Southern California Bight 2008 Regional Monitoring Program

Rocky Reefs

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SOUTHERN CALIFORNIA BIGHT 2008 REGIONAL MONITORING PROGRAM: V. ROCKY REEFS

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Foreword

The Southern California Bight 2008 Regional Monitoring Program (Bight'08) is part of an effort to provide an integrated assessment of the Southern California Bight through cooperative regional-scale monitoring. Bight'08 is a continuation of regional surveys conducted in 1994 (Allen *et al.* 1998), 1998 (Allen *et al.* 2002a) and represents the joint efforts of more than 90 organizations. Bight '08 is organized into three technical components: 1) Coastal Ecology; 2) Shoreline Microbiology; and 3) Water Quality. This report presents the results of the Rocky Reef portion of Bight'08, which is part of the Coastal Ecology Component. Other Coastal Ecology components include sediment toxicology, sediment chemistry, and benthic Macrofauna. Copies of this and other Bight'08 guidance manuals, data, and reports are available for download at www.sccwrp.org.

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EXECUTIVE SUMMARY

The Southern California Bight (SCB) is a unique and increasingly critical stretch of the California coastline. It is a transitional zone between the cold temperate (Oregonian) fauna fueled by the California Current to the north and the warm temperate (San Diegan) fauna from the south, exemplified by the distribution of subtidal rocky reef fishes (Hubbs 1960; Horn 1978; Pondella et al. 2005; Horn 2006). Including its eight channel islands, the linear coastline of the SCB is roughly equal to the rest of the state. Irrespective of the biogeographic intricacies, the physical constitution of the coastline along the mainland SCB is dominated by sandy beaches, with approximately 15% rocky-headlands, a stark contrast to the remainder of the state where rock is much more abundant. Due to accessibility and increasing stress by a growing population, these reefs are under a variety of anthropogenic stressors (e.g. turbidity, river plumes, sedimentation, overfishing and pollution) and harmful algal blooms, which in many instances are not well understood and in all cases necessitate a Bight-wide perspective and coordination to contextualize and manage these effects.

The Southern California Bight 2008 Regional Marine Monitoring Program (Bight '08) is an integrated, collaborative study and provides a unique platform for collecting data for bightwide perspectives. While the subtidal reefs in the SCB have been studied for decades, quantitative large scale spatial and temporal studies have been relatively limited. Some excellent programs have developed including the Channel Islands National Park Service's Kelp Forest Monitoring Program, the Partnership for the Interdisciplinary Study of Coastal Oceans (PISCO), the Vantuna Research Group at Occidental College and more recently Reef Check California (RCCA). The most recent bightwide survey of the regions subtidal rocky reefs, however, was in 2003-04 when the California Department of Fish and Game supported the Cooperative Research Assessment of Nearshore Ecosystems (CRANE) that sampled 88 reefs with a standardized protocol from Santa Cruz to the Mexico Border including the southern California islands.

In Bight '08, we build on CRANE to answer three primary questions:

1. What is the distribution of hard habitats in the southern California bight?

2. What is the range of natural biological conditions in these reef assemblages?

3. How do these conditions overlay or correlate with anthropogenic factors?

Here, we report on a novel method to determine the spatial scale of reefs in the SCB. Then, we contextualize this system by describing underlying substructure of nearshore reefs. With this backdrop, the influences of biological performance (e.g., diversity, biomass) for fishes, invertebrates and algae were examined.

This report is broken into three independent chapters. The first chapter addresses the first two management questions identifying the extent of resource and quantifying the biological conditions of these reefs. The last two chapters addresses anthropogenic factors by examining management units including Areas of Special Biological Significance (ASBS) or the Santa Monica Bay National Estuary Program, in order to discern human influences on rocky reefs.

Question 1. What is the distribution of nearshore hard bottom habitats in the southern California bight?

There are approximately 120 natural rocky reefs < 30m depth in the SCB, which comprise 48,221 hectares and extend across 46% of the region's coastline. Of course, rocky reefs are much more prevalent at the offshore islands (75%) than along the mainland (25%), illustrating the importance of this nearshore habitat along the mainland where potential stressors are greatest. Multiple data sources including side-scan sonar, aerial overflights, satellite imagery, and subtidal visual surveys were combined to create our estimates of habitat extent. As a result, our estimates are at least 20% greater than would be expected from just analyzing the GIS layers available in 2008 (Kelner 2005). Additional data continues to be collected, helping to refine our estimates of rocky reef extent.

Reef types based on substrate were identified during Bight '08 that can be grouped into six major reef categories: low relief and cobble (Type VI), flat reefs (Type V), middle relief (Type IV), high relief (Type III), wall reefs (Type II), and pinnacles (Type I). Higher relief sites were relatively more common at the offshore islands and lower relief reefs were relatively more common along the mainland. Low relief sites tend to be at greater risk from stressors such as burial and sedimentation. These differences in habitat, along with the predominant oceanic conditions, are important co-factors that must be accounted for when interpreting biological condition through the SCB.

Question 2. What is the range of natural biological conditions in these reef assemblages?

With only two exceptions, the conspicuous giant kelp, *Macrocystis pyrifera*, was present at all 68 monitored reefs. Densities of giant kelp varied appreciably by reef, but no consistent spatial trend in kelp density was observed. This is consistent with giant kelp canopy cover estimates from overflight monitoring that indicated oceanic conditions generated favorable conditions for kelp in 2008 (MBC 2009). Part of the reason for the variation in giant kelp was the distribution of herbivorous sea urchins. Urchin barrens were found at 38% of the reefs in the SCB, including most of the Channel Islands.

A total of 78 fish species were identified during the Bight '08 rocky reef survey. Fish biomass density at some reefs surveyed was on par with fish biomass at some isolated or protected ecosystems in other parts of the world. Fish biomass densities of 300 to 550 g/m^2 in this study are noteworthy because they are similar to fish biomass densities on some isolated coral reef ecosystems still dominated by large predators (Sandin et al. 2008), and in some cases double or triple the fish biomass found on rocky reefs in Marine Protected Areas in the Mediterranean (Harmelin-Vivien et al. 2008) and Australia (Edgar and Stuart-Smith 2009). Our biomass densities were typically driven by relatively high densities of large bodied fishes, although in some cases they were due to either an extremely high density of common small bodied reef fish or just a few very large-bodied fish (*Stereolepis gigas*).

Question 3. How do these conditions overlay or correlate with anthropogenic factors?

