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

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Technical Report 703 - May 2012

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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 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, 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 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*, 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 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.

METHODS

Comprehensive sampling of ecological communities on rocky intertidal habitats was done using protocols developed by the coastal biodiversity surveys (http://cbsurveys.ucsc.edu/). 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 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, 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. 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 10 cm for a 10 m 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 must fall 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, 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, transect line on which it was found.

***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 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.

For questions 1-3 two forcing (independent) variables were used in the statistical approaches. First – whether the sites 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 (Figure 1). 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 that sample is similar to a hypothetical typical sample, while large distances indicate samples 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.

RESULTS

Sites Sampled and Site Attributes

Sampling locations are shown in Figure 1. Descriptions of site metadata and site characteristics are in Tables 1 and 2 respectively.

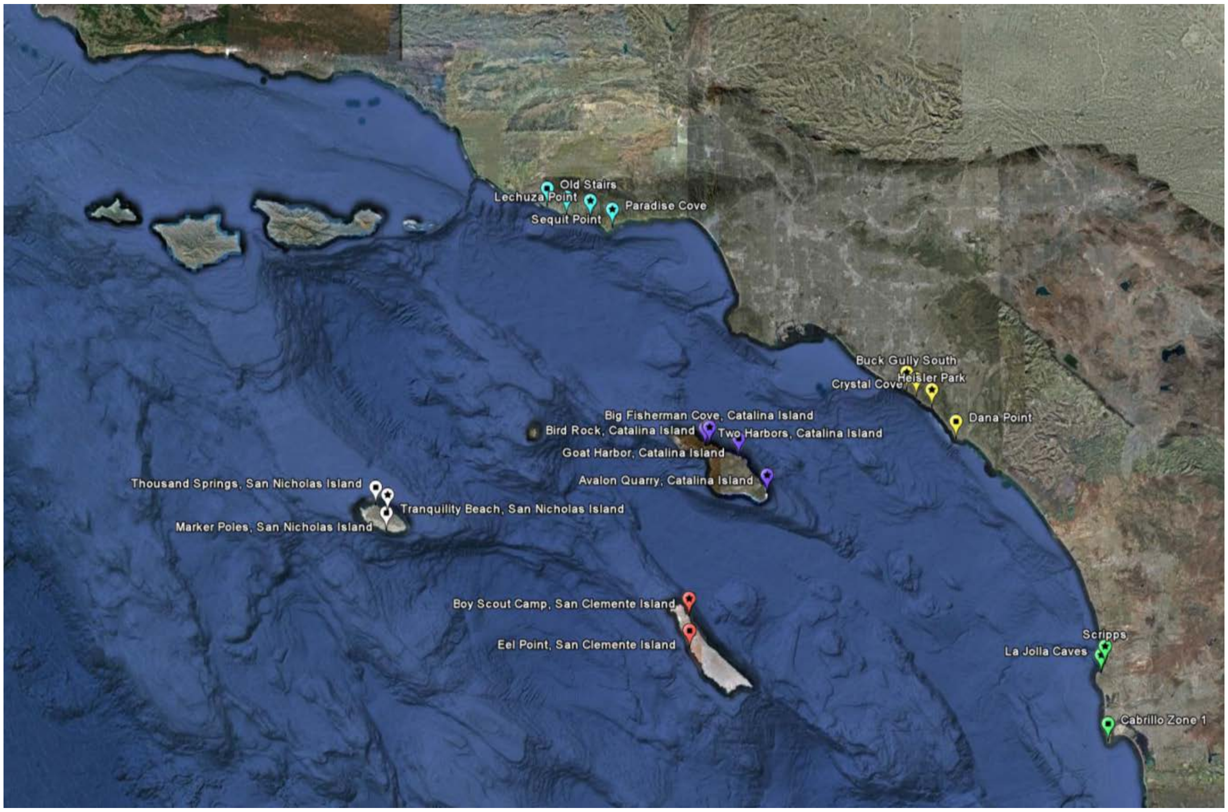

Figure 1: Map of sampling locations. Colors indicate geographic groups. Within each pointer the symbol represents site type: Star = Discharge site in ASBS, Square = reference site.

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
    j. **Species Richness:** a count of the total number of species found at a given site, using existing protocols.

Table 1: Metadata for site attributes.

Group	Attributes of Site	Buck Gully South	Crystal Cove	Heisler Park	Dana Point
1	Primary Bench Type	bedrock/boulders	bedrock	bedrock/sand	bedrock/boulders
	Slope	0-5 degrees	0-5 degrees	0-5 degrees	0-5 degrees
	Relief	moderate	low	moderate	moderate
	Extent	long	long	long	long
	Surrounding coast	bedrock/boulders/sand	bedrock/boulders/sand	bedrock/boulders/sand	bedrock/boulders/sand
	Species Richness	70	81 (2001); 74 (2003); 75 (2004)	71	71 (2001); 72 (2006); 73 (2010)
	Species of Special Interest (P for present)				
	Haliotis spp				
	Lottia gigantea	P	P	P	P
	Phyllospadix spp		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)	59	69 (2002); 84 (2004); 76 (2009)
	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
3	Primary Bench Type	bedrock/boulders/sand	bedrock	bedrock/sand	bedrock/sand
	Slope	5-15 degrees	0-5 degrees	5-15 degrees	5-15 degrees
	Relief	moderate	moderate	moderate	low
	Extent	long	long	long	intermediate
	Surrounding coast	boulders/sand	bedrock/boulders/sand	bedrock/sand	sand
	Species Richness	49 (2001); 44 (2008)	50	54	70 (2001); 61 (2006); 61 (2010)
	Species of Special Interest (P for present)				
	Haliotis spp				
	Lottia gigantea	P	P	P	P
	Phyllospadix spp			P	P
	Invasive species				
	Sargassum muticum				
	Sargassum agardhianum				
	Caulacanthus ustulatus				P

Table 2: 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)	70	75 (2003); 69 (2007)
	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)	68	75	50	53
	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	69
	Species of Special Interest (P for present)		
	Haliotis spp		
	Lottia gigantea		P
	Phyllospadix spp		P

Species Richness Analysis

There was no effect on species richness that was associated with geographic grouping, Site Type or interaction between Site Type and Geographic Group (see Table 2) indicating no difference between ASBS discharge and reference sites (Figure 2 and Table 3).

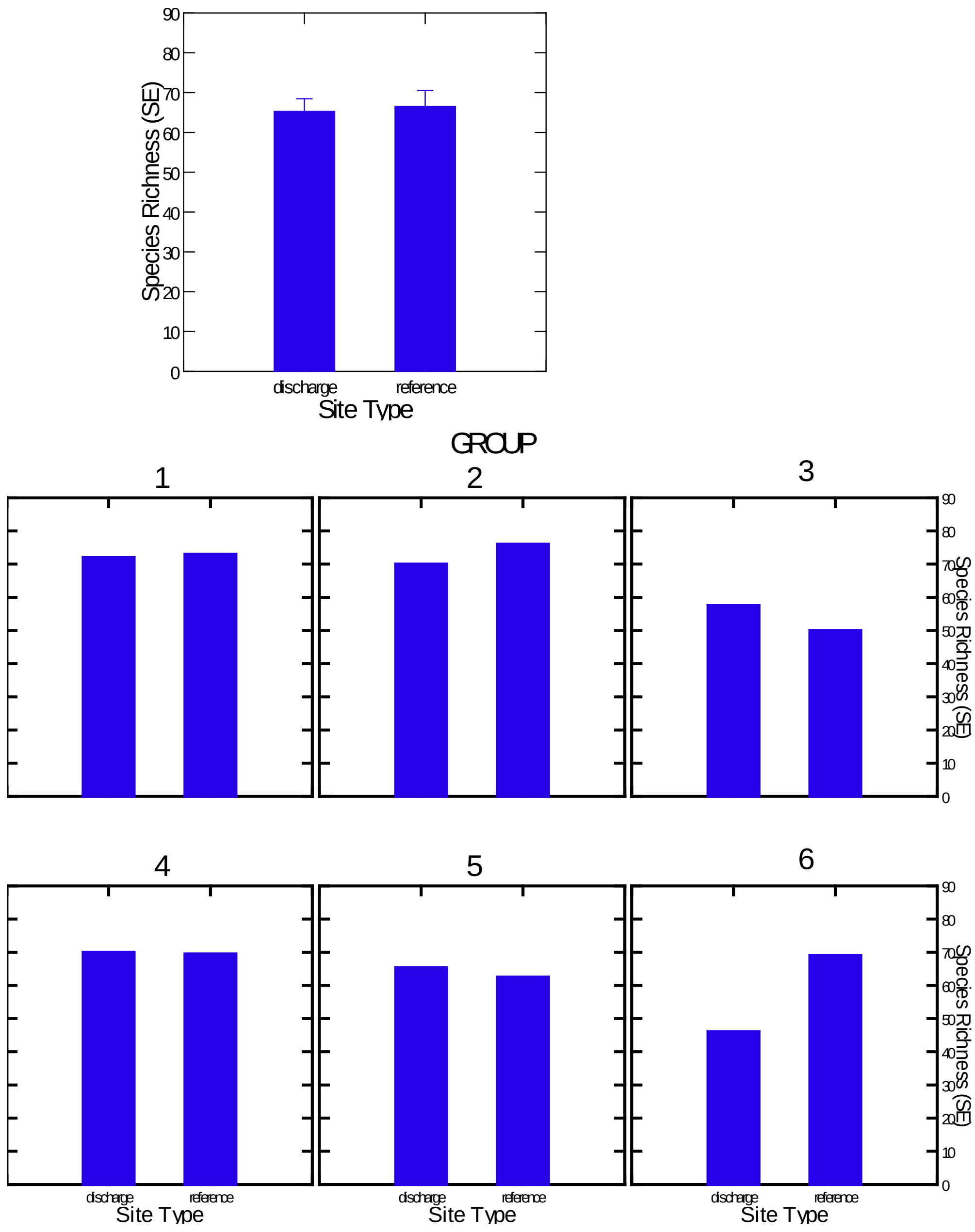

Figure 2: Top – Species richness as a function of site type. Bottom – Species richness as a function of geographic group and site type.

Table 3: ANOVA results for species richness.

Analysis of Variance - Species Richness					
Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
Site Type	42.387821	1	42.387821	0.400752	0.544369
Group	852.98689	5	170.597378	1.612896	0.260699
Group * Site Type	323.85331	5	64.770662	0.612368	0.694525
Error	846.16667	8	105.770833		

Community Composition of Sessile Species

There was a large effect of geography (Gr=Group), which reflects the biogeography of the bight. There was no significant effect of either Site Type (Si) or any evidence of an interaction between Site Type and Group, indicating no difference between ASBS discharge and reference sites (Table 4, Figure 3). The results are shown below in the PERMANOVA table and MDS plot. (Groups are shown as numbers).

Table 4: 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)
Si	1	1172.7	1172.7	1.0723	0.401
Gr	5	15015	3002.9	2.7457	0.001
SixGr	5	5813.1	1162.6	1.063	0.38
Res	9	9843.3	1093.7		
Total	20	33160			

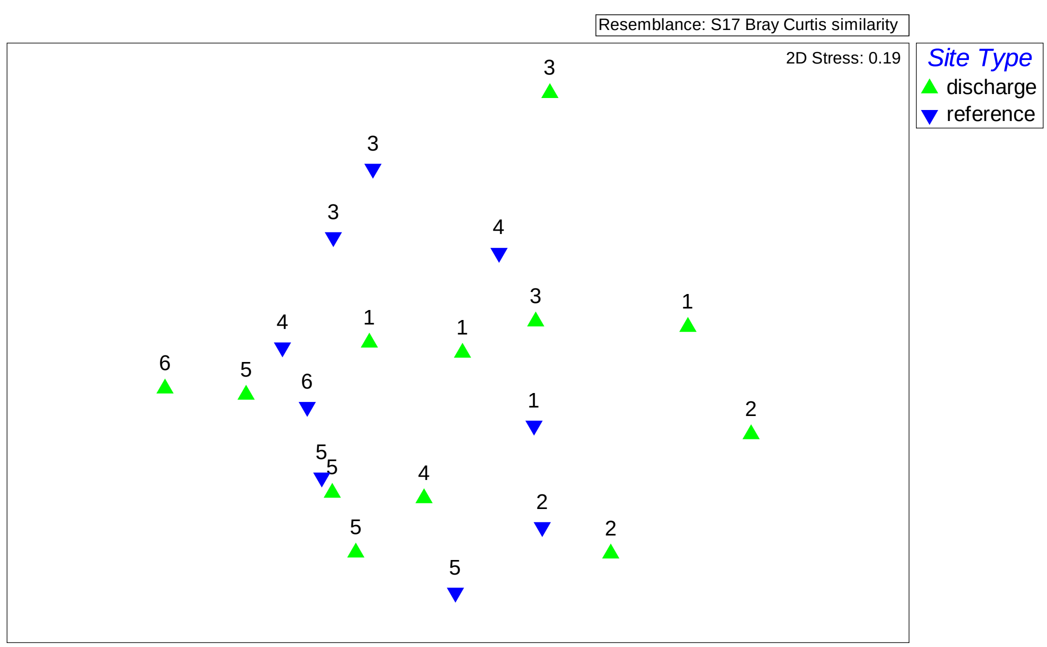

Figure 3: Multidimensional Scaling (MDS) figure for sessile species community composition. Numbers indicate geographic group.

Community Composition of Mobile Species

There was a large effect of geography (Gr=Group), which reflects the biogeography of the bight. There was no significant effect of either Site Type (Si) or any evidence of an interaction between Site Type and Group, indicating no difference between ASBS discharge and reference sites (Table 5, Figure 4).

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

Source	df	SS	MS	Pseudo-F	P(perm)
Si	1	1355.8	1355.8	1.1773	0.293
Gr	5	10369	2073.8	1.8007	0.006
SixGr	5	5573.7	1114.7	0.96794	0.537
Res	9	10365	1151.7		
Total	20	28240			

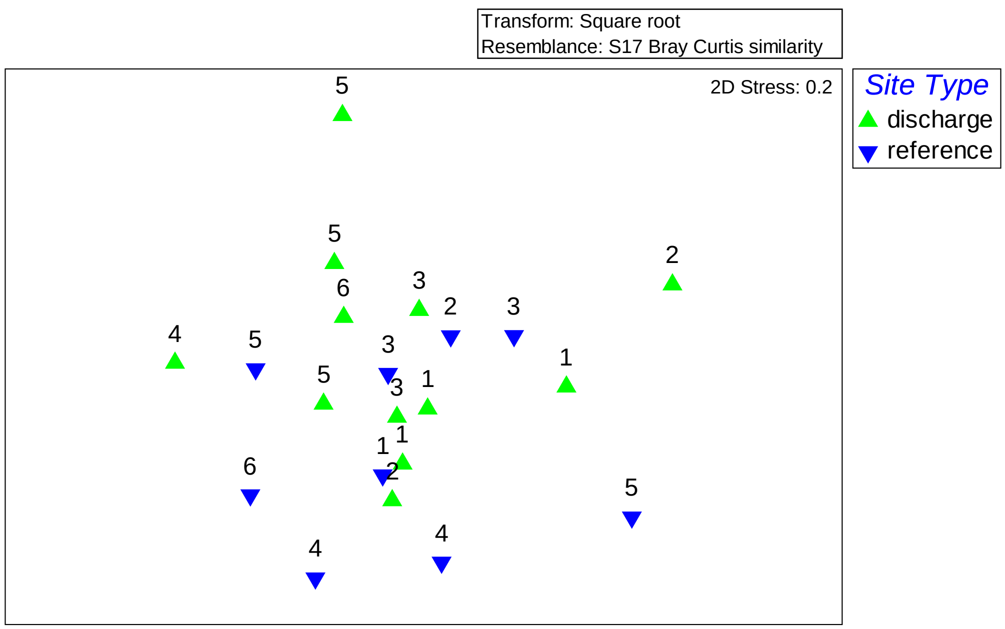

Figure 4: Multidimensional Scaling (MDS) figure for mobile species community composition. Numbers indicate geographic group.

While the PERMANOVA and MDS results are useful in a statistical assessment of the effect of discharges on intertidal communities, they don't convey information about the communities. Figures and tables showing species abundances are in APPENDIX 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 5). Two prediction limits are shown: 80 and 95%. Two sites, La Jolla Caves and Lechuza Point exceed the 95% prediction limit. An additional two sites, Avalon Quarry and Crystal Cove, exceed the 80% prediction limit. All four sites are discharge sites (ASBS).

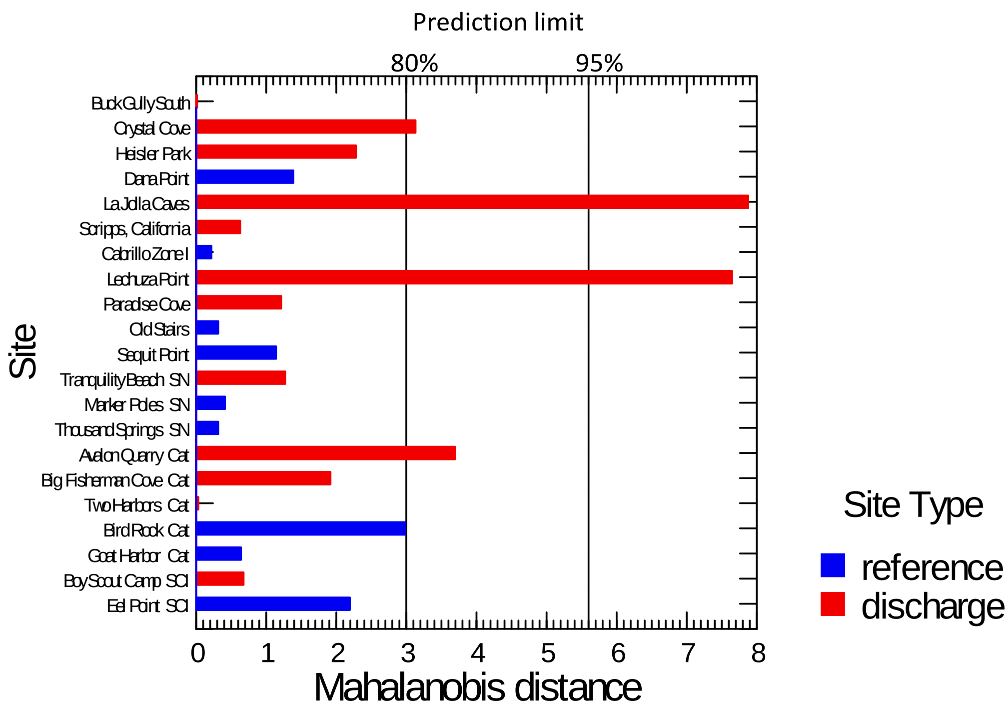

Figure 5: Mahalanobis distances for all sample sites. 80% and 95% prediction limits are also shown.

There is no way to specifically attribute the differences at these four sites to the effects of the discharge, however these results clearly indicate that the biological communities at these sites 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 6 through 9 and in Appendix 1) the source of the differences can be seen. In these figures the biological communities at the four sites that exceeded the 80% prediction limit are compared to the 'expected' biological community, represented by the average across all sites.

