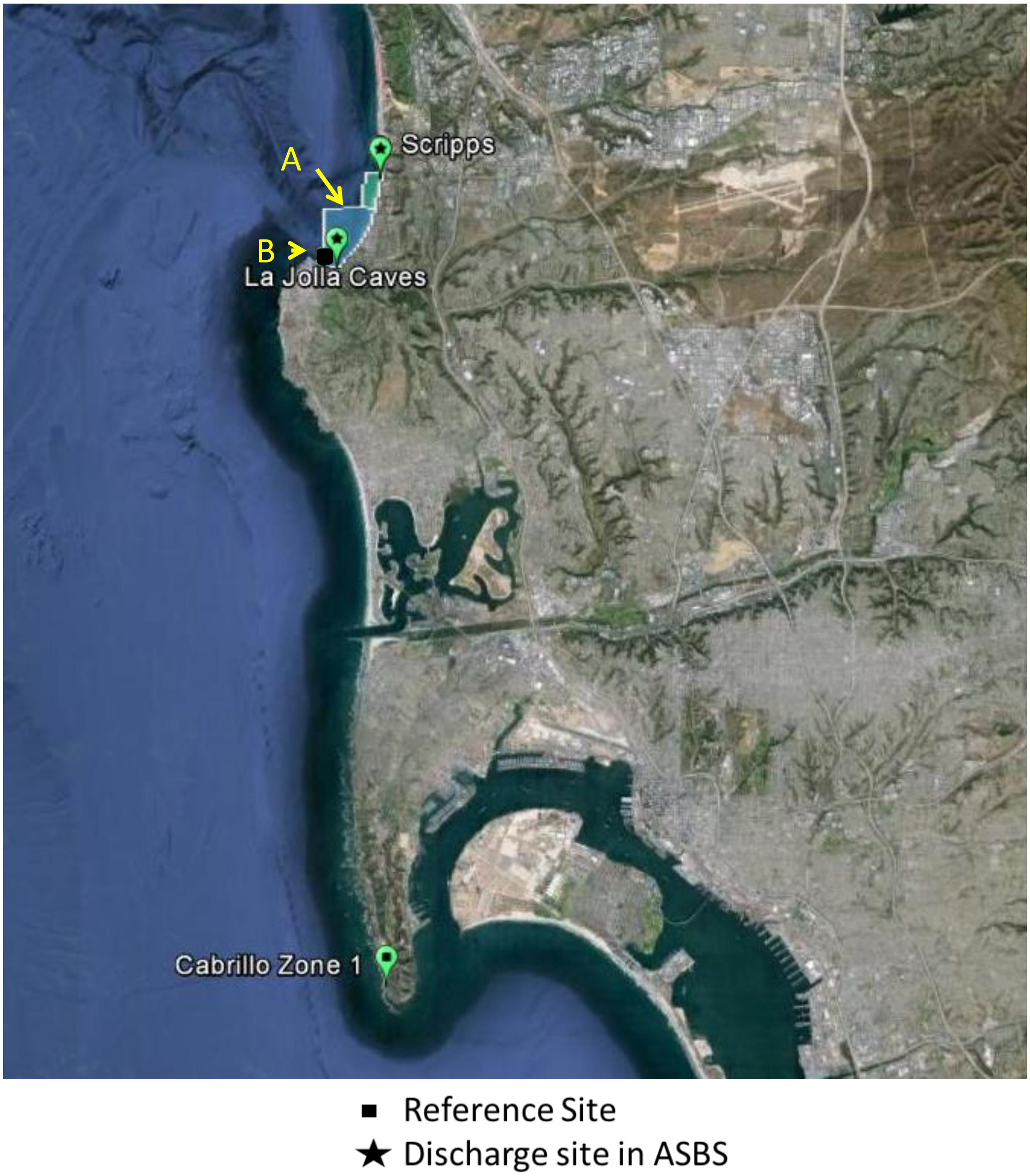


Figure B-23. Location of San Diego marine life reserve (A) and San Diego-La Jolla ecological reserve (B).

Figure B-24. Scripps is comprised of bedrock, boulders and sand with moderate relief. The surrounding coast is made up of boulders and sand. The survey area is 29.6 meters wide and 45 meters long.

Figure B-25. La Jolla Caves is comprised of bedrock, boulders and sand with low relief. The surrounding coast is made up of boulders, cobble and sand. The survey area is 30 meters wide and 50 meters long. This site differed greatly from expected based on other sites in the region.

Figure B-26. The nearest storm water discharge pipe (SDL186) to La Jolla Caves is approximately 50 meters from survey bolt OT1.

Figure B-27. Cabrillo Zone I is comprised of bedrock and boulders with moderate relief. The surrounding coast is made up of bedrock, boulders and sand. The survey area is 30 meters wide and 40 meters long.

■ Reference Site

★ Discharge site in ASBS

Figure B-28. San Nicolas Island locations.

Figure B-29. Thousand Springs is comprised of bedrock and boulders with moderate relief. The surrounding coast is made up of bedrock, boulders and sand. The survey area is 20 meters wide and 10 meters long.