Areas of Special Biological Significance are supposed to have stringent water quality protection including no discharge of waste. Yet more than 500 discharge outfalls into ASBS have been identified along the southern California mainland. Bight '08 examined four metrics that could indicate water quality impacts including urchin barrens, tube worm density, extent of bare rock, and kelp density. Of these, urchin barrens and tube worm density were significantly greater on average at ASBS than non-ASBS reefs. Urchin barrens are an indicator of a disturbed kelp ecosystem, where they may persist for years to tens of years as an alternative stable state (Steneck 2002). Unequivocally, urchins have been associated with pollution on mainland reefs (North 1964). While in other ecosystems urchins have been linked to top down (loss of predators) forcing, this has been suggested (Steneck 2002), but not demonstrated in Southern California (Foster 2010). Nonetheless, it is possible that variable fishing pressure among ASBSs influenced the presence/absence of urchin barrens. Given this variability and the lack of an apparent causal factor for the increased density of urchins in ASBS across all reef categories, further sampling over finer scales would be necessary to draw conclusions.

A relatively high percent cover of tube worms may be suggestive of high sediment loads, which these worms use to construct their tubes. Especially high densities of tube worms were found near discharges that generate large sediment yields (e.g., Los Angeles River, Santa Clara River). However, high suspended solid concentrations were also measured near direct ASBS discharges at these same reefs (Schiff et al. 2011). Whether the increased tube worm density is the result of local direct ASBS discharges or indirect distant discharges remains unknown.

Santa Monica Bay generates perhaps the greatest fishing pressure in the SCB because of its proximity to Los Angeles. Kelp bass and California sheephead had significantly smaller size structure compared to other mainland and island reefs, clearly indicating fishing pressure on these kelp bed species. Barred Sand Bass, which is not primarily a kelp bed species, was not significantly different from other mainland sites. Red Urchins, a commercially harvested species, were significantly larger in Santa Monica Bay than other mainland sites.

Recommendations

There were three overarching recommendations that came out of the Bight '08 Rocky Reef Program. The first overarching recommendation addressed improved assessments. Questions about water quality and/or fishing impacts were limited because tools for assessing these impacts were inadequate. For example, this was the first attempt to develop and apply tools to address water quality issues at a regional scale. New tools need to be developed, especially those that can incorporate, and hopefully differentiate between, stressors associated with water quality and overfishing. The second overarching recommendation was the integration of additional data types. For example, mapping could be improved with some of the new technologically advanced information being developed for resource management. Examining the effect of overfishing could be improved with additional information on fishing pressure. Even sampling method improvements could help identify fishing pressure by collecting additional information on density and size classes for certain species. The third overarching recommendation suggests follow-up actions in response to regional survey results. The regional survey produces a wealth of contextual information managers should use for initiating local actions. For example, where ASBS water quality impacts could be occurring, site specific monitoring should follow to confirm the impacts and identify remedial actions. Ideally, future surveys should be enhanced to maximize study designs for adaptive decision making.

I. PHYSICAL AND BIOLOGICAL CHARACTERISTICS OF NEARSHORE ROCKY REEFS IN THE SOUTHERN CALIFORNIA BIGHT

Introduction

The Southern California Bight (SCB) is a unique and increasingly critical stretch of the California coastline. It is a transitional zone between the cold temperate (Oregonian) fauna fueled by the California Current to the north and the warm temperate (San Diegan) fauna from the south, exemplified by the distribution of subtidal rocky reef fishes (Hubbs 1960; Horn 1978; Pondella et al. 2005; Horn 2006). Including its eight channel islands, the linear coastline of the SCB is roughly equal to the rest of the state. Irrespective of the biogeographic intricacies, the physical constitution of the coastline along the mainland SCB is dominated by sandy beaches, with approximately 15% rocky-headlands, a stark contrast to the remainder of the state. The southern California islands, however, support a greater proportion of coastal reefs versus soft substrate in the nearshore environment (Ebeling 1980; Pondella 2000). Due to accessibility and increasing stress by a growing population, these reefs are under a variety of anthropogenic stressors (e.g. turbidity, river plumes, sedimentation, overfishing and pollution) and harmful algal blooms, which in many instances are not well understood and in all cases necessitate a Bight-wide perspective and coordination to contextualize and manage these effects. Recently it has been demonstrated that significant management actions can have significant positive effects on this complex ecosystem (Pondella and Allen 2008). The next major management action in this arena will be the creation of Marine Protected Areas (MPAs) throughout the bight. These MPAs were generally placed on rocky headlands, as this habitat is limiting in the SCB. There is a great deal of impetus to generate and synthesize physical and biological data that will enable us to contextualize this management action.

While the subtidal reefs in the SCB have been highly studied for decades, quantitative large scale spatial and temporal studies have been relatively limited. Exceptions include the Channel Islands National Park Service's Kelp Forest Monitoring Program, the Partnership for the Interdisciplinary Study of Coastal Oceans (PISCO), the Vantuna Research Group at Occidental College and more recently Reef Check California (RCCA). In 2003-04 the CDFG supported a cooperative research program referred to as the Cooperative Research Assessment of Nearshore Ecosystems (CRANE) that sampled 88 reefs with a standardized protocol from Santa Cruz to the Mexico Border including the southern California islands.

The first quantitative assessment of many of the southern California and Baja Islands (Pondella et al. 2005) found that for fishes, island fauna are generally distinct from each other and that their similarities are not a function of distance, but rather reflect the physical oceanographic regime where they are found. Due to the unique physical oceanographic conditions in the SCB, we do not find a latitudinal clinal variation in these populations. Later, PISCO and the VRG combined their data for NOAA's (2005) Biogeographic Assessment of the Channel Islands National Marine Sanctuary (CINMS) and found that for the islands (San Miguel and Santa Rosa were not included) there were essentially three groups: a warm group (San Clemente, Santa Catalina, Santa Barbara, Anacapa and the east end of Santa Cruz) a transitional fauna (Santa Cruz and San Nicolas) and a cold group (Clark 2005). In an analysis of the CRANE data set, San Miguel and Santa Rosa fell into the cold temperate fauna

(Tenera_Environmental 2006). Analyses of the CRANE data found essentially a cold temperate, warm temperate and a transitional fauna in the SCB.

While general biogeographic patterns have been discerned for this ecosystem, a more surprising gap in our knowledge is the structure, quality and quantity of shallow nearshore reefs in the SCB. Complicating these knowledge gaps is the necessity of understanding processes on both small and large spatial scales (10^1-10^5 m) (Garcia-Charton 2004).