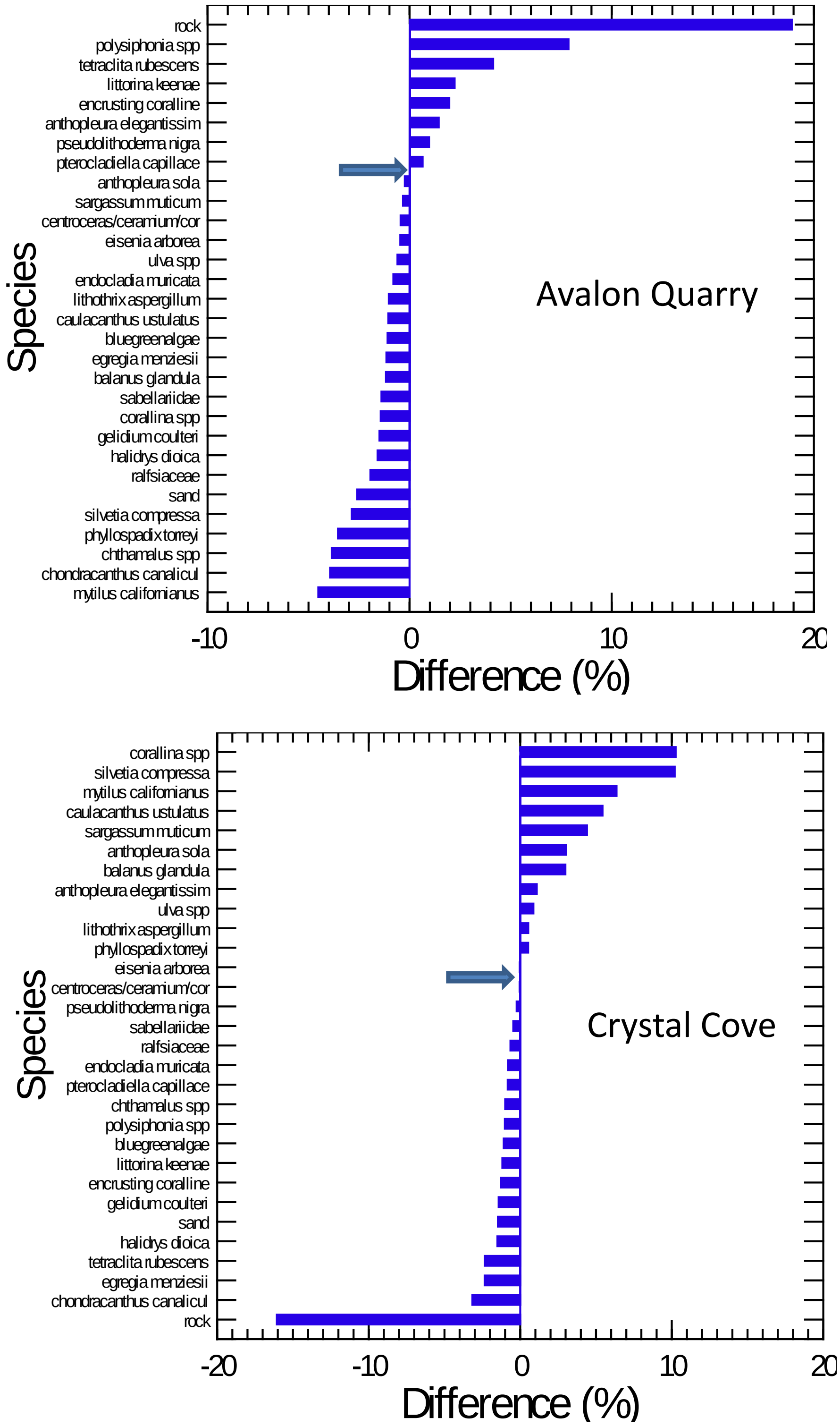

Figure 6: Differences in percent cover between specific sites (labeled) and expected values based on averages across all sites. Arrow indicates the transition between positive and negative differences.

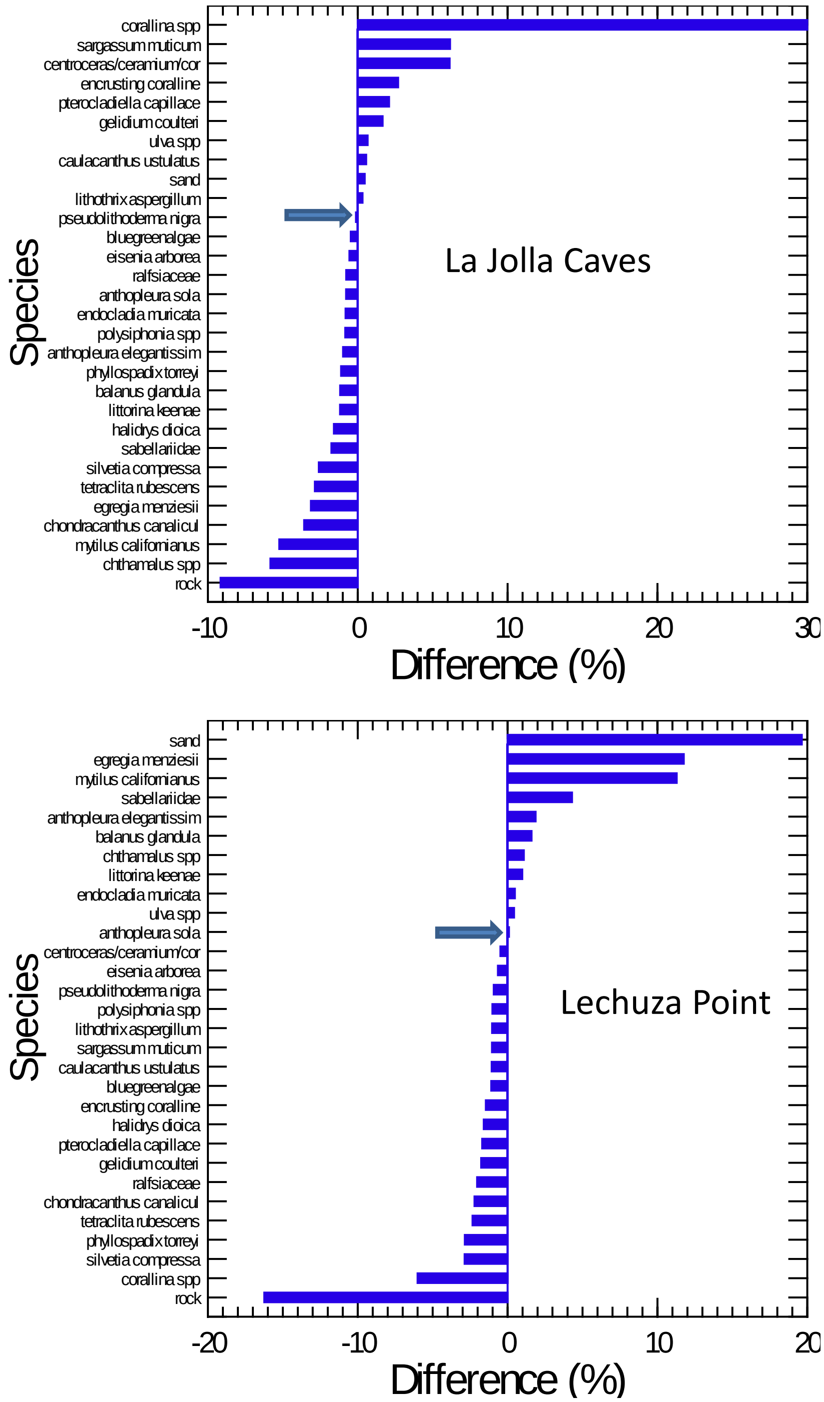

Figure 7: Differences in percent cover between specific sites (labeled) and expected values based on averages across all sites. Arrow indicates the transition between positive and negative differences.

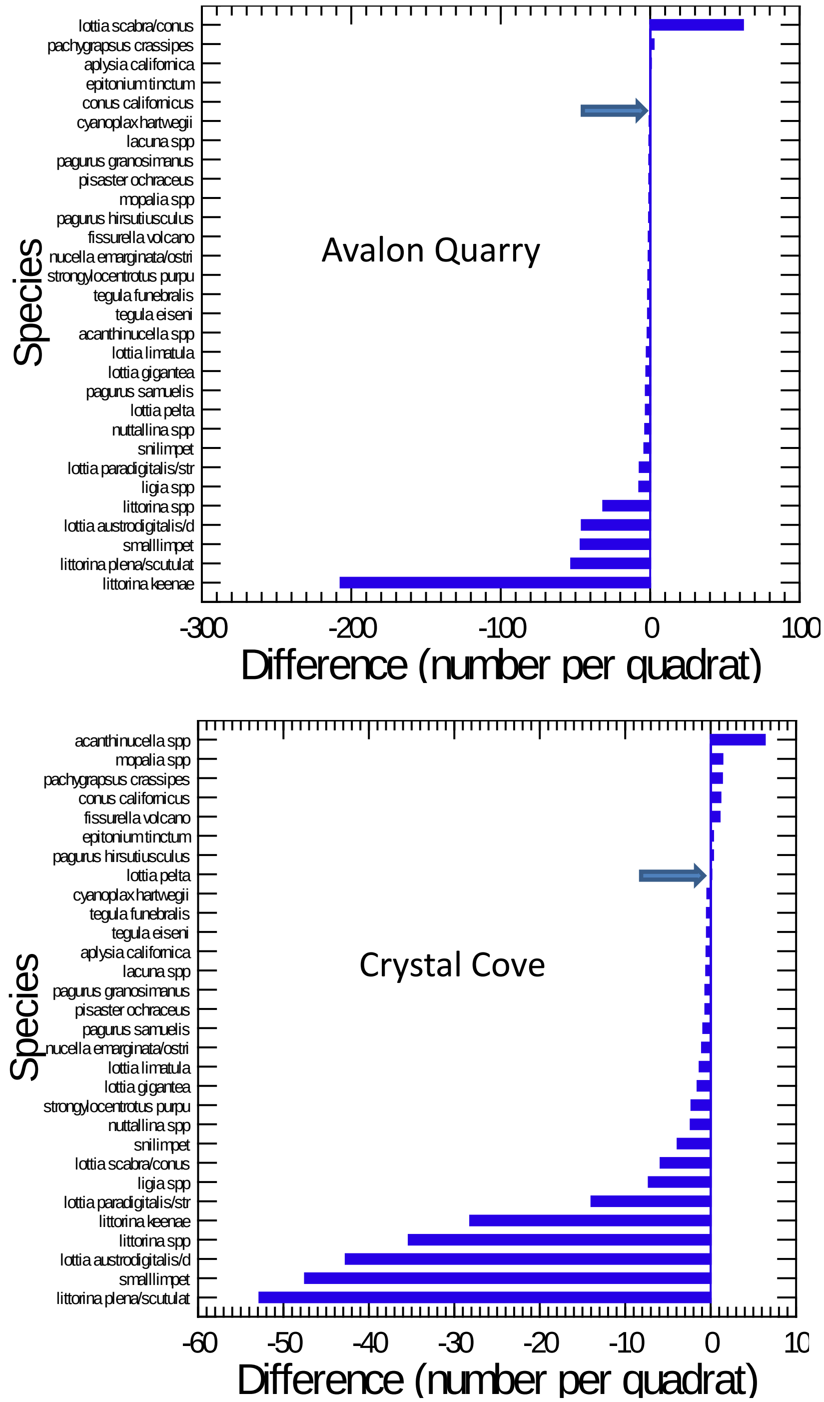

Figure 8: Differences in counts per quadrat between specific sites (labeled) and expected values based on averages across all sites. Arrow indicates the transition between positive and negative differences.

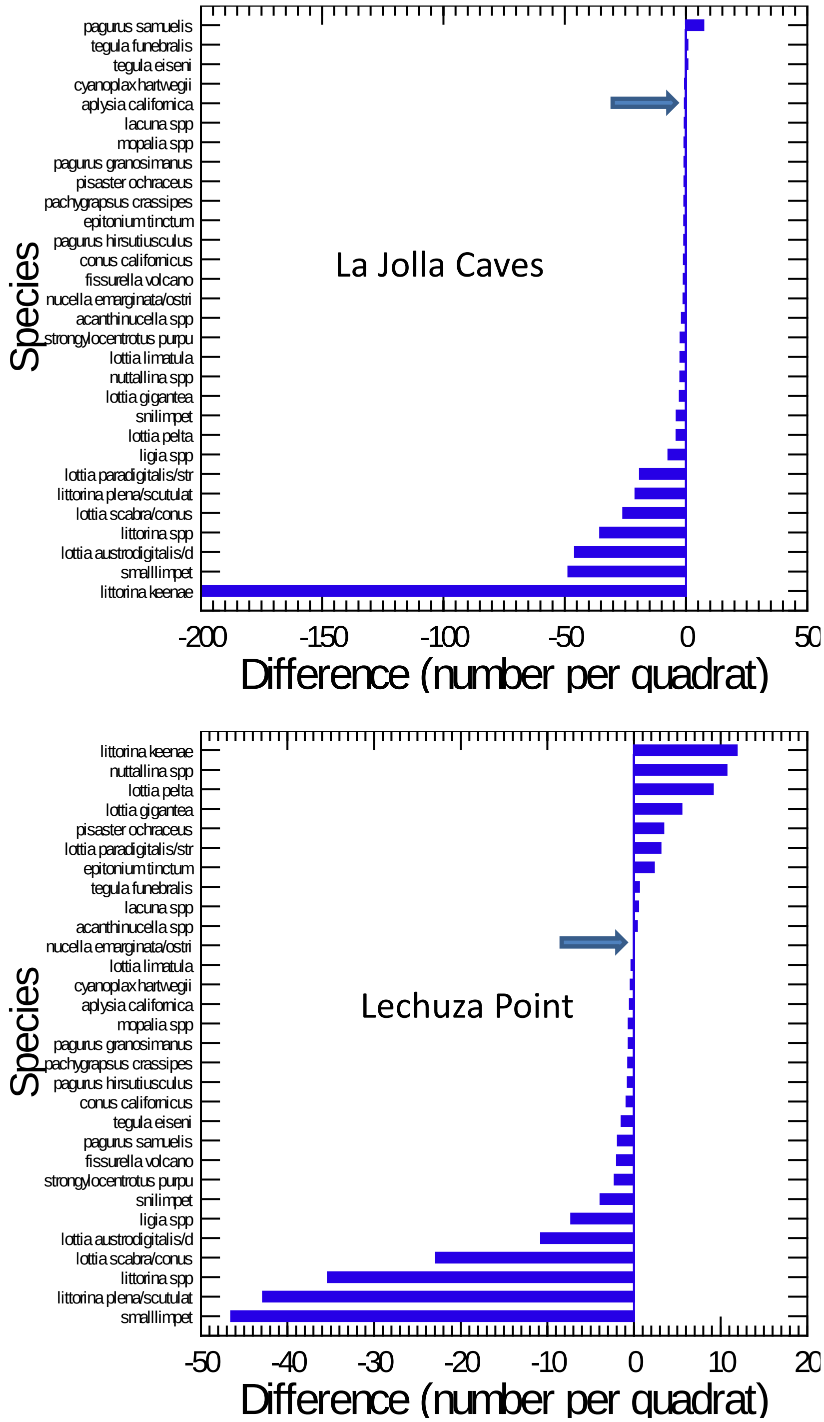

Figure 9: Differences in counts per quadrat between specific sites (labeled) and expected values based on averages across all sites. Arrow indicates the transition between positive and negative differences.

There are several general points that can be made based on results.

1) For all four sites and types of organisms (sessile, mobile) more species have below average than above average abundances.
2) Avalon Quarry has a relatively impoverished biological community (particularly for mobile species) that is indicative of high levels of disturbance or impairment.
3) Crystal Cove's sessile community is representative of an established bedrock community, although there is a high cover of the invasive species *Caulicanthus*. By contrast the mobile community is impoverished.
4) La Jolla Caves is relatively species poor site. Its biological community is dominated by 'disturbance tolerant" species, which is an indication of natural or anthropogenic disturbance. It also has high representation of invasive species (*Sargassum* and *Caulicanthus*).
5) Lechuza's community is characteristic of a sand influenced site with intermittent emergent rock.

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 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 (Littler and Murray 1975), which showed considerable spatial variability in the biological communities in this region. The figures in Appendix 2 also show the tremendous spatial variability among biological communities.

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. Using an analytical approach designed to assess site specific effects, we found that four sites exceeded the 80% prediction limit and 2 exceeded the 95% limit for community similarity (Figure 5). This means that they were substantially different from what would be expected based on all the rest of the sites. All 4 sites were associated with discharges and each characterized with lower than expected abundances of both mobile and sessile species as well as species composition different from expected. One has to be cautious in interpreting results of any community assessment, particularly when they come from surveys rather than experiments. 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 the details of the results to look for consistencies or deviations from patterns that would be expected under the posed hypothesis.

In this study we can look at the species composition associated with the four sites that differ from the expected species composition. The general question is whether the biological community is affected by discharge of water and associated components. Given a difference, 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 compared to reference areas. This expectation is true for all four sites
2) Communities characterized by disturbance associated species. This is true for Avalon Quarry, La Jolla Caves and Lechuza Point.
3) Of those communities characterized by disturbance associated species, there should be no other obvious driver of the pattern of species. This is true for Avalon Quarry and La Jolla Caves. By contrast, Lechuza Point has considerable sand influence, which is a clear driver of disturbance associated communities.

Based on the match between pattern and expectations, we can conclude that Avalon Quarry and La Jolla Caves are sites that are possibly affected by compromised water quality associated with discharges.

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 are listed below:

1) Like biological communities, water quality near ASBS discharges following storm event was similar to the water quality observed near discharges at reference sites, no laboratory toxicity was observed at any ASBS following storm events.
2) Lechuza Point is located in ASBS 25; while no water quality information was collected specifically near Lechuza Point discharge, water quality in ASBS 25 exceeded reference-based thresholds in 35% of the analyses conducted.
3) La Jolla Caves is located in ASBS 29; while no water quality information was collected specifically near La Jolla Caves discharge, water quality in ASBS 29 exceeded reference-based thresholds in 5% of the analyses conducted.
4) Crystal Cove is located in ASBS 33; water quality information was collected near Crystal Cove discharge, water quality in ASBS 33 exceeded reference-based thresholds in 15% of the analyses conducted.
5) No water quality information is available for Avalon Quarry

In summary, this project provided the first condition report for the rocky intertidal zone in Southern California Areas of Special Biological Significance and serves as a good trigger for focused additional work. In particular we recommend that water quality assessments be made concurrently with biological sampling at the discharge and reference areas for the Avalon Quarry and La Jolla Caves. Such additional and spatially explicit sampling should allow a more robust determination of the likelihood that discharge related impacts “hinder the ability of marine life to respond to natural cycles and processes” that, by definition, would not be protective of the beneficial use of these areas.