Figure B-30. Tranquility Beach is comprised of bedrock with moderate relief. The surrounding coast is made up of bedrock, boulders and sand. The survey area is 20 meters wide and 40 meters long.

Figure B-31. The nearest storm water discharge to Tranquility Beach is approximately 100 meters from survey bolt OT1.

Figure B-32. Marker Poles is comprised of bedrock with moderate relief. The surrounding coast is made up of bedrock and sand. The survey area is 30 meters wide and 40 meters long.

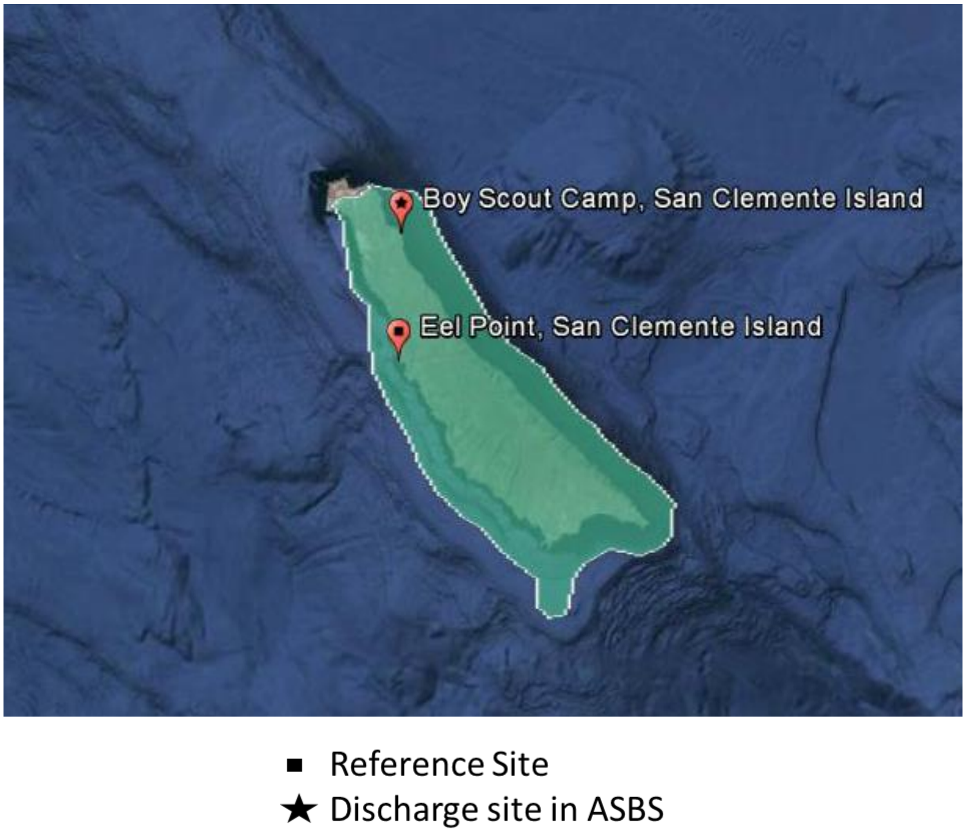


Figure B-33. San Clemente Island locations.

Figure B-34. Eel Point is comprised of bedrock with moderate relief. The surrounding coast is made up of bedrock and boulders. The survey area is 20 meters wide and 25 meters long.

Figure B-35. Boy Scout Camp is comprised of bedrock and boulders with moderate relief. The surrounding coast is made up of bedrock and boulders. The survey area is 30 meters wide and 15 meters long.

■ Reference Site
★ Discharge site in ASBS

Figure B-36. Santa Catalina Island locations.

Figure B-37. Bird Rock is comprised of bedrock with moderate relief. The surrounding coast is made up of bedrock and boulders. The survey area is 30 meters wide and 13 meters long.

Figure B-38. Big Fisherman Cove is comprised of bedrock with moderate relief. The surrounding coast is made up of bedrock and boulders. The survey area is divided into two sections. The upcoast section is 8 meters wide and 11 meters long.

Figure B-39. The downcoast section of Big Fisherman Cove is 10 meters wide and 12 meters long. The nearest storm water discharge is approximately 100 meters from survey bolt OT6.

Figure B-40. Two Harbors is comprised of bedrock and boulders with moderate relief. The surrounding coast is made up of bedrock, boulders and sand. The survey area is 20 meters wide and 10 meters long.

Figure B-41. The nearest storm water discharge pipe to Two Harbors is approximately 150 meters from survey bolt OT1.

Figure B-42. Goat Harbor is comprised of bedrock and boulders with moderate relief. The surrounding coast is made up of bedrock, boulders and cobble. The survey area is 20 meters wide and 10 meters long.

Figure B-43. Avalon Quarry is comprised of boulders with moderate relief. The surrounding coast is made up of boulders. The survey area is 20 meters wide and 10 meters long. Based on the substrate and level of potential impact, this site was expected to differ from other sites. Our analyses confirmed this expectation.

Figure B-44. The nearest storm water discharge to Avalon Quarry is approximately 25 meters from survey bolt OT1.