Here we report on a novel method to determine the spatial scale of reefs in the SCB. Then, we contextualize this system by describing underlying substructure of nearshore reefs. With this backdrop, the influences of biological performance (i.e. diversity, biomass etc.) for fishes, invertebrates and algae were examined.

Methods

Mapping-The best compilations of mapped rocky reef habitat in the SCB were assembled in GIS. These included maps of hard bottom habitats and kelp canopy (Kelner 2005). GIS spatial analysis techniques were used to integrate existing spatial data that characterizes bottom type, kelp cover, and bathymetry to create a preliminary habitat map. Using these data in GIS, we met with experts who have conducted multiple subtidal scuba research projects on various geographic areas of the SCB. These working groups delineated and categorized all reefs in the SCB (Figure I-1). The size of each reef was calculated in GIS and categorized as large, medium or small based upon the distribution of reef sizes. In more well-studied regions (i.e. Palos Verdes, Catalina etc.) investigators tended to identify reefs on a finer scale, which would bias the sampling draw to these regions. Similarly, large reef tracks would be deemphasized. Thus, reef designations were adjusted to be as consistent as possible in size and distribution throughout the bight. At Horseshoe Kelp in Los Angeles County and Point Loma, the large reef areas were broken into two and three reefs, respectively, for the sampling draw.

***Station Draw*-**Reefs were coded as island or mainland within each biogeographic realm, San Diegan (warm temperate) or Oregonian (cold temperate). Biogeographic realm was determined by biogeographic assessment of benthic fish assemblages studied during the 2003-04 CRANE survey (Tenera_Environmental 2006). In this biogeographic analysis young-of-year (YOY) fishes whose density is seasonal, and highly abundant pelagic species (*Engraulis mordax* and *Sardinops sagax*) present at only two sites were excluded from the data set. All statistics were run using PRIMER (version 6). The number of fishes observed by station were Log (x+1) transformed. A Bray-Curtis similarity matrix was then calculated and a hierarchical cluster analysis was performed. Using the similarity matrix, non-metric multi-dimensional scaling was performed and using 45% similarity ellipses calculated from the Bray-Curtis cluster the biogeographic regions were determined. Oil platforms, artificial reefs, breakwaters and jetties were not included in this mapping effort because they are well mapped and not part of the random station draw. For the spatial scale aspect of this program, 60 natural rocky reefs (Figure I-1) from this map were selected using the Generalized Random Tessellation Stratified (GRTS) Spatially-Balanced Survey Designs (Stevens and Olsen, 2004), a probability-based design developed for Monitoring Aquatic Resources, through EPA's Environmental Monitoring and Assessment Program

(EMAP) (Stevens 1999). The advantage of the GRTS design is that it allows for random sampling in a way that provides good spatial coverage (without the clumping of sites often seen with simple random sampling). In addition, various strata or subpopulations can be defined and weighted proportionally to a host of subpopulation characteristics (e.g., the size of the resource, the size of the reef, variabilities of subpopulation estimates, etc.) so as to maximize efficiency when estimating population totals or comparing among subpopulations.

Sampling Unit-a sampling cell consisted of at least 250m of reef habitat. Within each cell four depth strata (if present) were sampled and geo referenced. These strata are the inner (~5m), middle (~10m) and outer (~15m) and deep strata (~25m) portions of a natural reef or kelp bed. Within each depth strata two benthic sampling protocols were completed: Uniform Point Contact (UPC) and macro invertebrate and algae sampling (Swath). For fishes, four benthic, mid-depth and canopy (when present) transects were completed in each depth zone. Canopy transects were completed only if kelp reached the surface, then the canopy transects were completed. The maximum sampling effort for a reef included 16 benthic fish transects, 16 midwater fish transects, 16 canopy fish transects, 8 UPC and 8 Swath transects. In addition, 100 red and 100 purple urchins were measured in each cell. All transects were 30m; swath and fish transects were 30m x 2m belt transects. Considering their paucity for the majority of the SCB the size and species of any abalone was recorded.

In addition, nine breakwater habitats were sampled at King Harbor, Redondo Beach (3 reefs) and six reefs at the Port of Los Angeles. Eleven of the 27 southern California oil platforms (B, Edith, Ellen, Elly, Esther, Eureka, Eva, Gilda, Grace, Holly and Irene) and three offshore pinnacle reefs (The Nine, San Luis, SuperPin) were sampled for fishes using a previously determined optimal sampling strategy due to their configuration (Love 2003; Martin 2010).

UPC- Percent cover of substrate type, substrate relief and benthic organisms were recorded at each meter mark along the 30 m transect tape. Substrate percentages in the following categories were estimated within each 10 m segment: bedrock (≥ 1 m), boulder (1 m), cobble (≤10 cm), and sand. Substrate relief was the maximum relief within a rectangle centered on the point that is 0.5 meter along the tape and 1 meter wide. To contact benthic organisms, the line is pushed down and the species under the tape is recorded. If the line could not contact the substrate, the diver's finger was used to mark the spot. Epiphytes, epizooids and mobile organisms were not recorded. If the contact point was on a blade of *Laminaria*, brittlestars or the sea cucumber *Pachythione rubra*, the organism under the point was recorded and it was noted that the point was under one of these organisms. The superlayer was also recorded. In addition to quantifying benthic organisms, the following types of bare substrate were recorded, if contacted: rock, sand, shell debris, and mud.

The percentage of each type of substrate category (bedrock, boulder, cobble or sand) was determined by pooling the number of contact points for all replicates at each site by category, and dividing the sum of each category by the total number of contact points at that site. Percentage of reef relief category (0-0.1m, 0.1-1m, 1-2m or >2m) was calculated in the same manner. All benthic reef coverage was categorized into groups that roughly follow taxonomic divisions or appropriately named abiotic groups and densities for each group were calculated by site. Reef structure categories (% relief and substrate) were square root transformed and normalized prior to being clustered using Euclidean distances. Percent reef cover categories were square root transformed and then clustered using a zero-adjusted Bray-Curtis similarity index. These two hierarchical clusters were examined using the RELATE statistic, ρ, using the Spearman Rank Correlation with 999 permutations.