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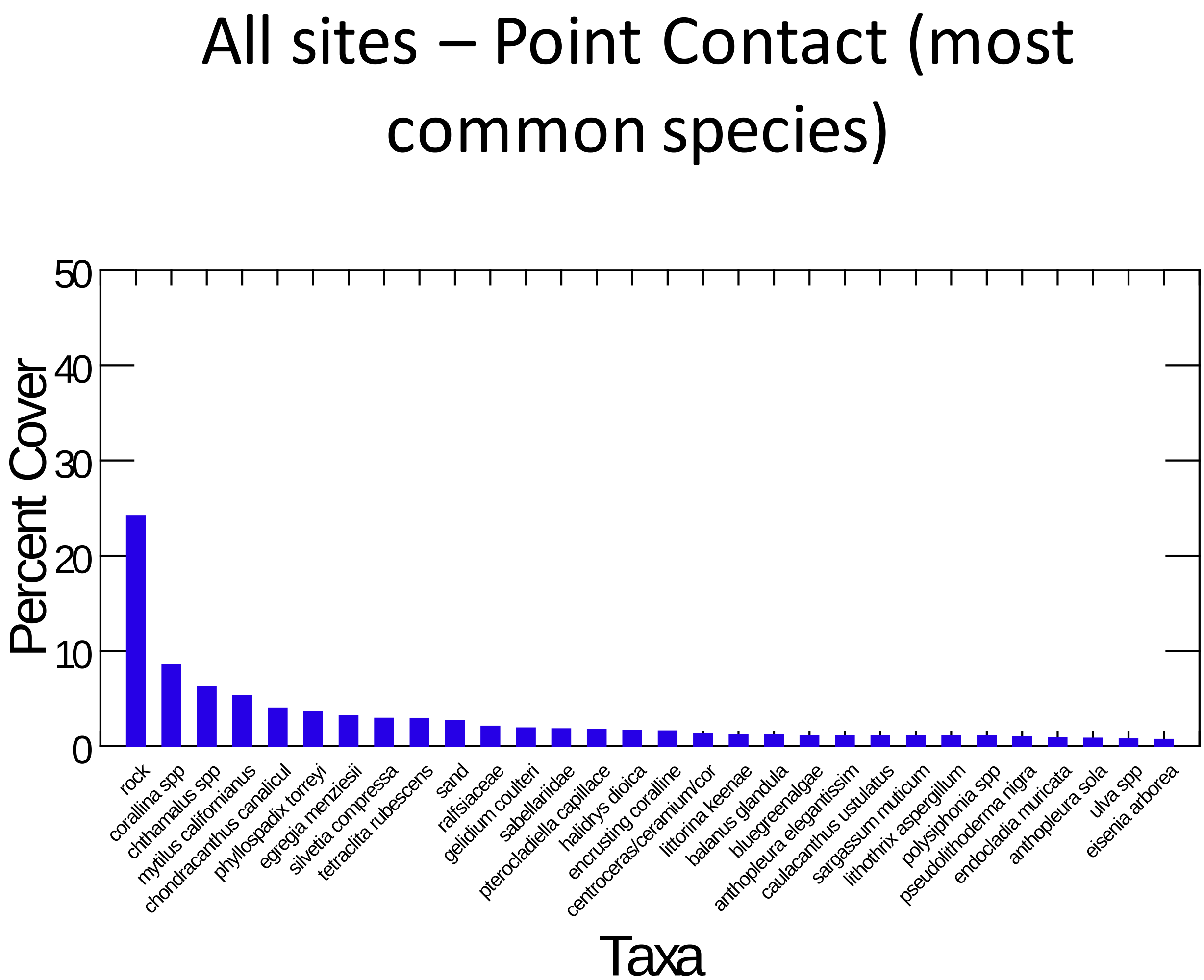
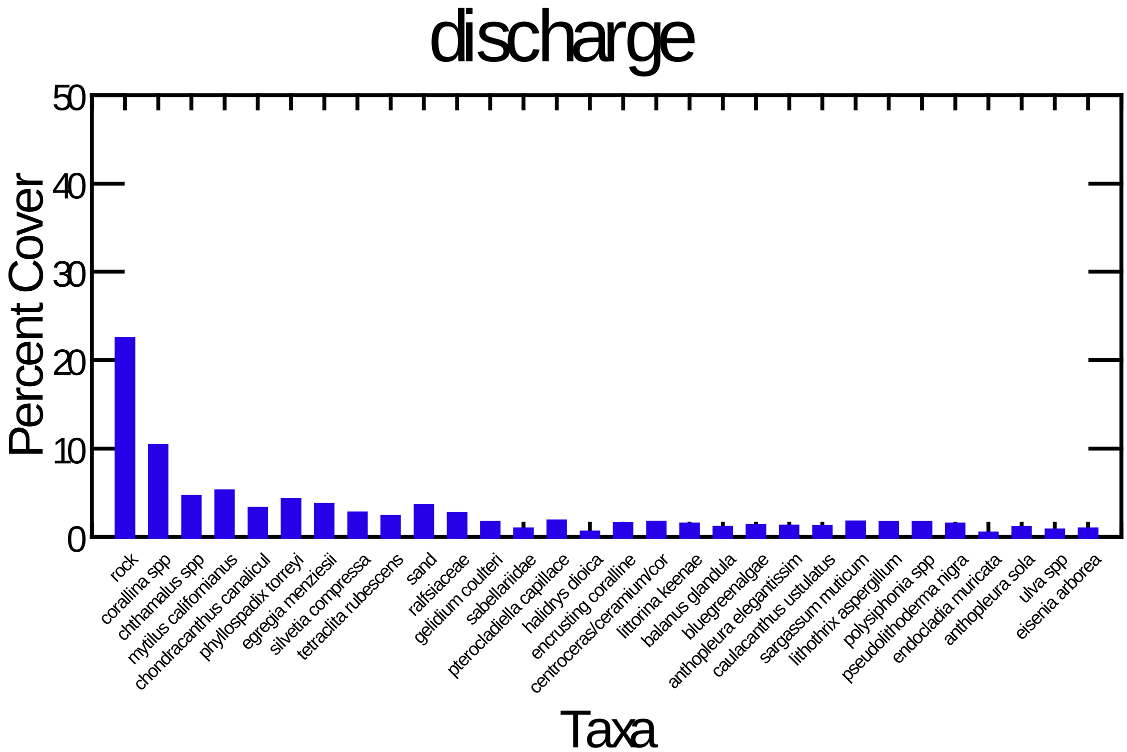
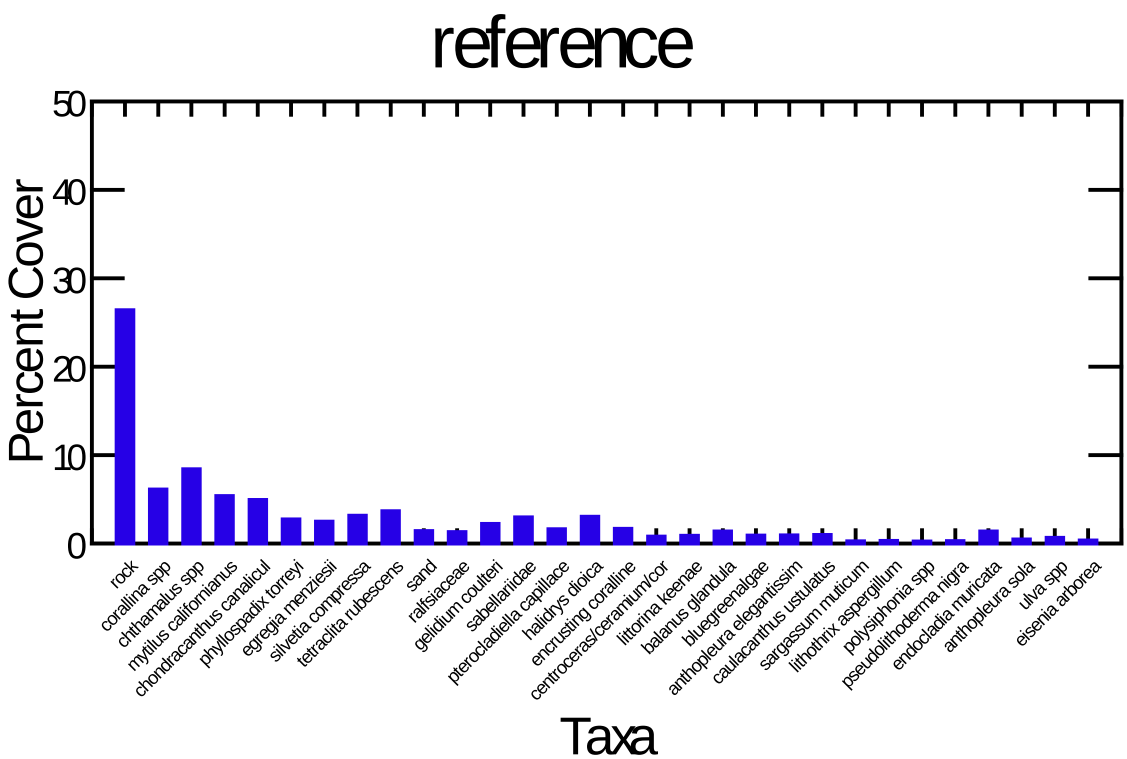
APPENDIX 1: ADDITIONAL FIGURES

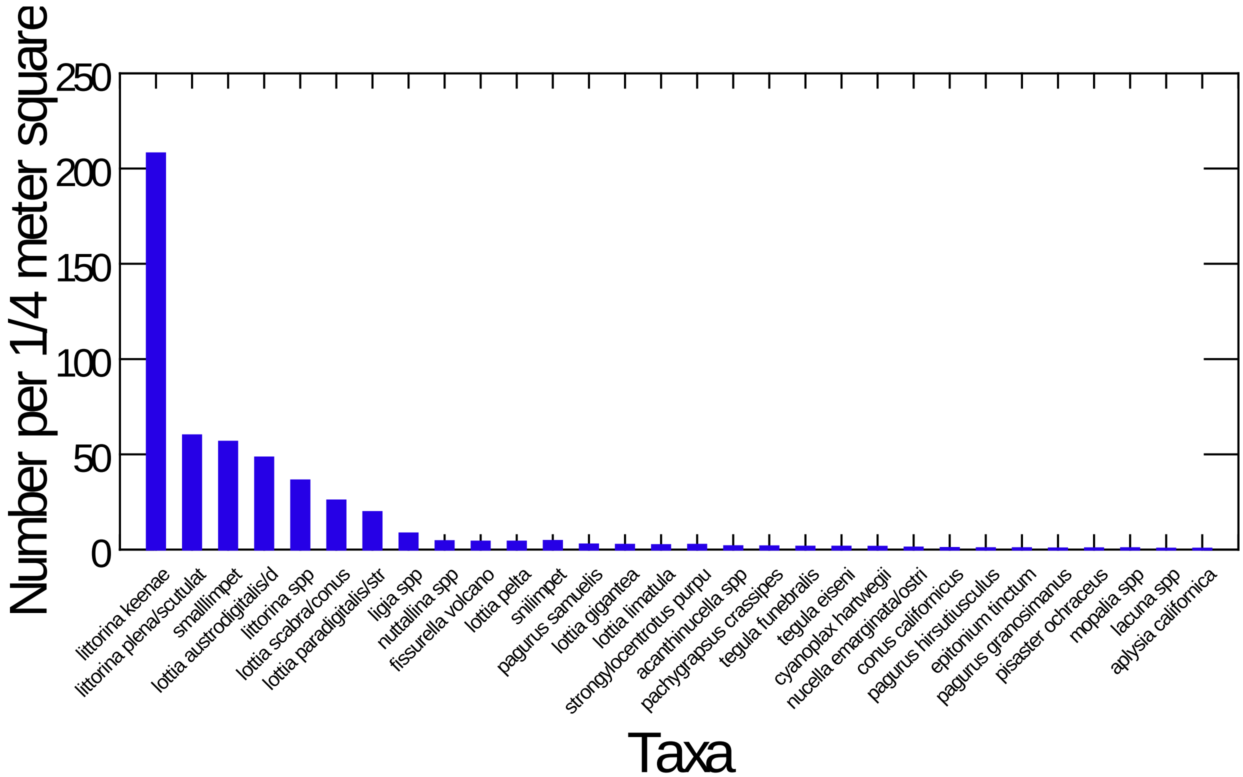


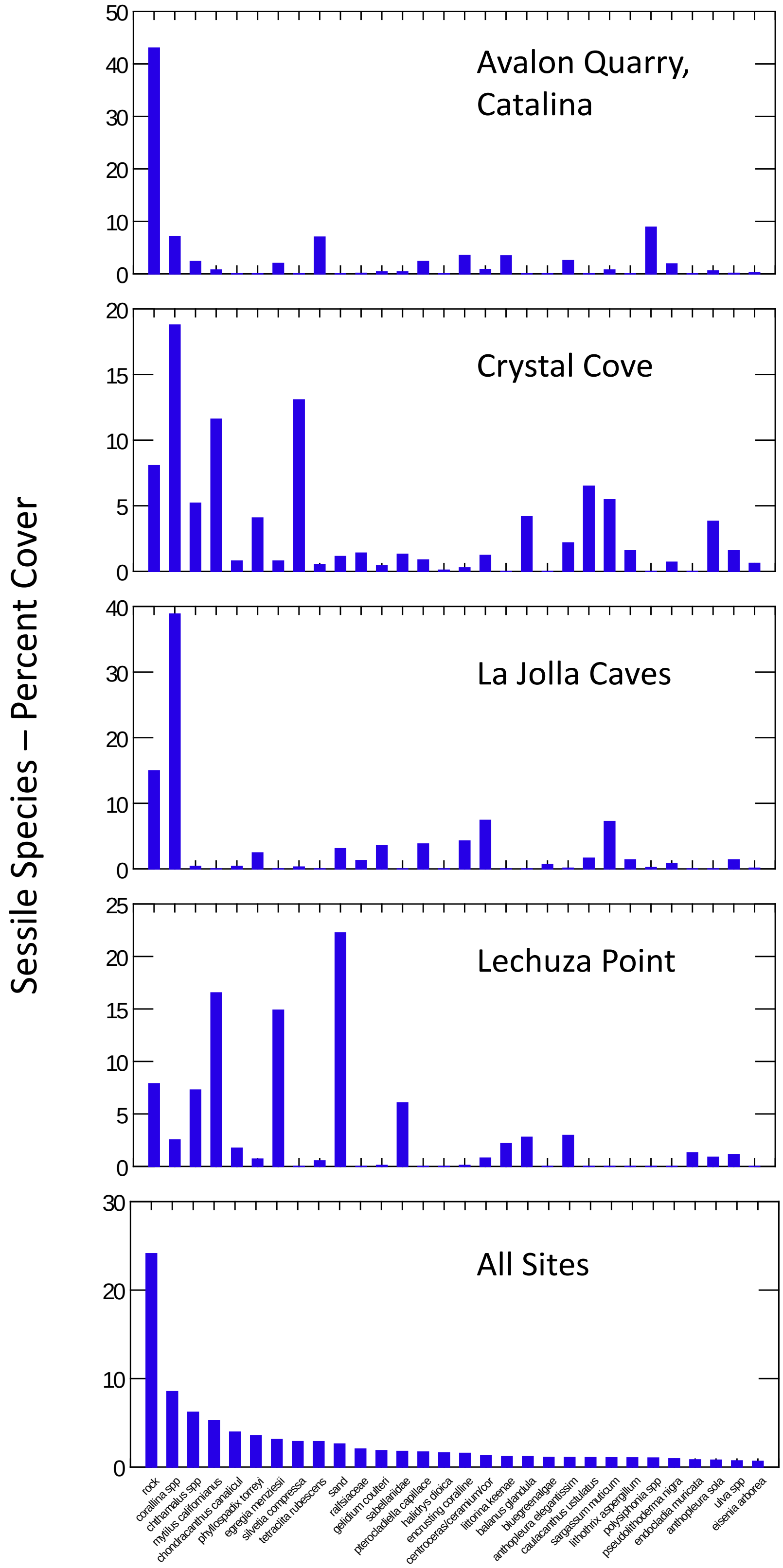
Across all sites – Point Contact (most common species)



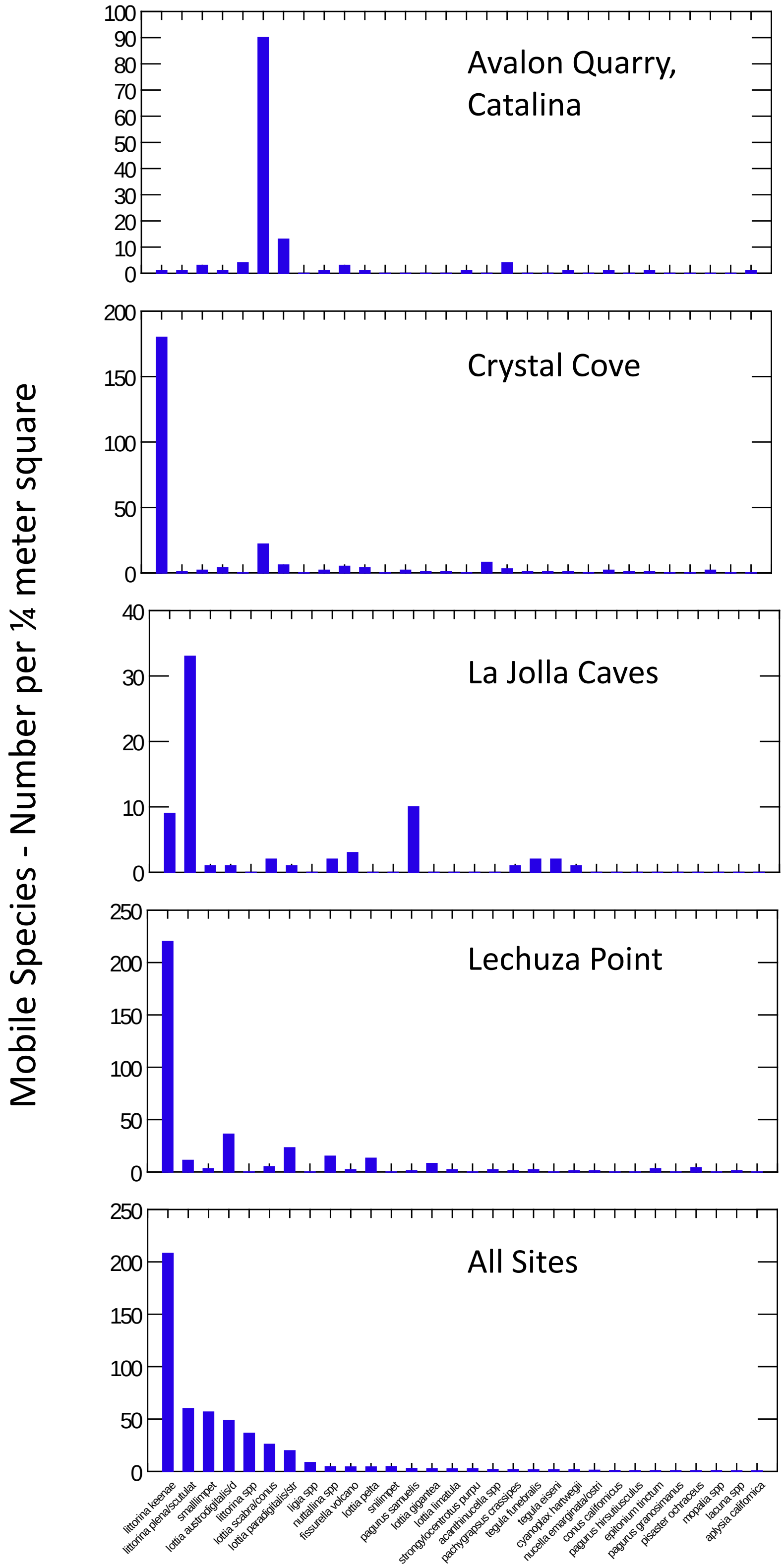


All sites – Mobile Species (most common species)





Percent cover of the most common sessile species across all sites and at the four sites that exceeded the prediction limit (Figure 5). Note differences in scale.



Density of most common mobile species across all sites and at the four sites that exceeded the prediction limit (Figure 5). Note differences in scale.

APPENDIX 2: SITE LOCATIONS, DESCRIPTIONS, PICTURES AND SITE-SPECIFIC COVER AND SPECIES DENSITY

Figure A2-1: locations of ASBS and reference sites

Magu Lagoon to Latigo Point

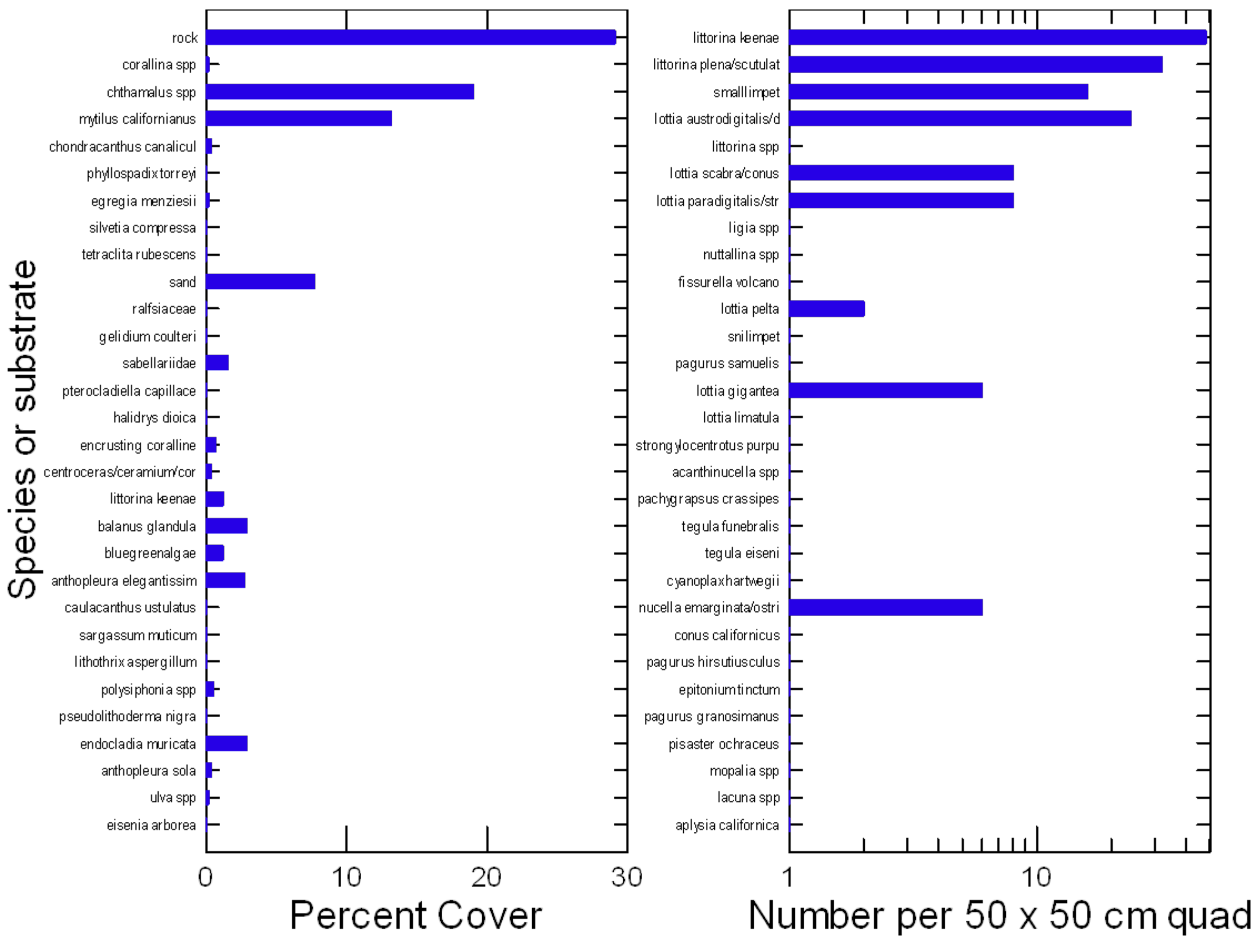
★ Discharge site in ASBS

■ Reference Site

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. The up coast section is 6 meters wide and 20meters long.

The downcoast section is 21meters wide and 20meters long.

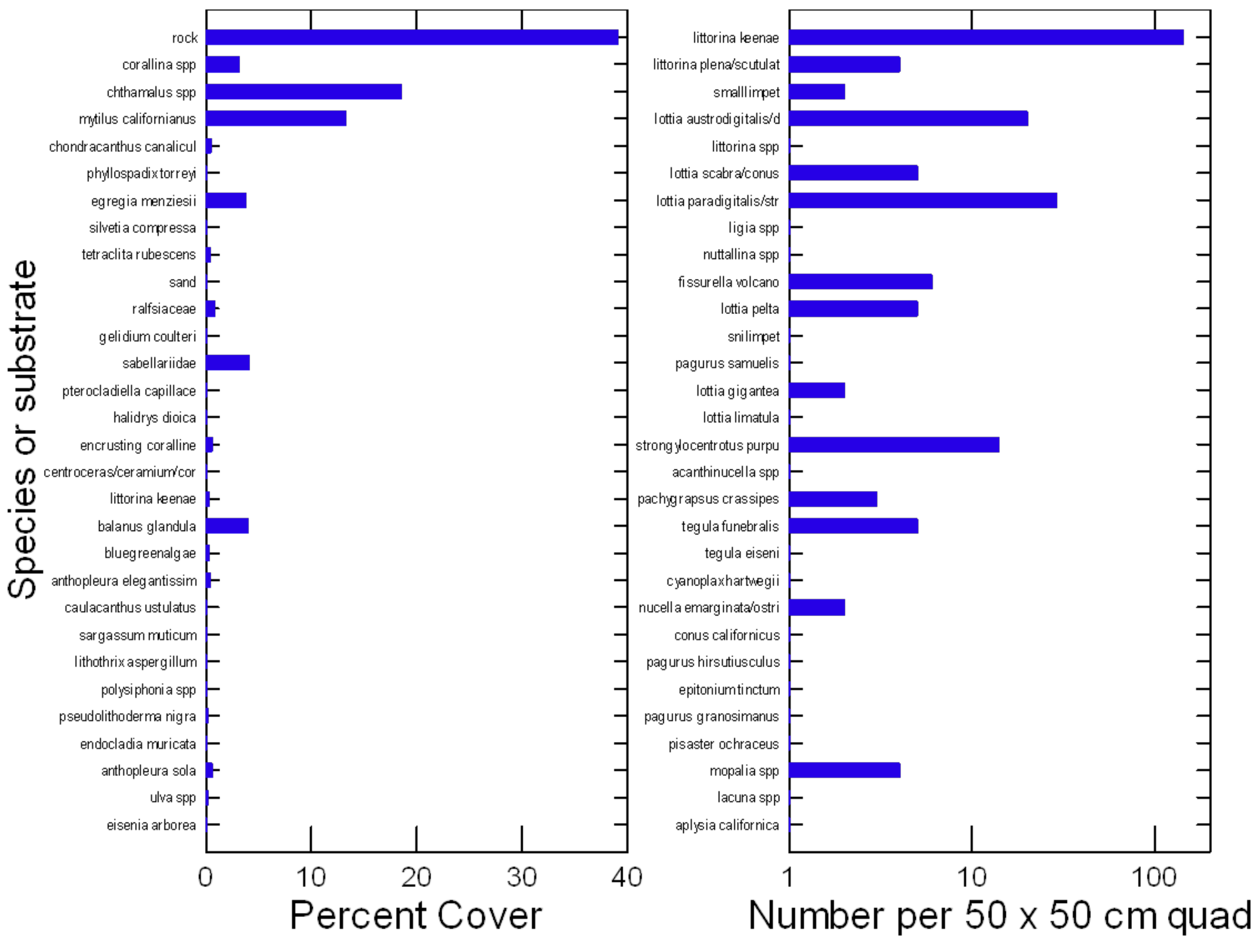
Old Stairs



Percent cover (from point contact surveys) and density (from mobile species surveys). Species order is based on ranking across all sites.

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

Sequit Point



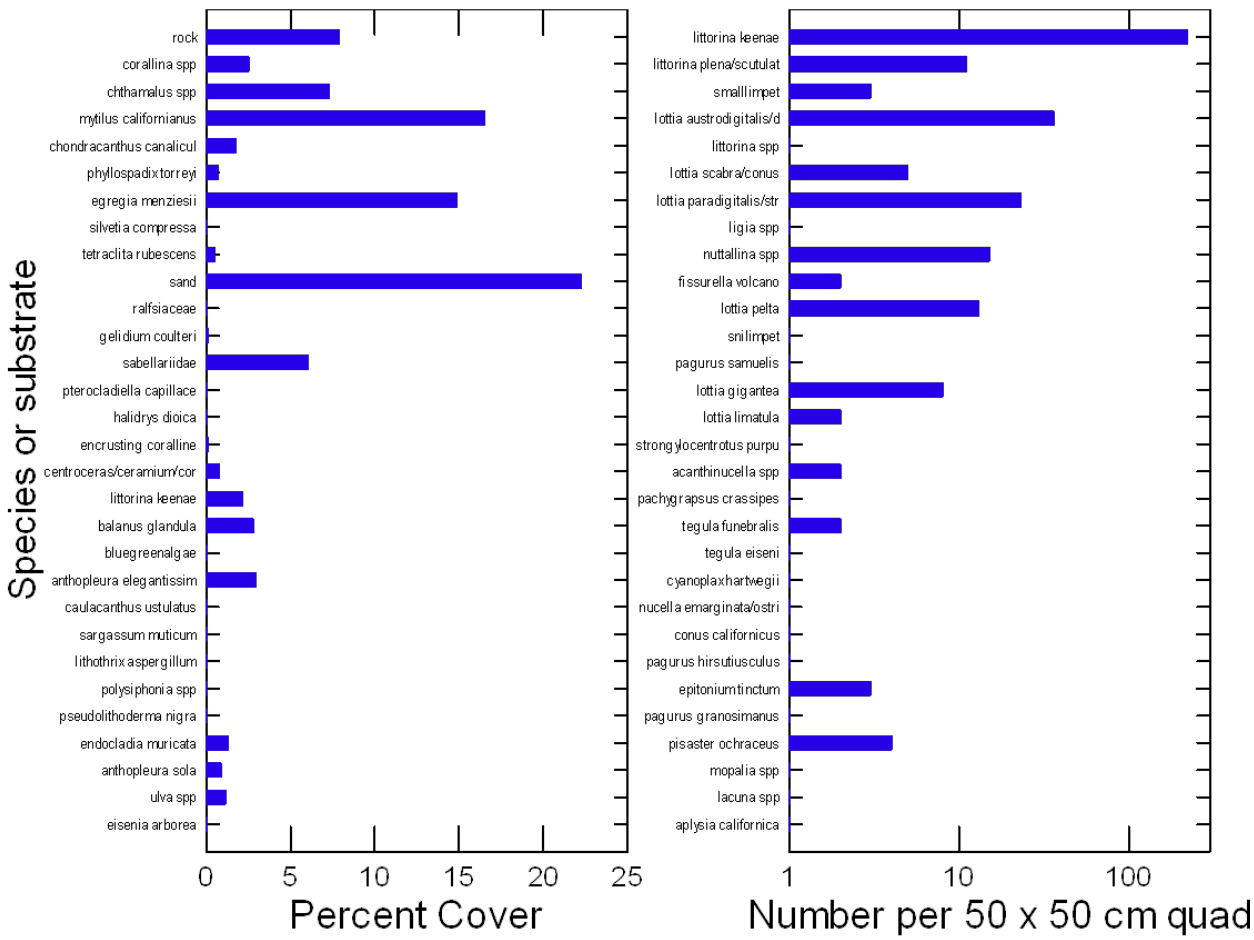
Percent cover (from point contact surveys) and density (from mobile species surveys). Species order is based on ranking across all sites.

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 14meters wide and 45meters 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.

The downcoast section is 4meters wide and 30meters long.

The nearest storm water discharge pipe is 25meters from survey bolt OT1.

Lechuza Point

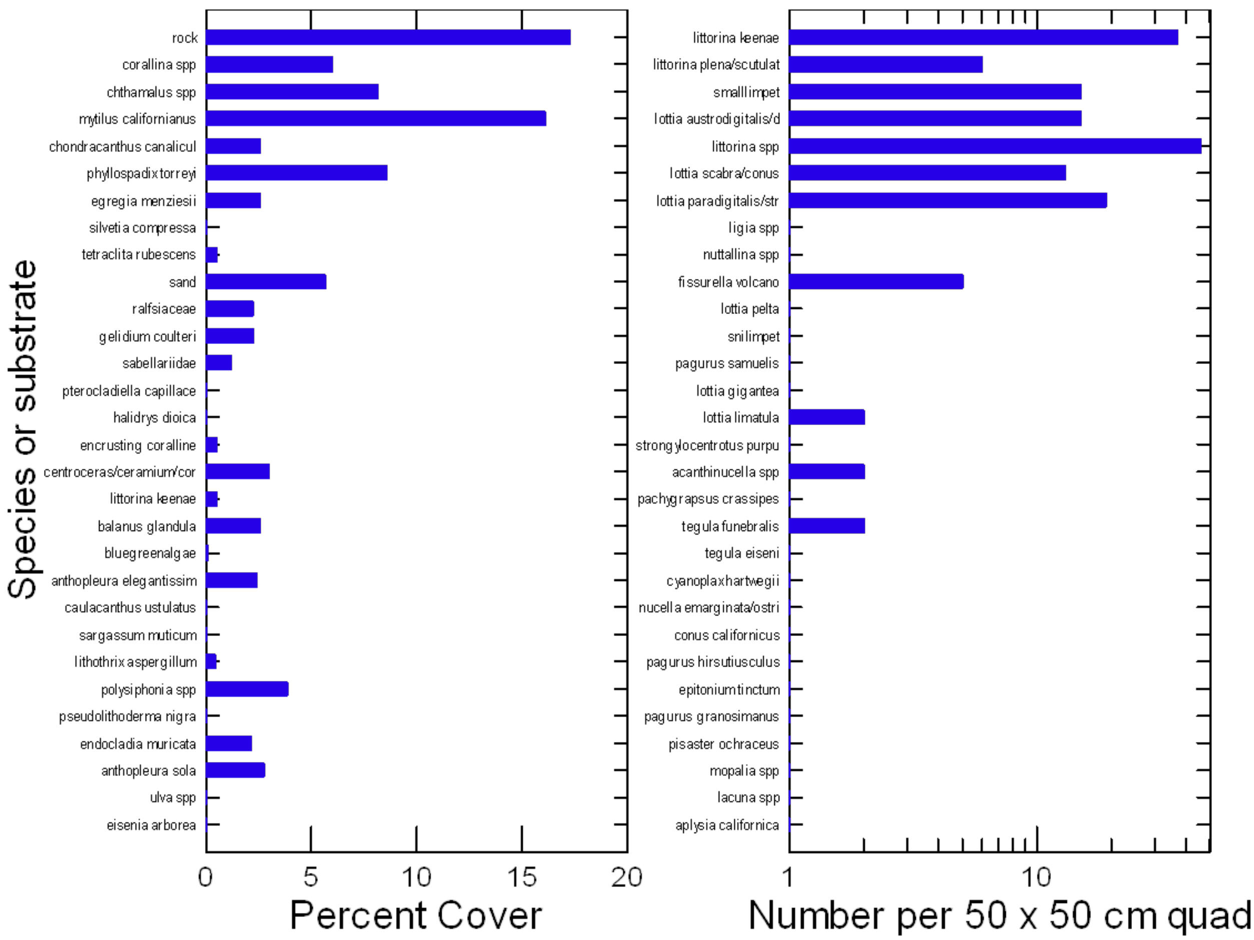


Percent cover (from point contact surveys) and density (from mobile species surveys). Species order is based on ranking across all sites.

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 12meters wide and 10meters long. The downcoast section is 15meters wide and 10meters long.

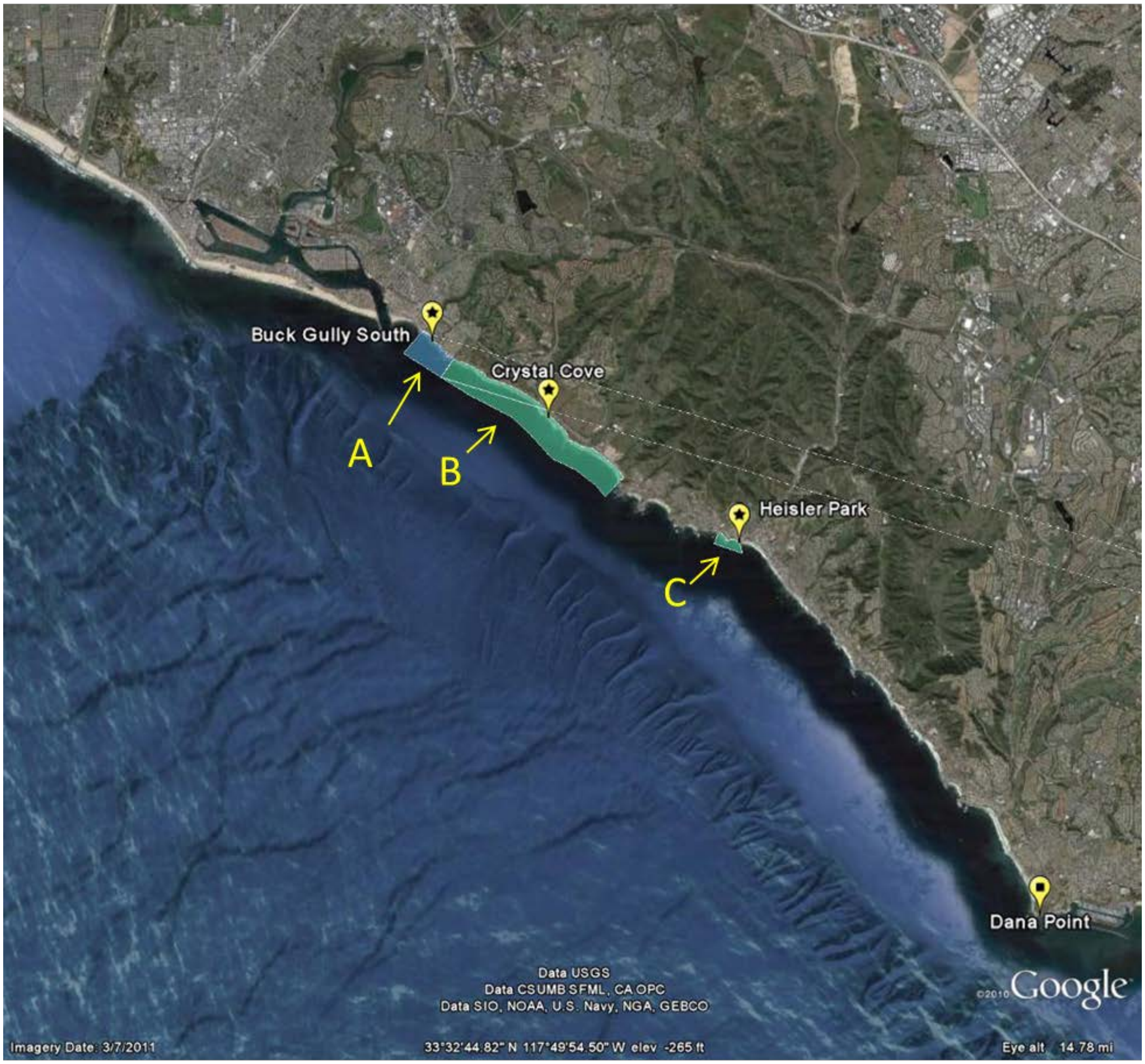
The nearest storm water discharge pipe (MUG379) is approximately 20meters from survey bolt R2.