Swath-The purpose of the swath sampling was to estimate the density of conspicuous sessile and mobile macroinvertebrates (>2.5cm) as well as specific macroalgae. Individual invertebrates and algae were counted along the entire 30 m x 2 m transect. Transects were completed even if sand is encountered, but when there was sand for more than 5 m the direction of the transect was changed to the minimum necessary to remain on rocky habitat. Divers slowly swim one direction counting targeted invertebrates and then swim back along the transect counting targeted macroalgae. Cracks and crevices were searched and understory algae pushed aside. No organisms were removed. Any organism with more than half of its body inside the swath area was counted.

The following size criteria applied to counting macroalgal species: a) *Macrocystis* taller than 1 m (3.3 ft), and number of stipes per plant at 1 m above the substrate. *Macrocystis* is not subsampled; b) *Nereocystis, Pterygophora*, *Laminaria setchellii* and *Eisenia arborea* taller than 30 cm (11.8 in); c) *Laminaria farlowii* with blade greater than 10 cm (3.9 in) wide; d) *Cystoseira osmundacea* greater than 6 cm (2.4 in) wide; and e) *Costaria* and *Alaria* no size restrictions.

Transects were divided into three, 10-meter segments. Species that occurred in high densities (e.g., purple urchins) were sub-sampled if greater than 30 individuals occurred within any of the three 10 m segments on a transect. When 30 individuals of one species were counted, the diver records the meter mark at which the threshold abundance is reached and then stopped counting that species for the remainder of that segment. The species continued to be counted at the start of each following segment and the same threshold abundance rule was applied. The subsampled abundances were then extrapolated per segment to calculate an estimated total abundance per transect. All swath taxa densities were estimated based on the count or estimate of the number of each taxa over the 60 m^2 area covered by a single transect and scaled to 100 m^2. Swath species were grouped into large taxonomic categories. Mean number of stipes per *M. pyrifera* holdfast was also calculated.

Urchins- In order to gain a more accurate estimate of the size frequency distribution of local sea urchins populations, specimens were collected and measured in the areas on and around each transect. In areas where urchins were abundant at least 100 red and 100 purple urchins were collected and their test diameters measured to the nearest millimeter. Specimens were collected from each depth zone and multiple areas of the site, if possible. To avoid bias in size measurements, all emergent urchins were collected from each patch unless the patch is very large, in which case only a portion of the patch was completely collected. Urchins were measured on the boat. Very small urchins (< 1 cm) under the spine canopy of larger urchins are not measured. If it is not possible to collect 100 of each species within a total dive time of one hour, the search for urchins was suspended. Mean test size and standard error for red (*S. franciscanus*) and purple (*S. purpuratus*) urchins were calculated along with 95% confidence intervals.

Fish-The purpose of the fish sampling was to estimate density and length frequency distributions by fish species at each site. A minimum of 3 m of horizontal visibility was the acceptability cutoff. Divers swim in the pre-arranged compass direction for a distance of 30 m while counting and estimating the sizes of the fish along an isobath. All conspicuous fishes encountered along the transects were recorded. Divers count and estimated total length (TL) of small fish (< 15 cm TL) to the nearest cm, and larger fish (> 15 cm) to the nearest 5 cm interval. If a school of fish (>10 fish) is encountered, the number of fish is estimated within each size group. The observer censused fishes within the boundaries of an imaginary observation "box" slightly ahead of them as they swim along, sometimes stopping, scanning and searching within discrete areas of the "box" that is delimited by the 2 m transect width and natural features such as kelp plants or large boulders. If there is an intervening obstacle, the transect continued over it so long as the depth change was less than 2.5 m. If the obstacle is greater than 2.5 m in height, the transect circumvented it. Transects are completed even if sand is encountered. When there was sand for more than 5 m and it appeared that the habitat continued primarily as sand, the transect direction was changed to the minimum necessary to remain on rocky habitat. Physical data collected on each transect included observation depth (m), water temperature (C^o), horizontal visibility (m), surge (0-4 relative scale), and kelp canopy cover (%).

Transects were completed in 3-6 minutes depending on the number of fishes and the complexity of the habitat. Upon completing a transect, the divers then swim to the starting point of their next replicate transect within the same zone by choosing a haphazard direction along a similar depth contour. The preferred distance between transects is at least 10 m.

By dividing the number of individuals by the surface area covered on a transect (typically 60 m^2), the mean density (abundance/m^2) of fishes were calculated for each site and for each bottom, midwater and canopy transect type at each site. In addition, the total length (TL) estimates were converted to biomass using species-specific length-weight conversion power equations of the form:

$$Wt = a\mathrm{TL}^b,$$

where weight (g) is calculated from the total length (TL) estimate and ***a*** and ***b*** are species-specific constants. These constants were obtained from the literature, calculated in the laboratory or, when these two avenues were not available, adapted from the most similar morphological or proxy species. For some species only standard length (SL) to weight conversion equations were available. In these cases, TL was converted to SL using the linear function:

$$\mathrm{TL} = a\mathrm{SL} + b,$$

where ***a*** and ***b*** are species-specific parameters of the line. After the length-to-weight conversions were made, biomass density (g/m^2) was calculated in a similar fashion for each site. Site specific density and biomass were plotted with the values for benthic, midwater and canopy transects indicated separately.

All transect types were pooled for calculations of Shannon's diversity (H'). Species specific mean density and mean biomass was also calculated for all fishes observed across all sites. Prior to statistic calculation, filter criteria were applied to remove fish species or size classes that would disproportionately weight the data toward a certain site for certain statistics. Pelagic species that are not characteristic of rocky reef habitats were excluded from the data set for all analyses because they occurred infrequently, but when they were present, they generally occurred in very large numbers. These included unidentified pelagic species (i.e. "Baitball") and the following species: *Engraulis mordax, Sarda chiliensis, Sardinops sagax, Scomber japonicas, Sphyraena argentea,* and *Trachurus symmetricus*. Additionally, because sites were sampled over a time period of several months, young-of-the-year (YOY) were removed prior to density calculations because they could numerically dominate the assemblage at some sites sampled early during the sampling season but decline later in the year as a result of natural mortality. YOY were generally defined as fishes <10 cm for all species except: *Aulorhynchus flavidus, Brachyistius frenatus, Cymatogaster aggregata, Gibbonsia elegans, Gibbonsia sp., Lethops connectens, Micrometrus minimus, Rhinogobiops nicholsii*, and *Syngnathus sp*. (YOY were < 5 cm) and *Gobiidae sp.* and *Lythrypnus dalli* (YOY were <1.5 cm). YOY were not excluded from biomass calculations as their small size would tend to have a more minimal impact.