Paradise Cove



Percent cover (from point contact surveys) and density (from mobile species surveys). Species order is based on ranking across all sites.

Newport Beach marine life refuge (A), Irvine Coast marine life refuge (B) and Heisler Park ecologicial reserve (C)



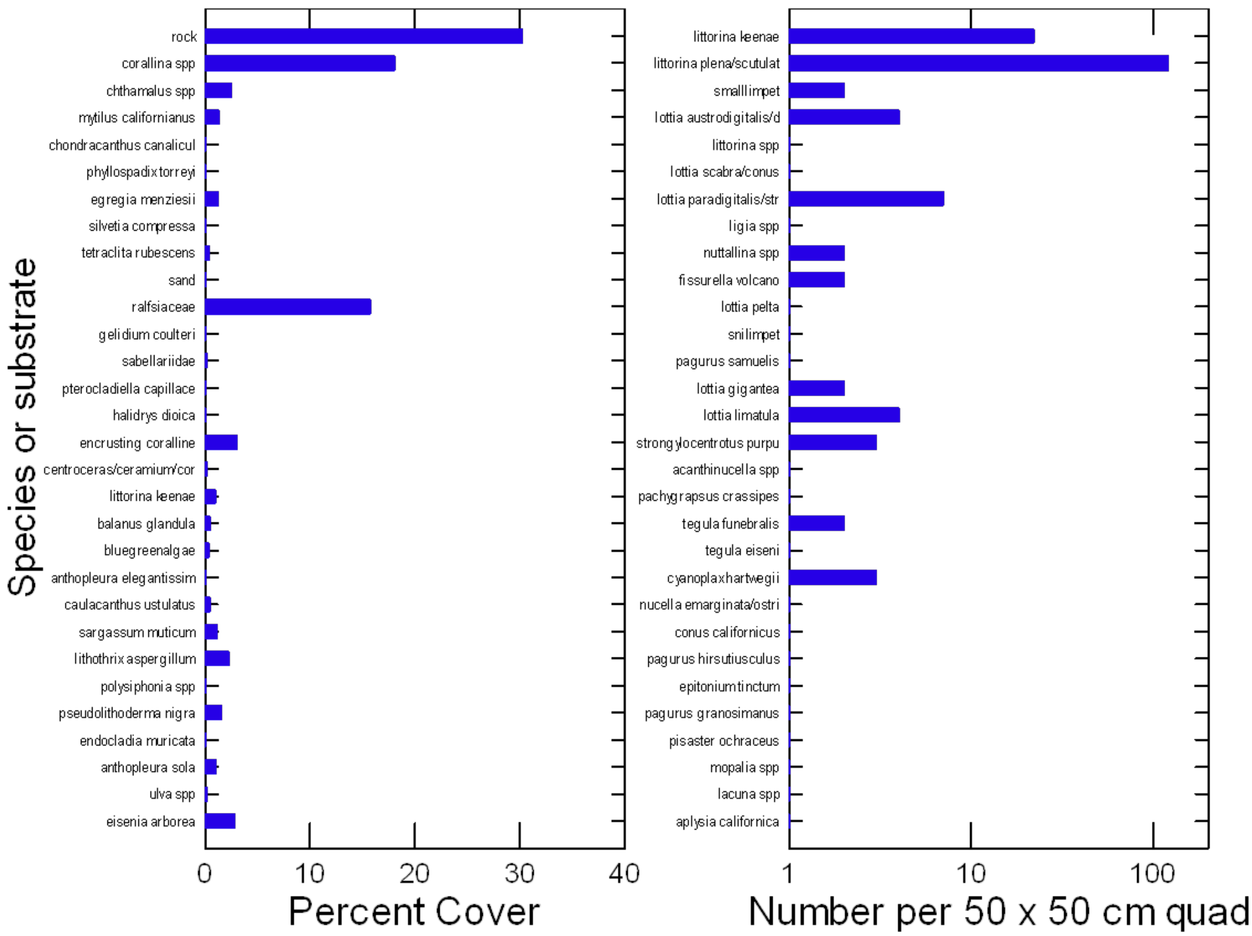
★ Discharge site in ASBS

■ Reference Site

Buck Gulley 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 30meters wide and 35meters long.

The nearest storm water discharge pipe (NEW016) is 5meters from survey bolt OT2.

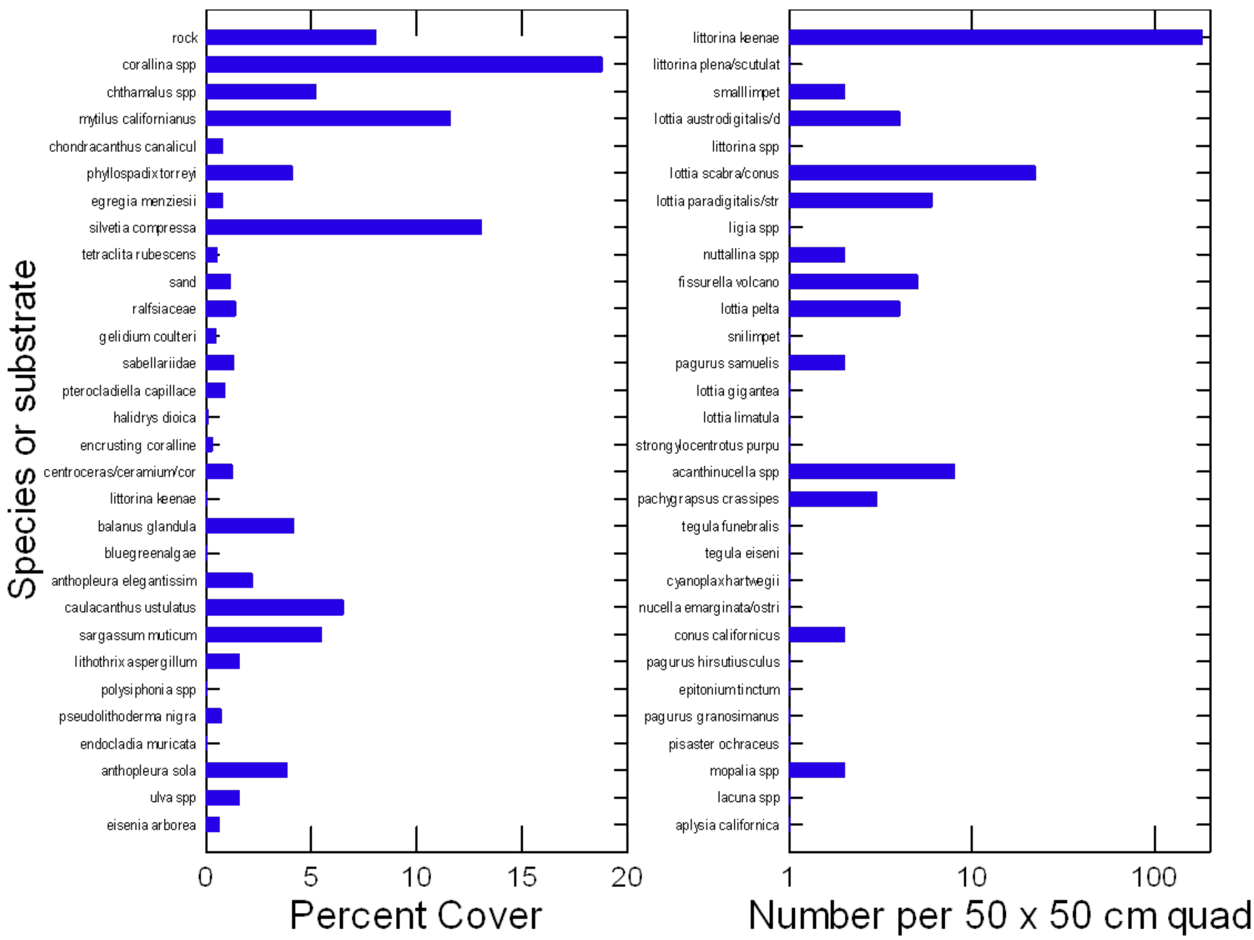
Buck Gully, south



Percent cover (from point contact surveys) and density (from mobile species surveys). Species order is based on ranking across all sites.

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

Crystal Cove

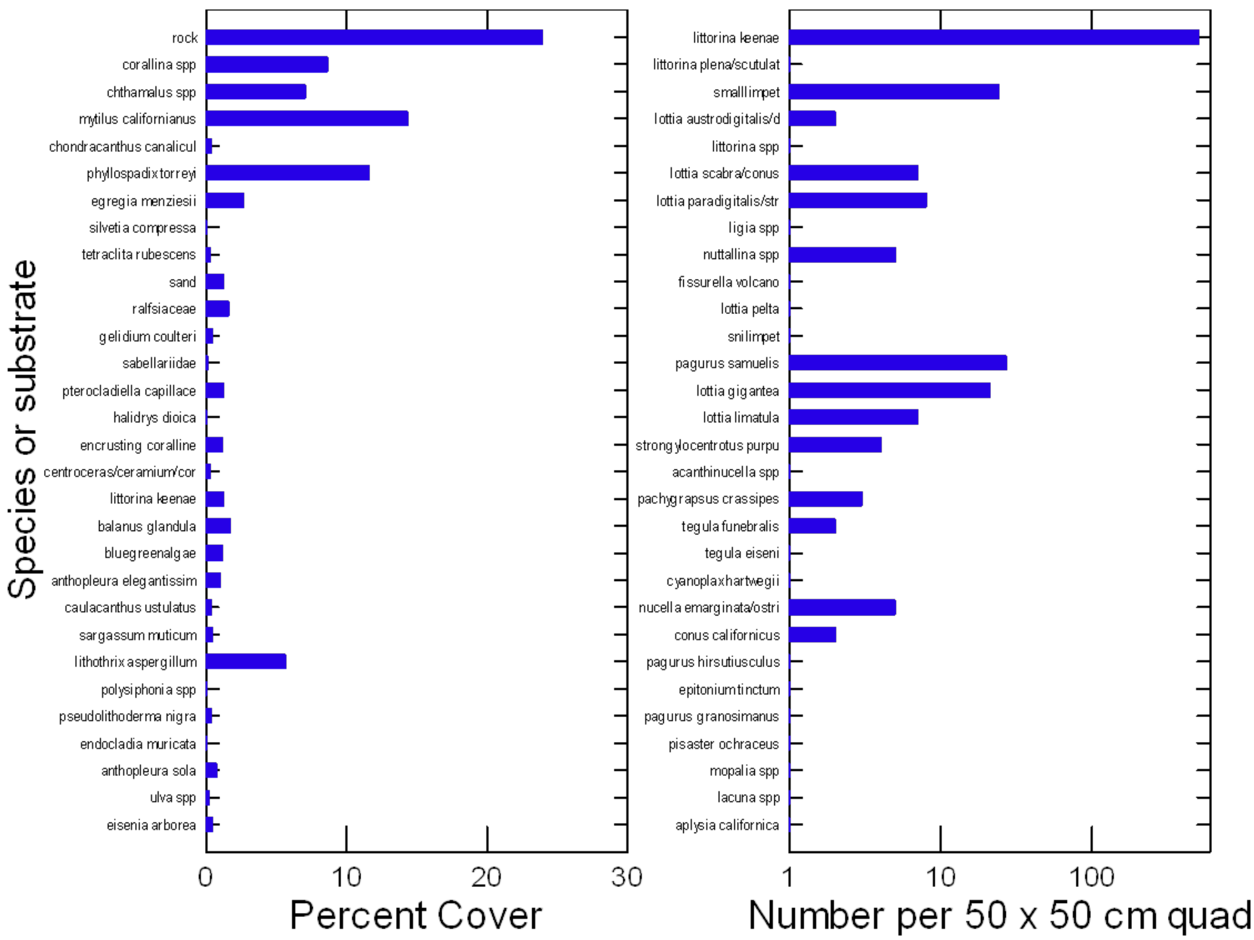


Percent cover (from point contact surveys) and density (from mobile species surveys). Species order is based on ranking across all sites.

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 20meters wide and 35meters long.

The nearest storm water discharge pipe (HSL013) is 52meters from survey bolt OT1.

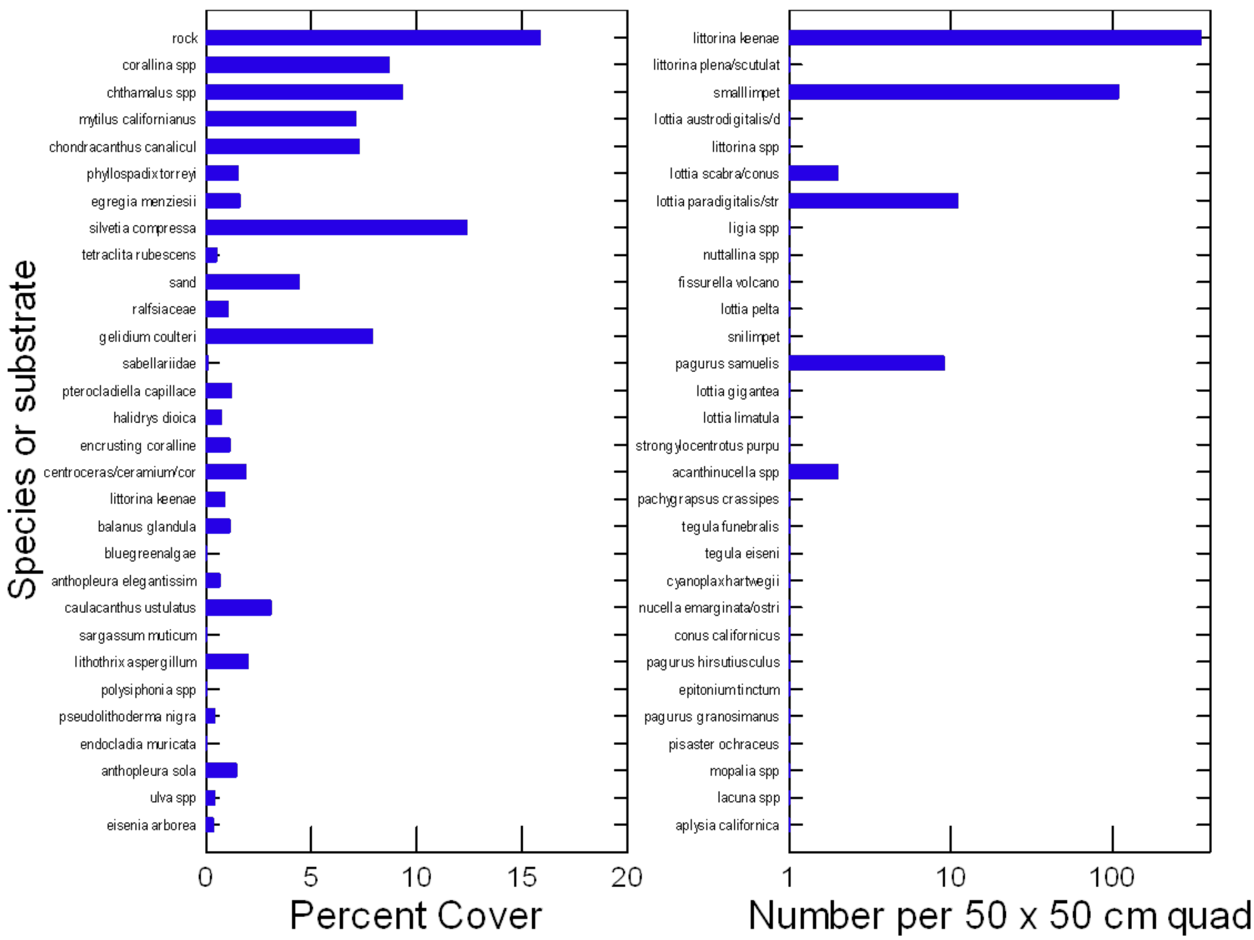
Heisler Park



Percent cover (from point contact surveys) and density (from mobile species surveys). Species order is based on ranking across all sites.

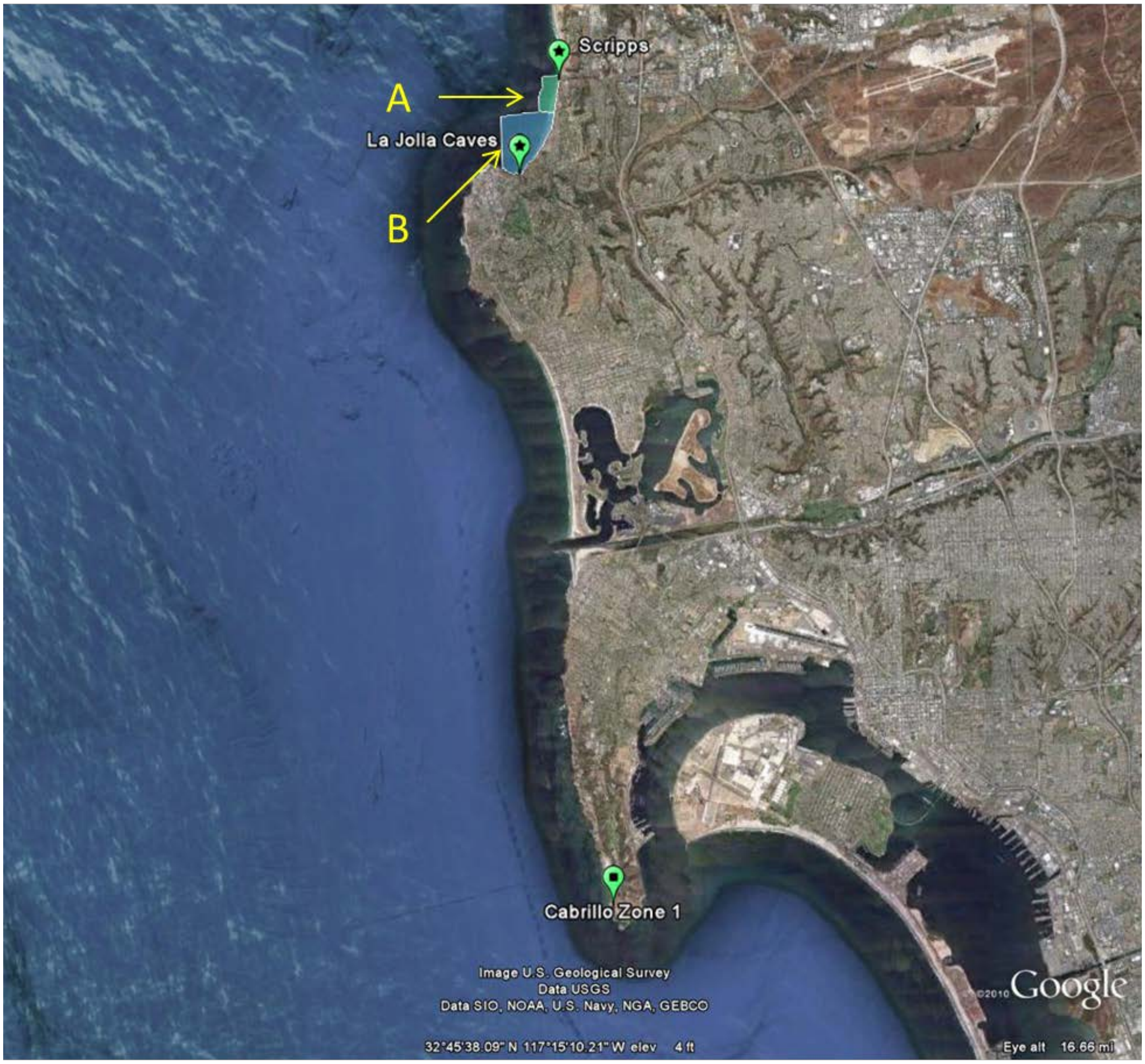
Dana Point is comprised of bedrock and boulders with moderate relief. The surrounding coast is made up of bedrock, boulders and sand. The survey area is 30meters wide and 29meters long.

Dana Point



Percent cover (from point contact surveys) and density (from mobile species surveys). Species order is based on ranking across all sites.

San Diego marine Life reserve (A) and San Diego-La Jolla ecological reserve (B)

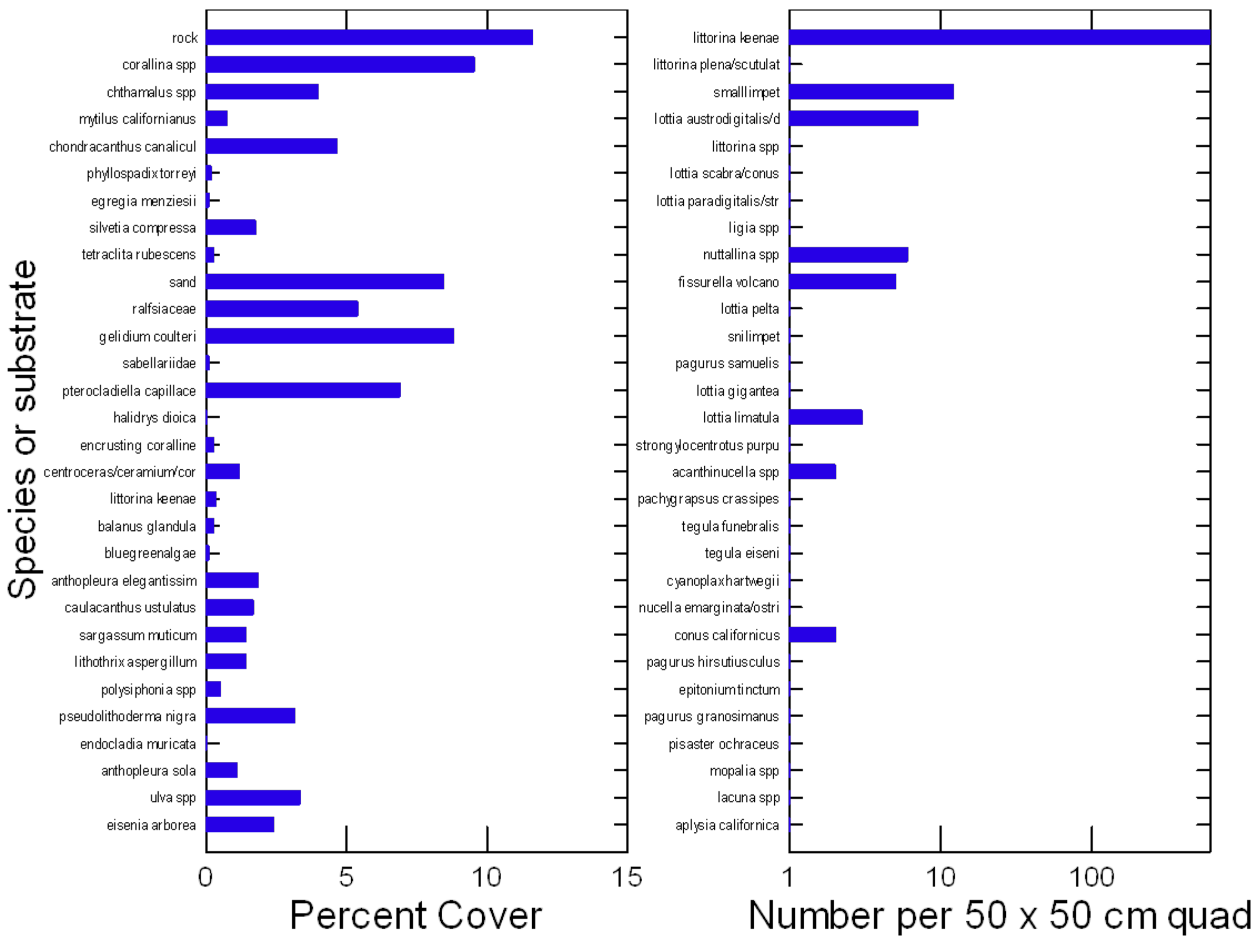


★ Discharge site in ASBS

■ Reference Site

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 29.6meters wide and 45meters long.

Scripps

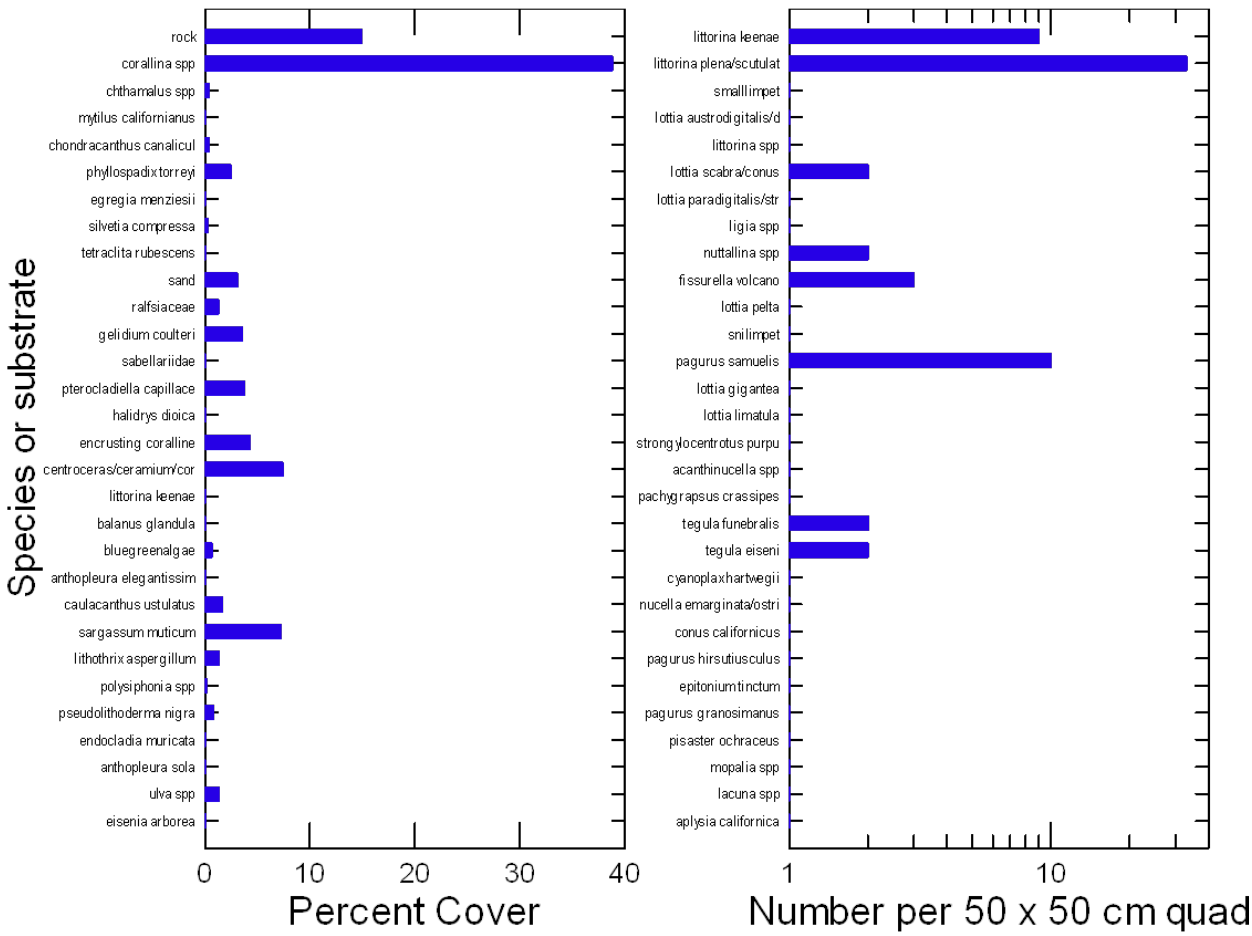


Percent cover (from point contact surveys) and density (from mobile species surveys). Species order is based on ranking across all sites.

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 30meters wide and 50meters long. This site differed greatly from expected based on other sites in the region.

The nearest storm water discharge pipe (SDL186) is approximately 50meters from survey bolt OT1.

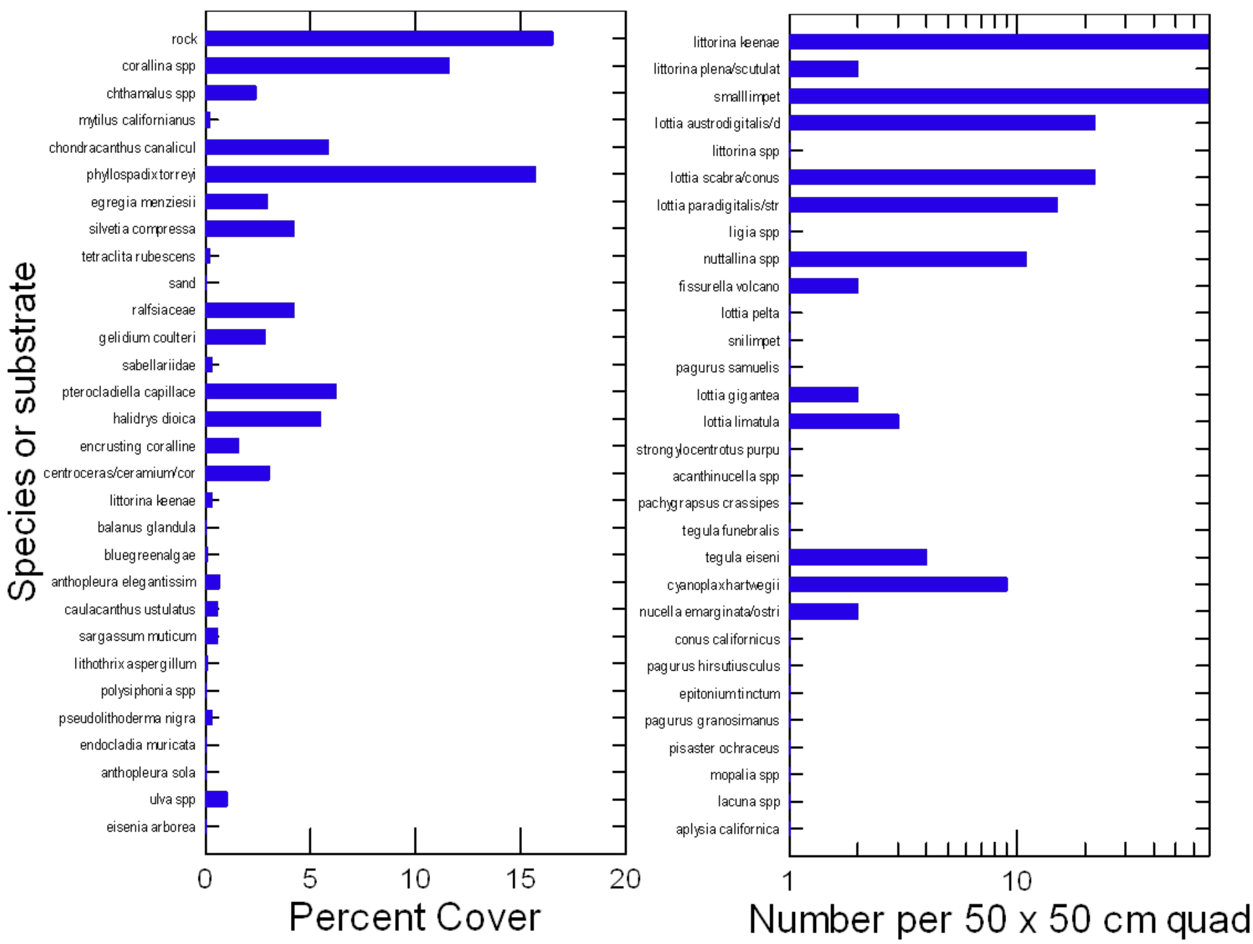
La Jolla Caves



Percent cover (from point contact surveys) and density (from mobile species surveys). Species order is based on ranking across all sites.

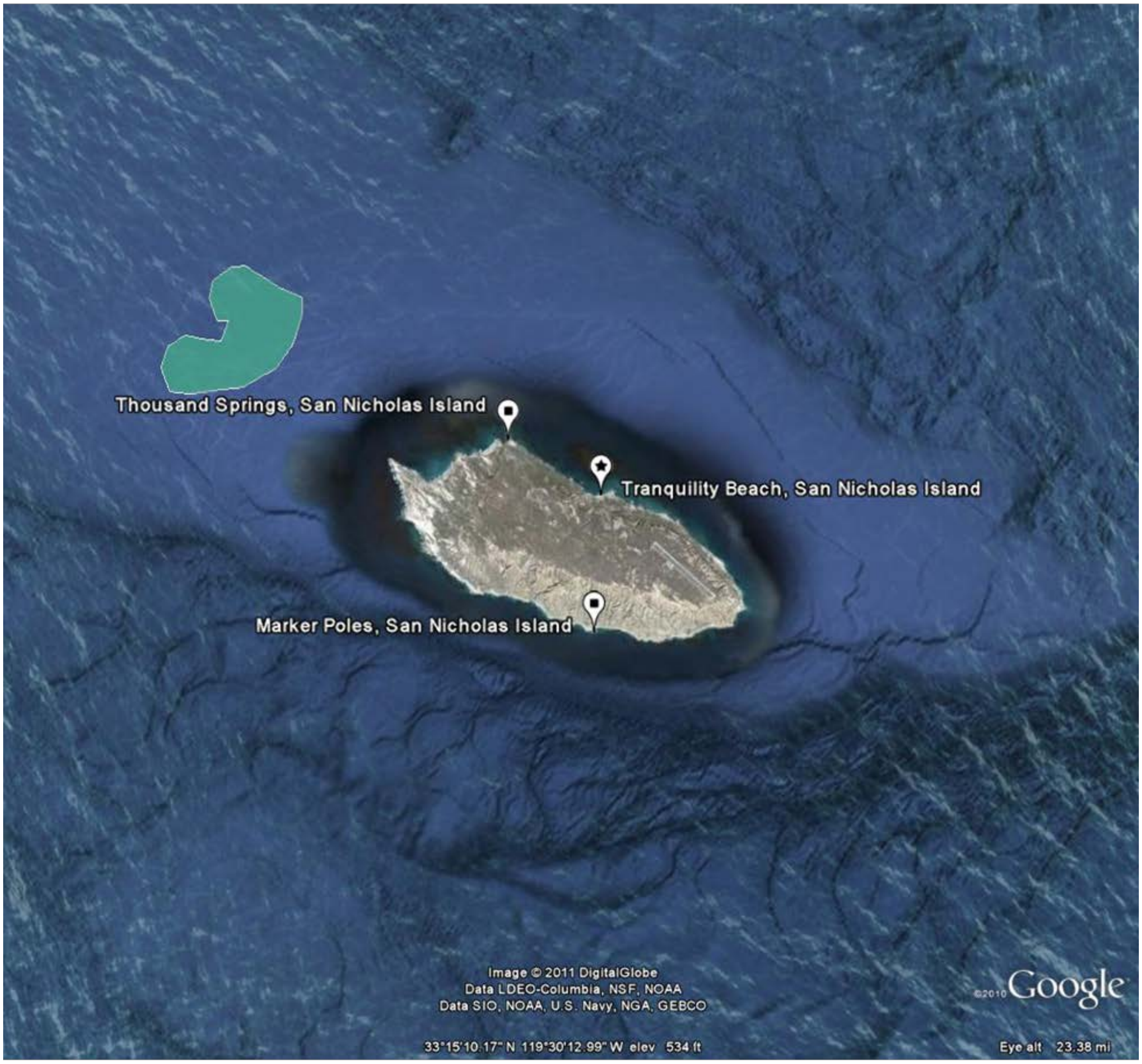
Cabrillo Zone I is comprised of bedrock and boulders with moderate relief. The surrounding coast is made up of bedrock, boulders and sand. The survey area is 30meters wide and 40meters long.

Cabrillo Zone I



Percent cover (from point contact surveys) and density (from mobile species surveys). Species order is based on ranking across all sites.