A guild value was calculated for each site. This is a three parameter model where fish assemblages are quantified based upon feeding guilds (Bond et al. 1999) using mean size (TL), density (*D*: per hectare), and fidelity (*F*). Thus, the model incorporates trophic levels (feeding guilds), a diversity factor (# of guilds), density, size and fidelity. Fidelity, defined as the proportion of occurrence of a guild at a site per sampling period, was set to 1 as there was only a single sampling period for this study. The three parameters are treated equally such that for each guild, the guild value is the square root of the product of the three parameters. The guild values are then summed to yield a guild value (GV) for each depth zone as follows:

$$GV = \sum \sqrt{mean(TL) * F * D}$$

A GV was calculated for each depth zone sampled in the survey and then summed across all depth zones to yield a guild value for each site. Density was calculated by summing the density across the three transects types (bottom, mid water and canopy) per depth zone (inner, middle, outer, deep), with the aforementioned pelagic species excluded, but YOY were included as their impact would be mitigated by mean (TL) in the model.

Results

In our calculations the Southern California coastline is 1197.2 km in length. The islands have 502.7 km of coastline while the mainland coast has a length of 694.5 km. On the mainland, rocky reefs (within 500 m) are offshore of 176.2 km (25.4%) of the coastline. At the islands, reefs are offshore of 377.4 km (75.1%) of the coastline. For the islands the faunal break was in the middle of Santa Cruz Island, on the mainland it fell in the middle of Santa Monica Bay (Figure I-1). In the cold temperate region reefs span offshore of 290.7 km of the coast and in the warm temperate region they span 262.9 km of coastline. We identified 120 natural reefs comprising 48,221 hectares in the Southern California Bight (Figure I-1, Table I-1). Roughly half the reef habitat is found in each biogeographic province (cold temperate = 52.5%). At the islands 65% of the reefs comprising 61% of the rocky habitat were described. Eighty-nine reefs were classified as major reef complexes. A priori, we also identified seventeen patchy reef areas, two cobble reefs, and twelve pinnacle/offshore deep reefs. 10,164 ha of the reefs identified in this study were previously described as soft bottom habitat. Demarcated by the 30 isobath, there are 184,439 ha of nearshore habitat in the bight, of which reefs comprised approximately a quarter (26.1%).

Natural reefs (<30 m) ranged in size from 6.2 (Begg Rock) to 2497.5 hectares (Cojo) followed by Talcot, Santa Rosa Island (2492.6 hectares). The total for three Point Loma reef designations is 2296.4 hectares. The mean size of a natural reef was 408.8 hectares (SE ± 45.3). Sixty-seven reefs were classified in the small category, with 40 as medium and 13 as large. Reef size categories had a mean of 68.5 hectares (SE ± 8.4) for small reefs, medium reefs (558.3 hectares ± 28.9) and large reefs (1566.6 hectares ± 134.4).

Table I-1. The following metrics for the Southern California Bight are summarized below for the islands, mainland, the cold temperate (Oregonian) and warm temperate (San Diegan) provinces: the length of the Southern California Coastline (Mexico to Point Conception); reef coastline length in km (reefs which are within 500m of the coast); and reef substrate for natural reefs.

Southern California Coastline length (km)

Mainland	694.5
Island	502.7
Total	**1197.2**

Reef coastline length (km)

Mainland	176.2	Cold Temperate	290.7
Island	377.4	Warm Temperate	262.9
Total	**553.6**	**Total**	**553.6**

Reef substrate by location and bioregion (ha)

Region	**Hard**	**Soft**	**Total**
Mainland	13995	4989	**18984**
Island	24062	5175	**29237**
Total	**38057**	**10164**	**48221**

Bioregion	**Hard**	**Soft**	**Total**
Cold Temperate	22636	6741	**29377**
Warm Temperate	15421	3423	**18844**
Total	**38057**	**10164**	**48221**