San Nicolas Island

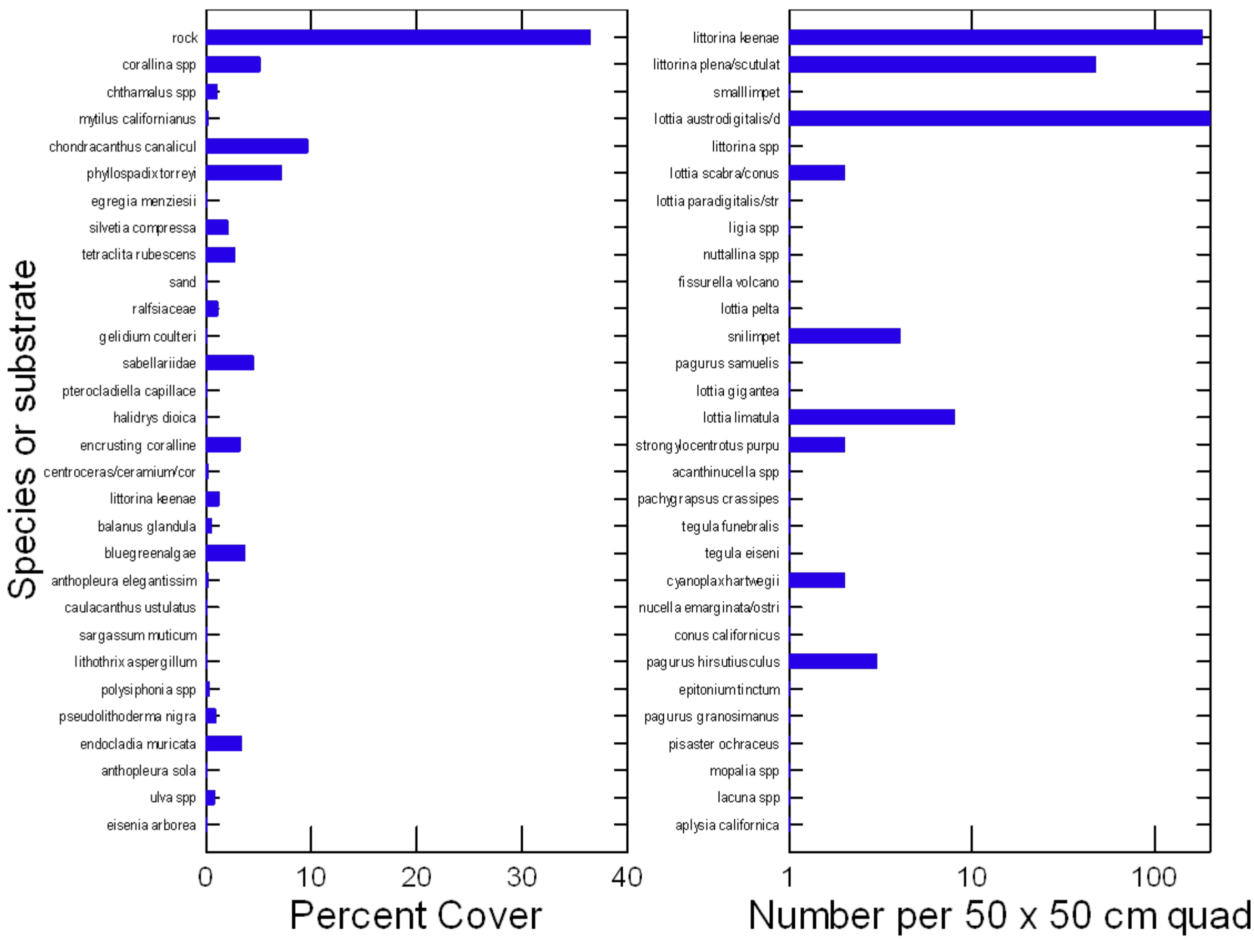


★ Discharge site in ASBS

■ Reference Site

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 20meters wide and 10meters long.

Thousand Springs

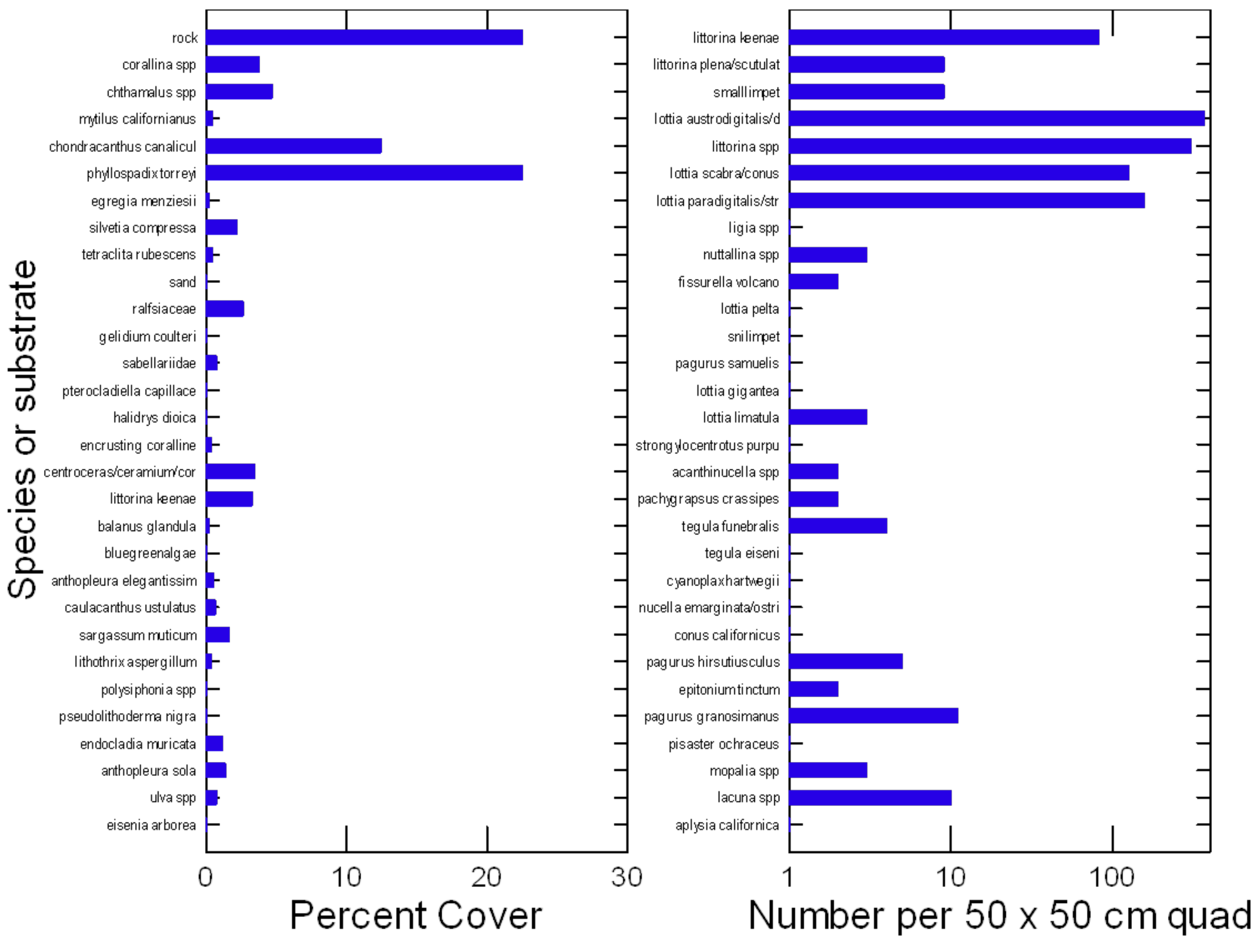


Percent cover (from point contact surveys) and density (from mobile species surveys). Species order is based on ranking across all sites.

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

The nearest storm water discharge is approximately 100meters from survey bolt OT1.

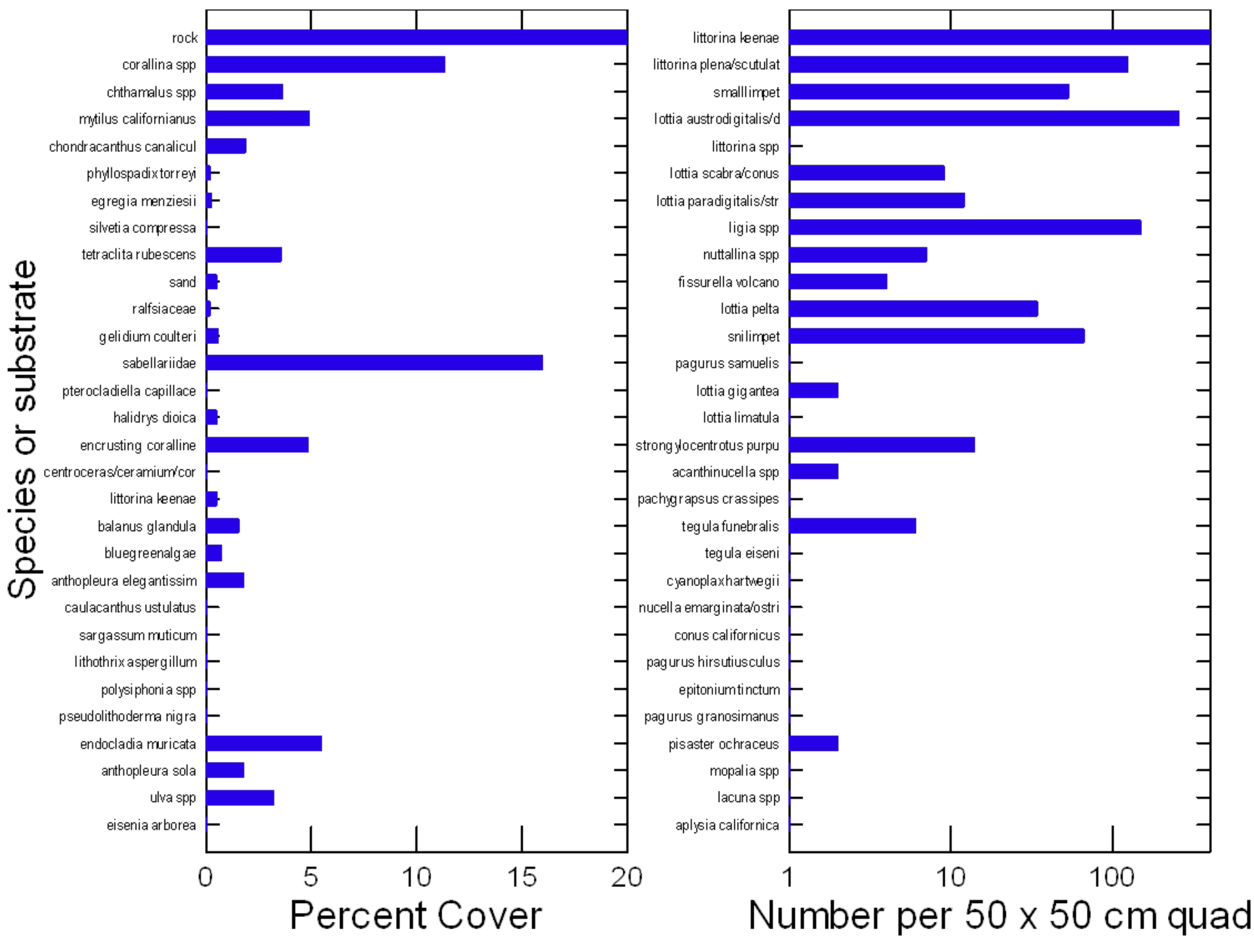
Tranquility Beach



Percent cover (from point contact surveys) and density (from mobile species surveys). Species order is based on ranking across all sites.

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

Marker Poles



Percent cover (from point contact surveys) and density (from mobile species surveys). Species order is based on ranking across all sites.

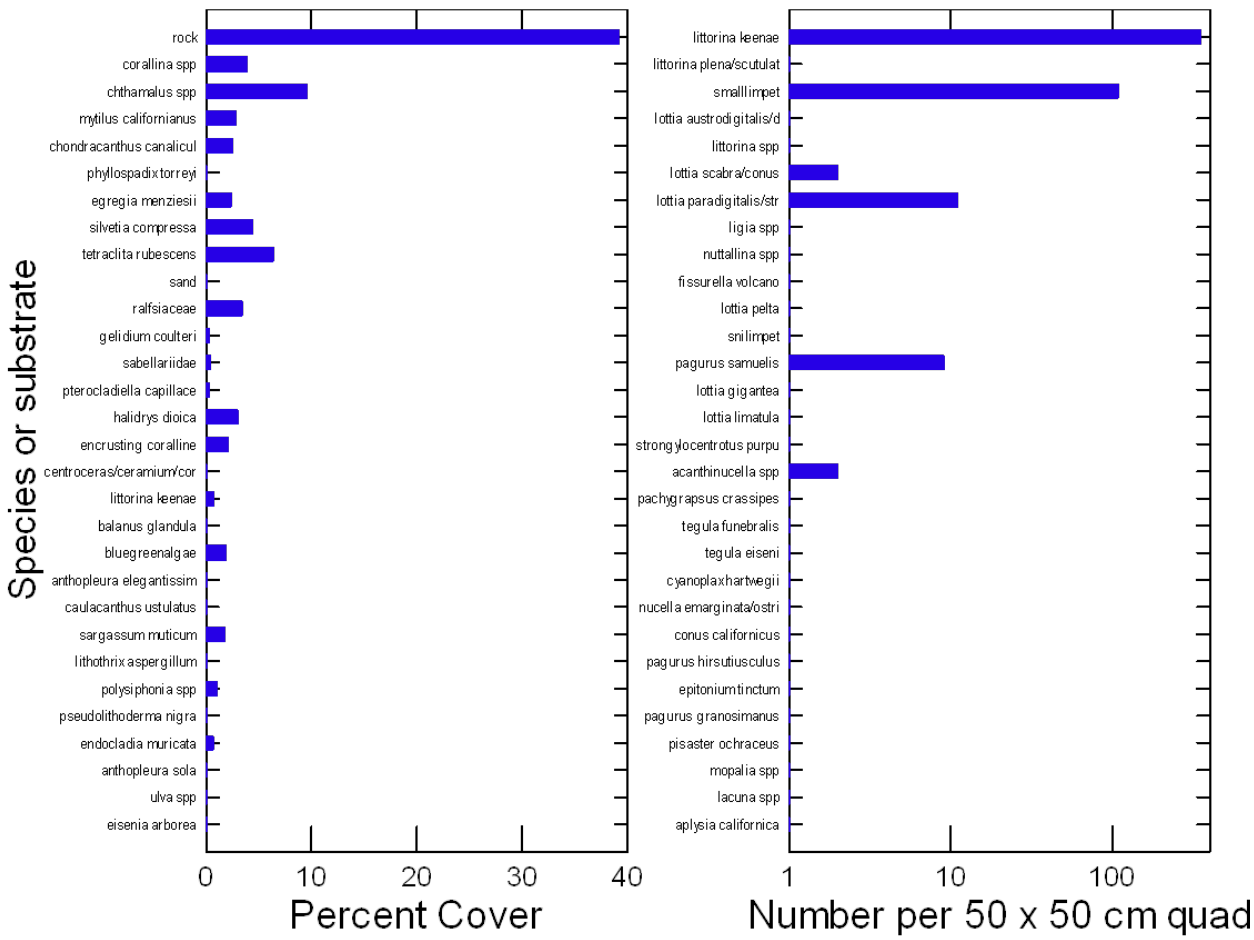
San Clemente Island

★ Discharge site in ASBS

■ Reference Site

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

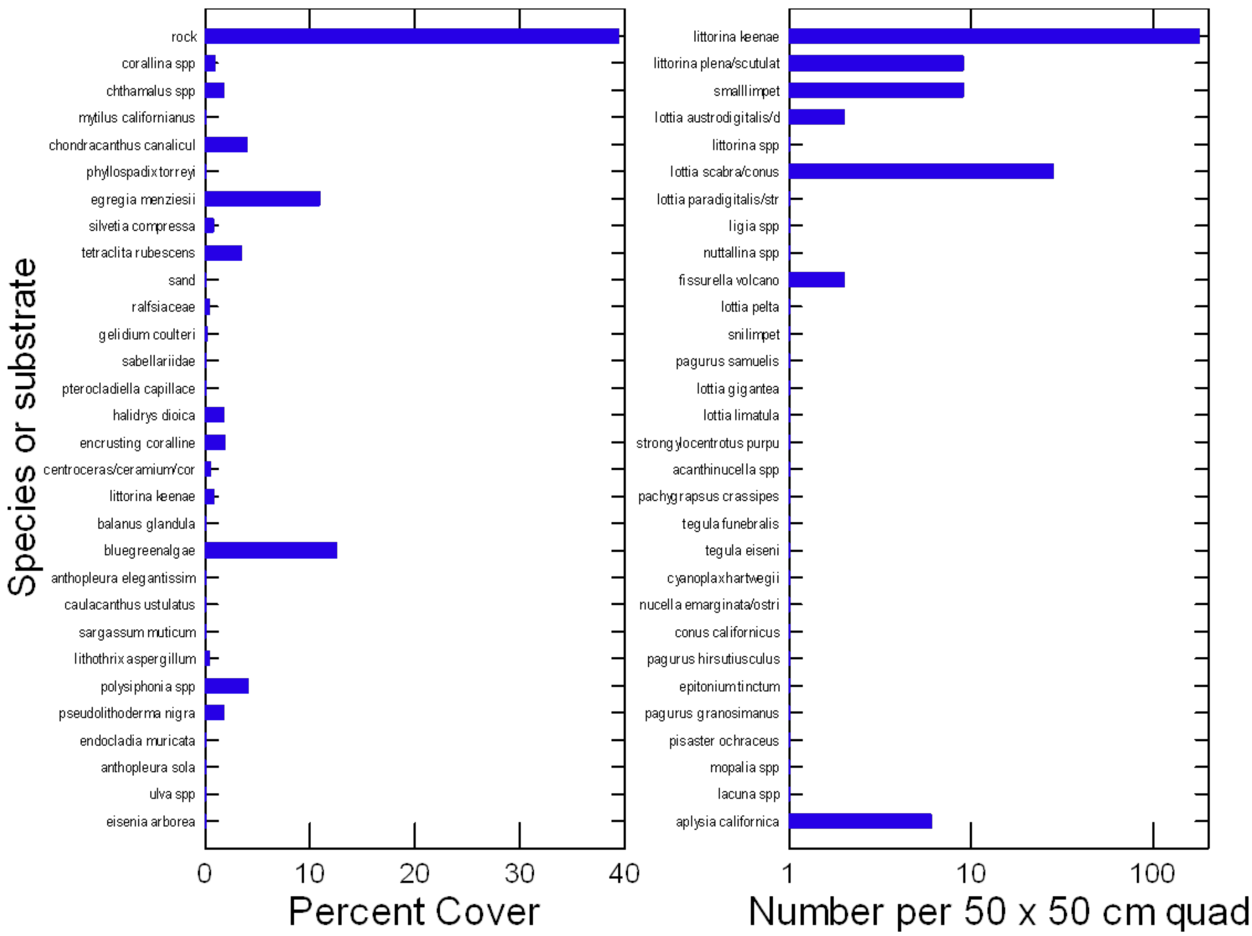
Eel Point



Percent cover (from point contact surveys) and density (from mobile species surveys). Species order is based on ranking across all sites.

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 30meters wide and 15meters long.

Boy Scout Camp



Percent cover (from point contact surveys) and density (from mobile species surveys). Species order is based on ranking across all sites.

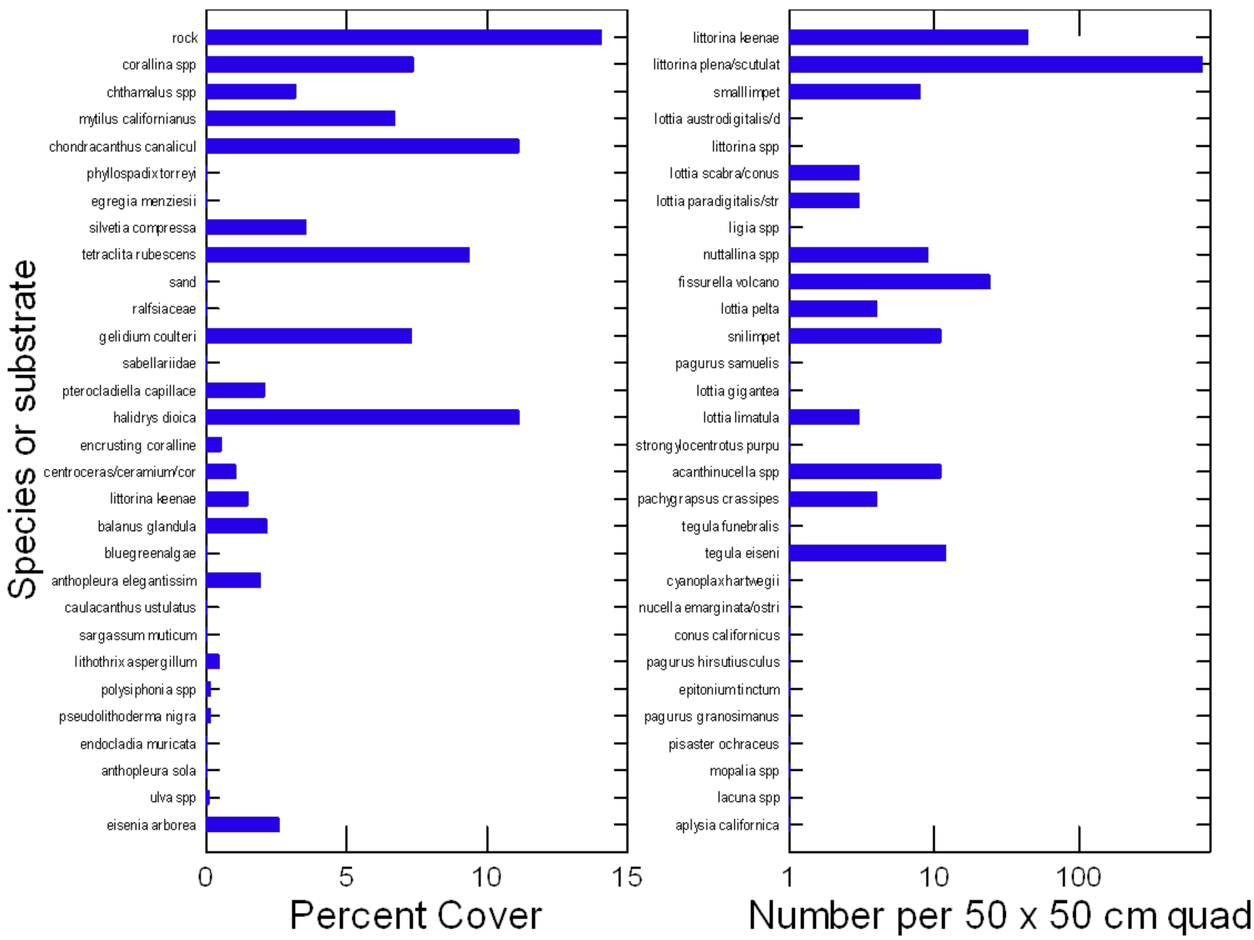
Santa Catalina Island

★ Discharge site in ASBS

■ Reference Site

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

Bird Rock

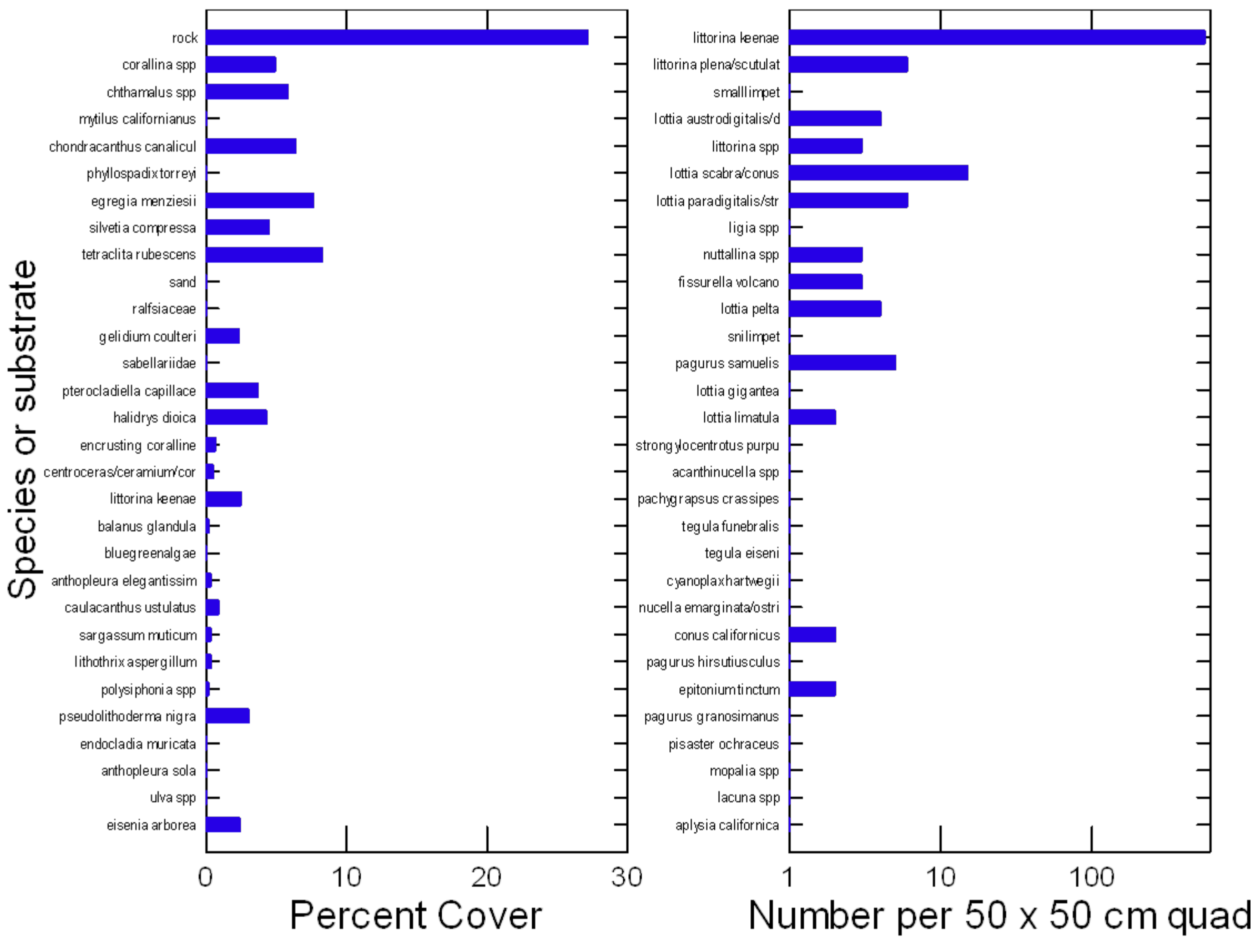


Percent cover (from point contact surveys) and density (from mobile species surveys). Species order is based on ranking across all sites.

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 8meters wide and 11meters long.

The downcoast section is 10meters wide and 12meters long. The nearest storm water discharge is approximately 100meters from survey bolt OT6.

Big Fisherman Cove

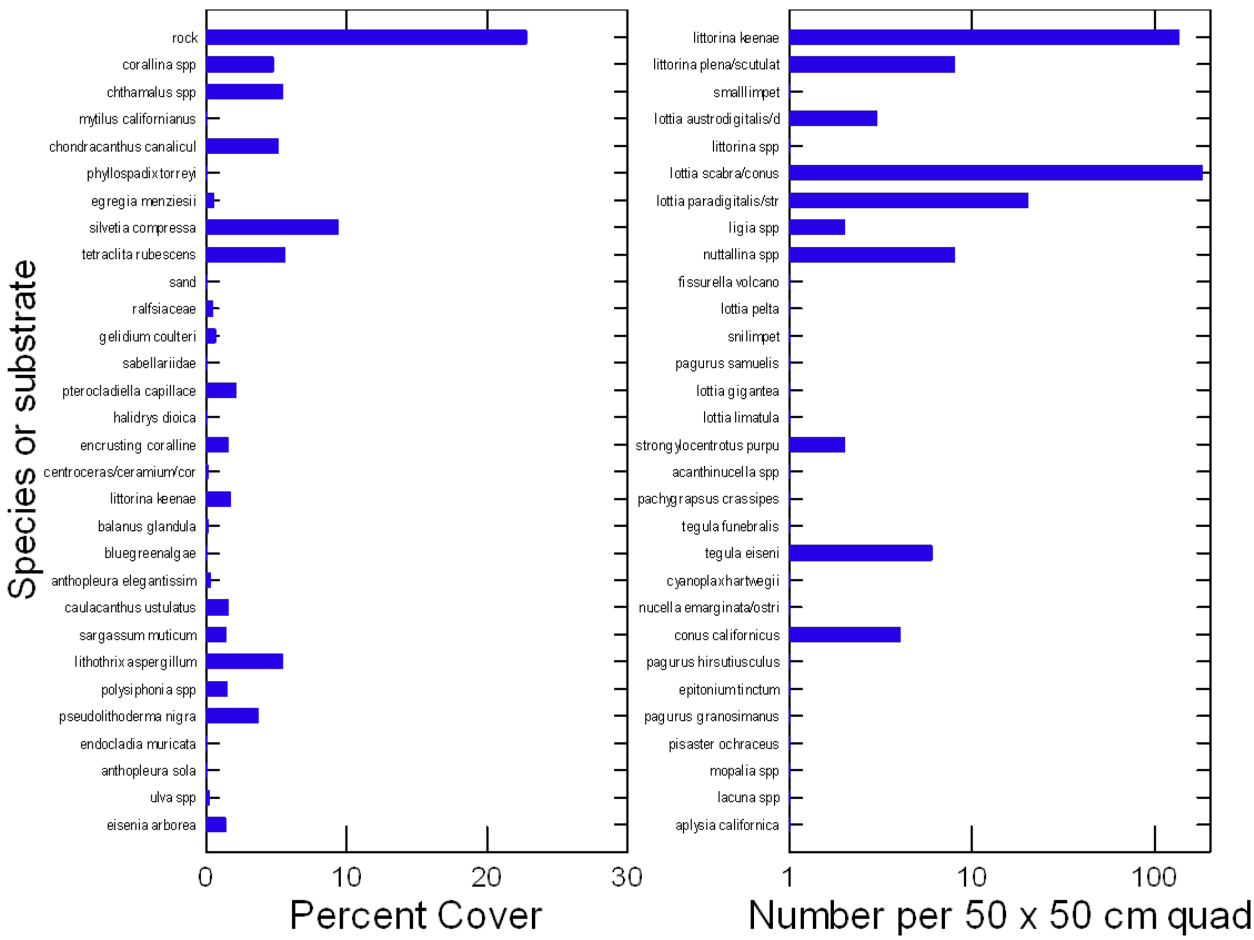


Percent cover (from point contact surveys) and density (from mobile species surveys). Species order is based on ranking across all sites.

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 20meters wide and 10meters long.

The nearest storm water discharge pipe is approximately 150meters from survey bolt OT1.

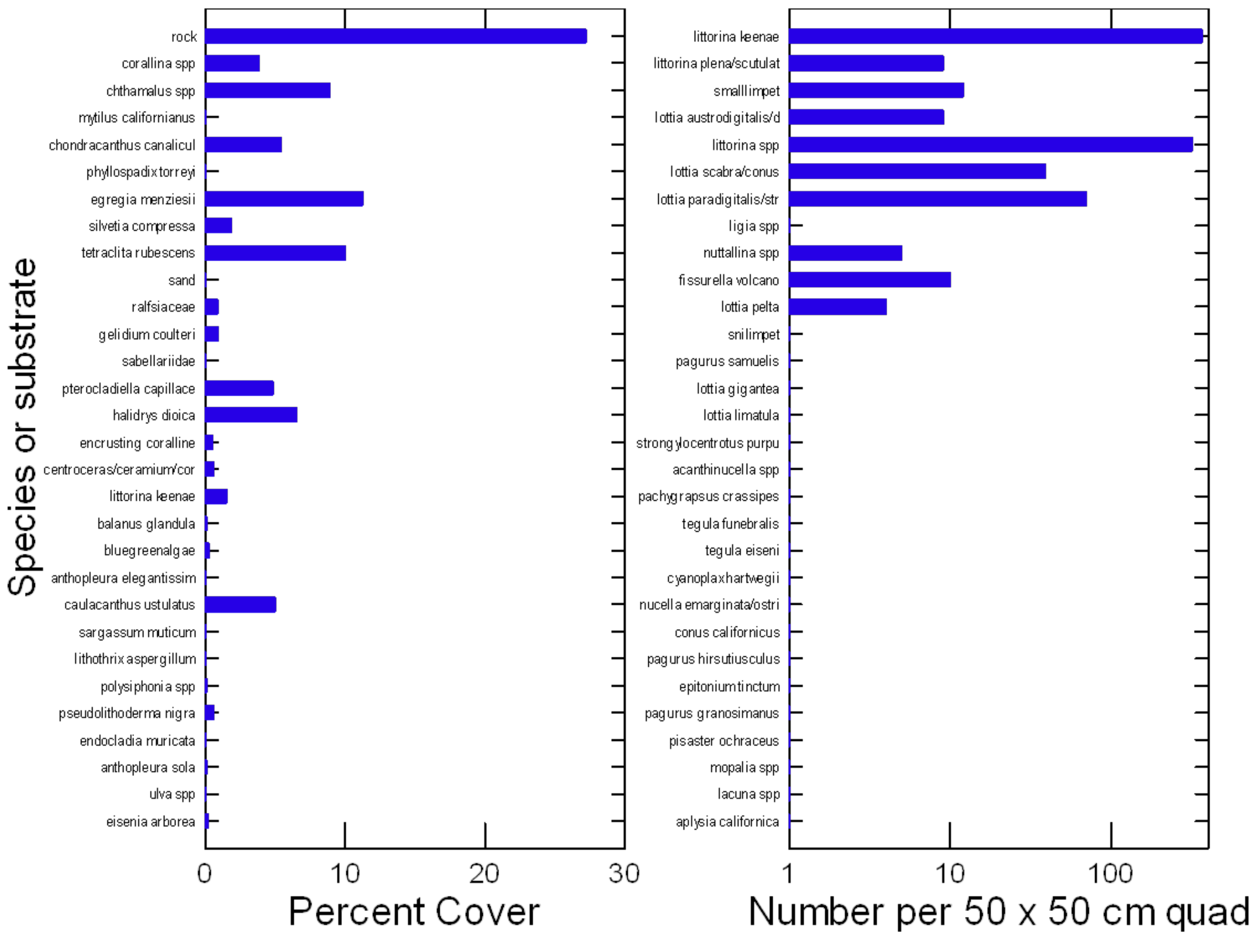
Two Harbors



Percent cover (from point contact surveys) and density (from mobile species surveys). Species order is based on ranking across all sites.

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 20meters wide and 10meters long.

Goat Harbor

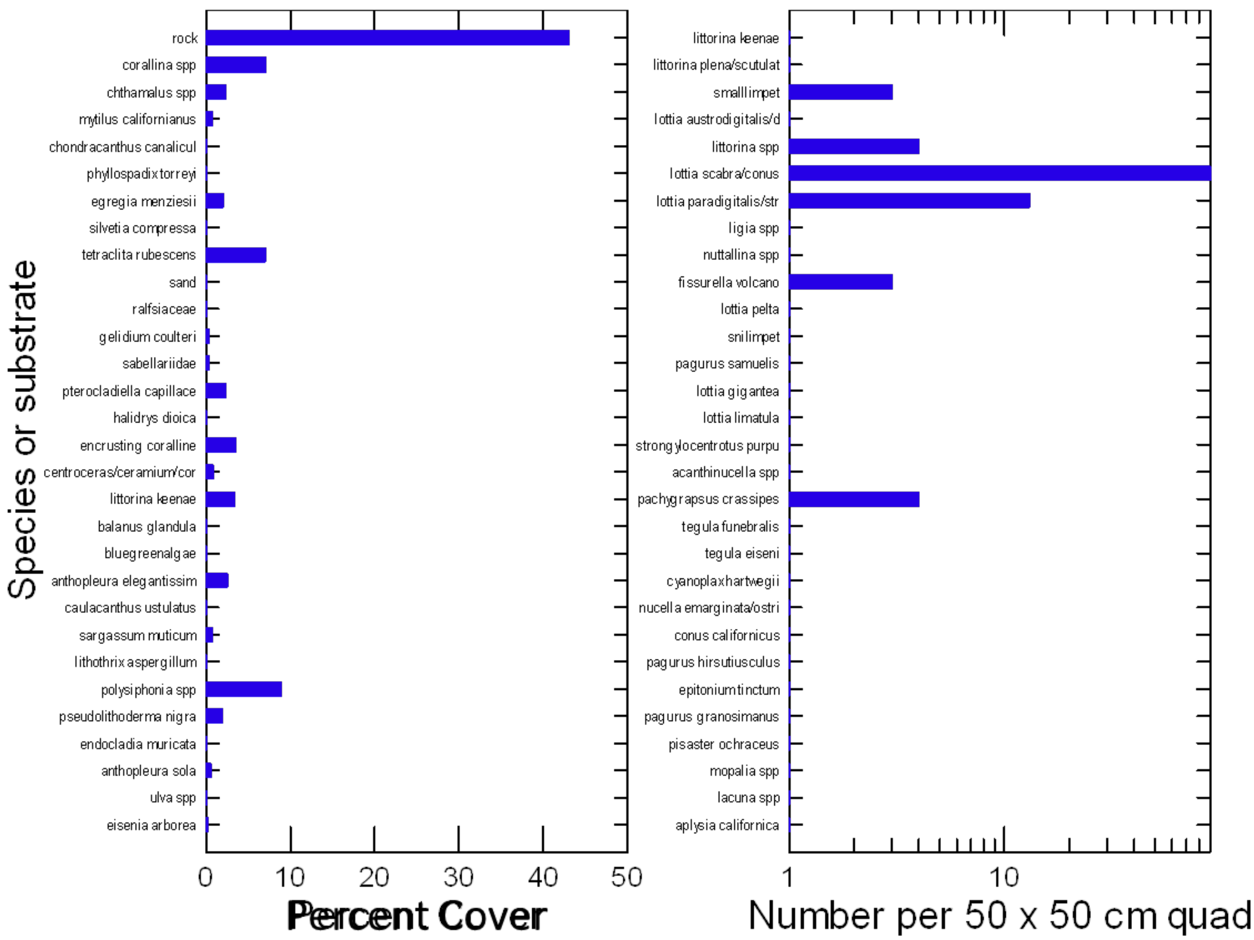


Percent cover (from point contact surveys) and density (from mobile species surveys). Species order is based on ranking across all sites.

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

The nearest storm water discharge is approximately 25meters from survey bolt OT1.

Avalon Quarry



Percent cover (from point contact surveys) and density (from mobile species surveys). Species order is based on ranking across all sites.