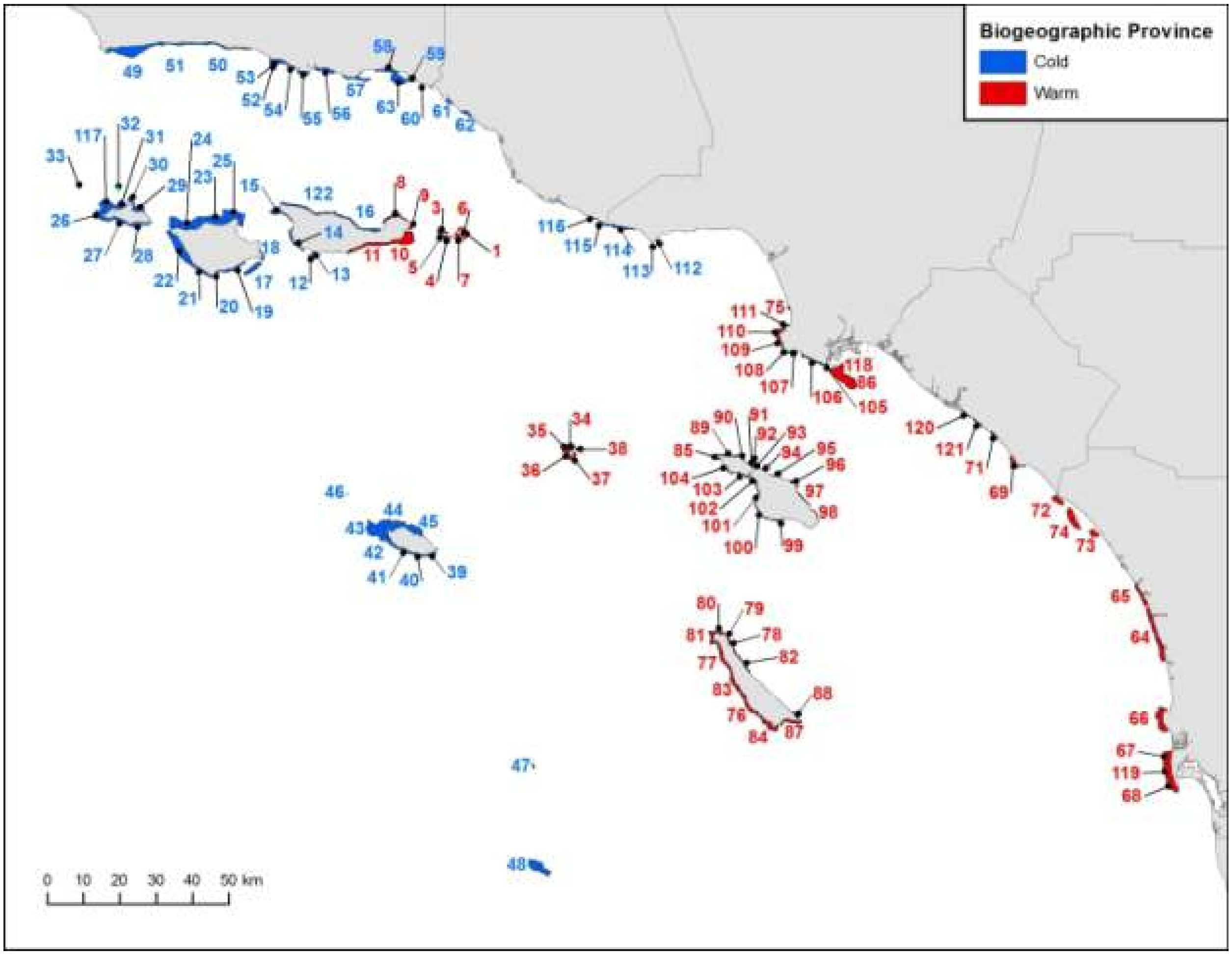

Figure I-1. Nearshore rocky reefs of the SCB. Reefs are color coded by biogeographic province (cold vs. warm) and numbers correspond to the table used for the sampling draw.

UPC

To begin to assess the range in biological conditions of the nearshore rocky reefs in the Southern California Bight, we began with a physical characterization of the reef habitat including, substrate type, relief and cover (Appendix II). Island reefs were primarily composed of bedrock or boulders (85.9%) while mainland reefs had a more even mix of substrate types (Table I-2, Figure I-2). Nearly half (47.8%) of mainland reefs had a 0-0.1 relief – more than double the fraction at the islands (23.3%). The 1-2 m and >2m relief reefs at the islands were 2 and 6 times the fraction found on the mainland, respectively (Figure I-3). For relief, breakwaters were generally more similar to island reefs. The highest fraction of abiotic cover categories (bare rock, sand, detritus, mud and shell hash) was at the mainland reefs (26.3%), followed by breakwaters (20.2%) and islands (14.3%). Algal and plant cover was fairly uniform among the three reef categories, with island reefs and breakwater having a higher percentage of invertebrate cover than mainland reefs (Table I-2, Figure I-4).

Reef structure, classified by relief and substrate (Figure I-5), varied from an oceanic pinnacle (Begg Rock) that was a sheer vertical structure composed of bedrock and an intertidal component to mainland cobble reefs such as La Jolla or Carp Reef with large fractions of sand (Figure I-2) and abiotic cover (Figure I-4) with little or no relief (Figure I-3). Six reef types were found. Type I were pinnacle reefs (Begg Rock and Banana Rock) and breakwaters comprised almost completely of bedrock or large boulders. The second grouping (Type II) was formed by two mainland pinnacle reefs (Pt. Dume and Southeast Rock) and two island reefs (Cat Canyon, SBI and Ripper's Cove, SCAI). Type II reefs had high fractions of bedrock and boulder habitat, but had a much smaller fraction of sheer or wall (> 2m relief) components as opposed to Type I reefs. Type III reefs were predominantly island reefs with some exceptions (Big Rock, Cabrillo Breakwater, Point Loma North, Point Vicente and Little Corona). These reefs were almost6 completely composed of high relief (0-2m) bedrock. Alternatively, Type IV reefs were predominantly mainland high relief reefs with three island reefs (East Quarry, SCAI, Lil Flower, SCLI, and Lion's Head, SCAI). These reefs were comprised of bedrock and boulders, but primarily lower relief (0-1m). Type V reefs were bedrock reefs that were primarily flat (0-0.1m relief). The last category (Type VI) were low relief and cobble reefs (Carp Reef and La Jolla) that had significant fractions of sand. Thus, reefs can be grouped into six major reef categories: low relief and cobble (Type VI), flat reefs (Type V), middle relief (Type IV), high relief (Type III), wall reefs (Type II), and pinnacles (Type I).

Reefs defined by their benthic cover were related in a similar manner. The distinctive offshore pinnacle reef, Begg Rock, was least similar to all other reef types. This reef supported an invertebrate-dominated benthic community (29% anemones, *Metridium senile* and *Anthopleura elegantissima*, and 41% sponges). Biogeographic processes became evident in this analysis. For instance, sites proximate to each other (ex. Laguna, Crystal Cove and Little Corona; the Horseshoe Kelp sites) were similar. The Type IV reefs which were comprised of many of the Palos Verdes Reefs were clustered together. A grouping of offshore island reefs (Type III) that include Point Vicente and Point Loma North were at the center of the cluster. Also, many of the breakwaters again fall together. Overall, this cluster was significantly related to reef structure ($\rho = 0.33$, $p < 0.1$). There was a greater fraction of abiotic cover (26.3%) at mainland reefs versus islands (14.3%) or breakwaters (20.2%). As a result island reefs had generally higher invertebrate and algal cover (Figure I-4, Table I-2). Reef structure and biogeographic affinities strongly influenced reef cover.

Table I-2. Substrate type, relief and cover categories for island reefs, mainland reefs and breakwaters.

		Islands	Mainland	Breakwaters
Substrate	**Bedrock**	68.8%	40.8%	58.5%
	Boulder	17.1%	21.4%	25.7%
	Cobble	6.6%	18.3%	4.3%
	Sand	7.5%	19.4%	11.5%
Relief	**0-.1m**	23.3%	47.8%	16.6%
	.1-1m	51.1%	43.8%	36.6%
	1-2m	12.3%	6.2%	27.5%
	>2m	13.2%	2.2%	19.3%
Cover	**Abiotic**	14.3%	26.3%	20.2%
	Algae and Seagrass	62.0%	57.1%	51.6%
	Invertebrate	23.7%	16.6%	28.3%

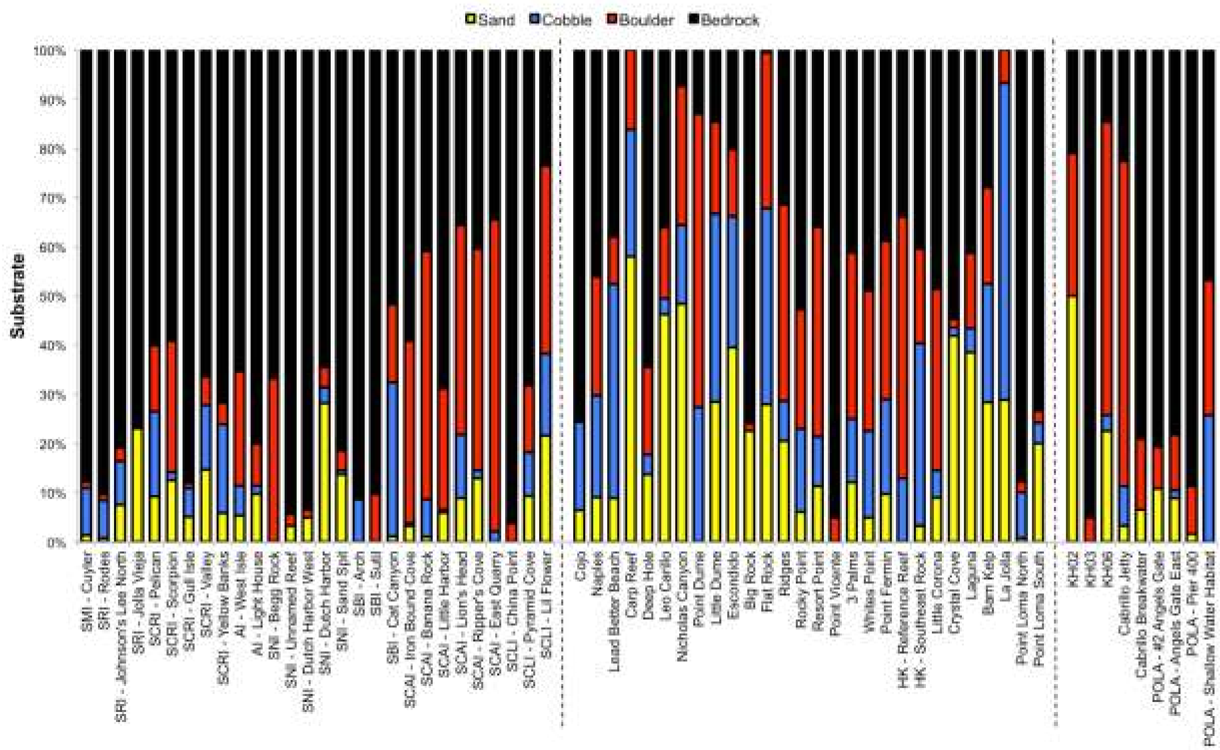

Figure I-2. Reef structure from south to north for island reefs (left), mainland reefs (middle) and breakwaters (right)

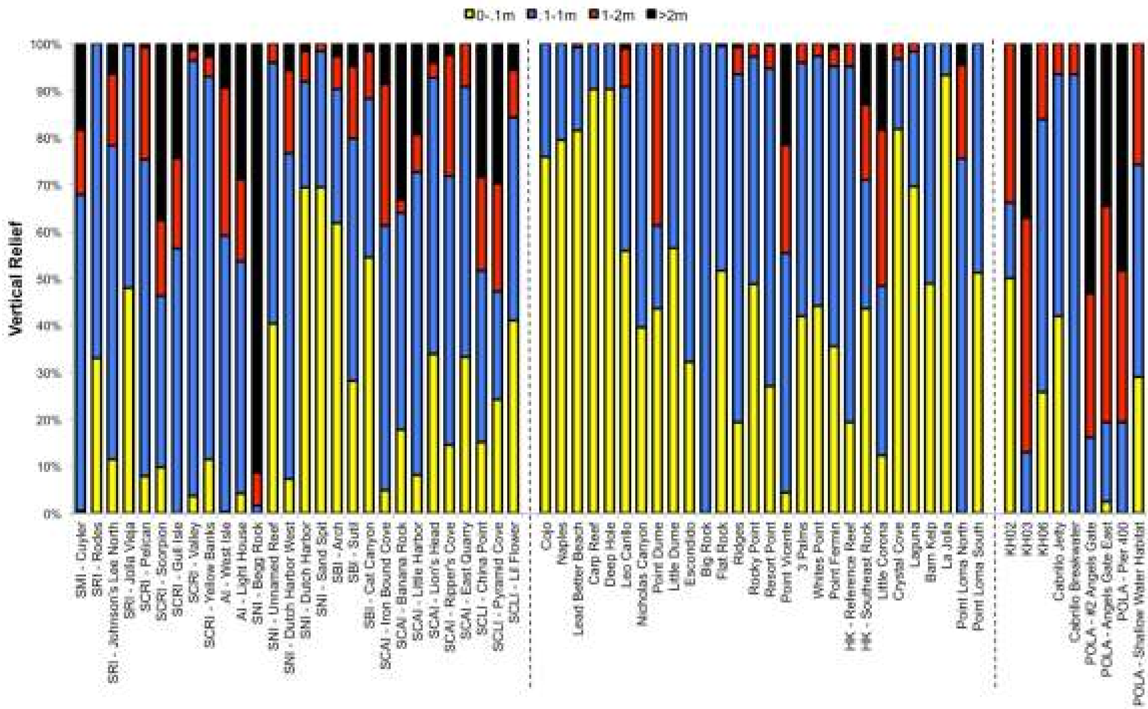

Figure I-3. Reef relief from south to north for island reefs (left), mainland reefs (middle) and breakwaters (right).

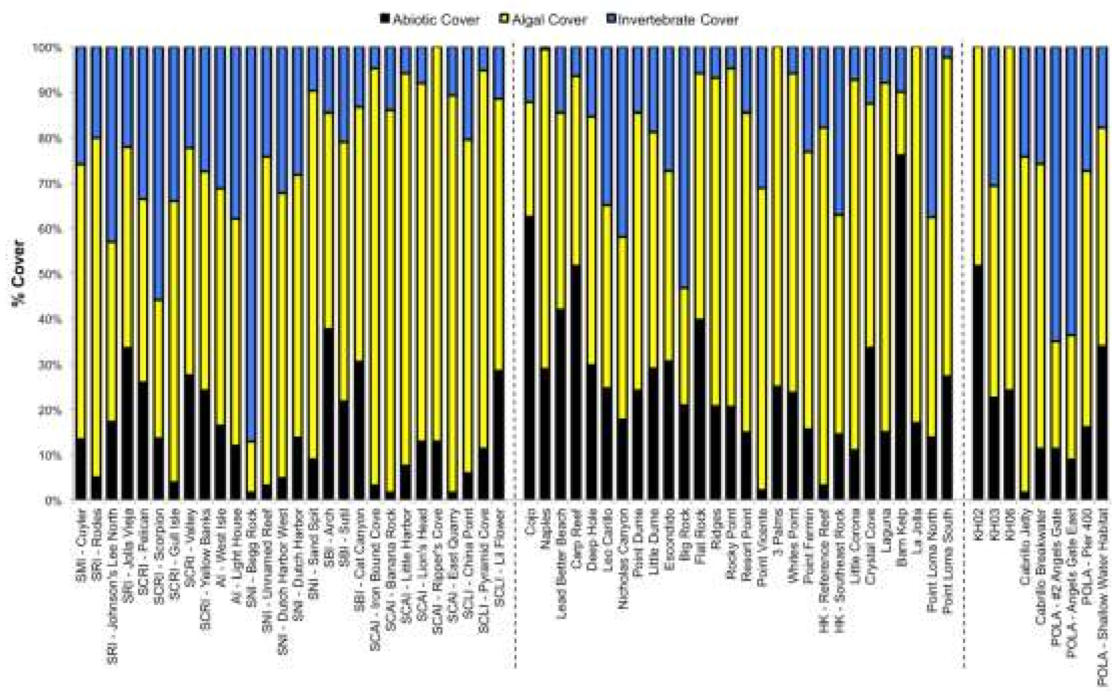

Figure I-4. Major reef cover categories: abiotic, algae (including seagrasses) and invertebrates from CRANE UPC transects for island reefs (left), mainland reefs (middle) and breakwaters (right). Reefs were organized by latitude, north to south.

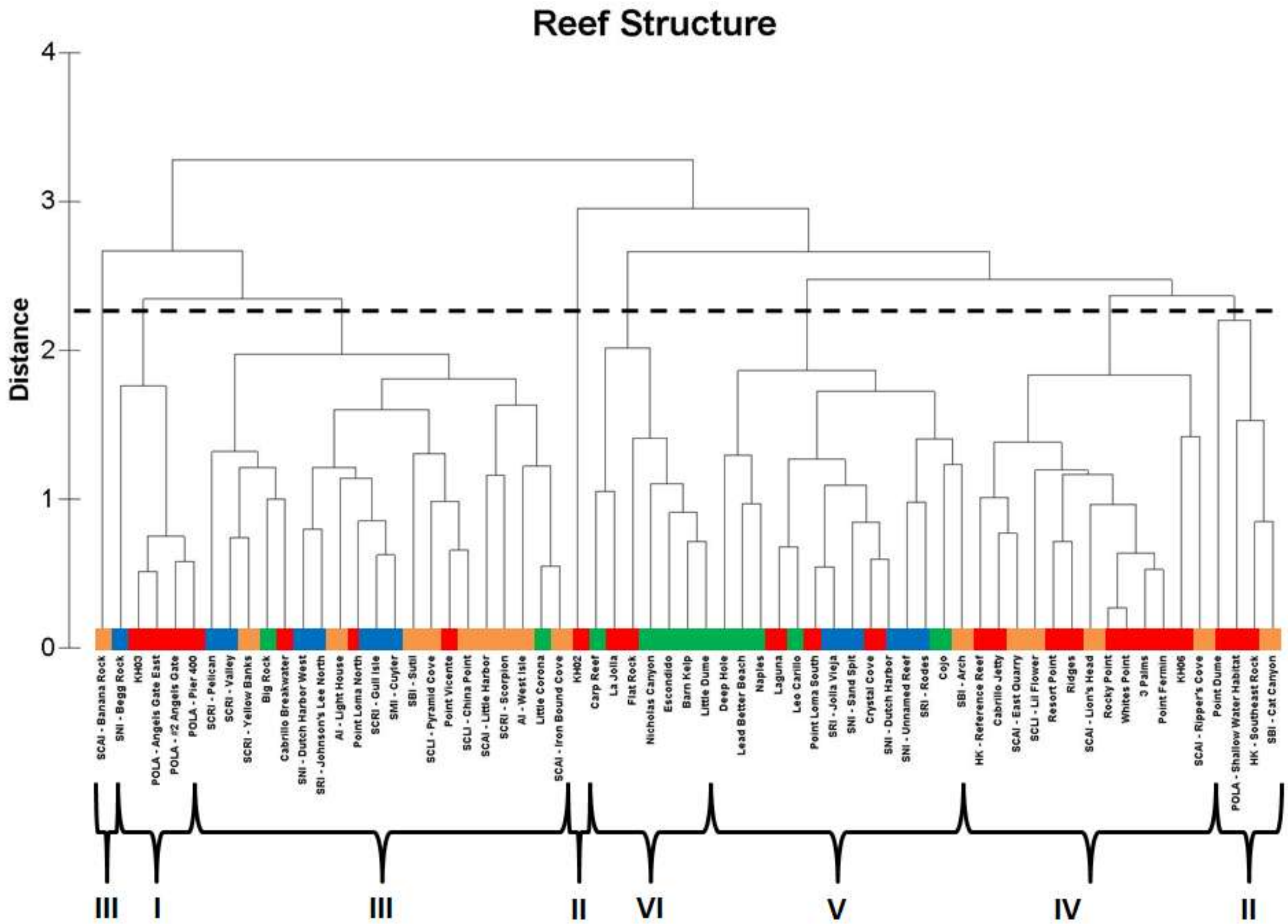

Figure I-5. Reef structure determined by clustered Euclidean distances from UPC substrate and relief measures. Habitat measures were square root transformed and normalized. Dashed line indicates reef clusters found in MDS. Colors refer to biogeographic provinces: blue = cold temperate islands, orange = warm temperate islands, green = cold temperate mainland, red = warm temperate mainland.

Giant kelp, *Macrocystis pyrifera*, was present at all sites except Begg Rock, Arch (SBI), and both Horseshoe Kelp sites (Reference and Southeast Rock; Appendix IV). Giant kelp density was fairly consistent among reefs where present (Figure I-6), while the density of understory algae fluctuated appreciably (Figure I-7). It should be noted that giant kelp density is underestimated on mainland reefs where a deep component was surveyed (i.e. Ridges and Rocky Point) since few giant kelp can survive at depths greater than 20m. The two Point Loma stations had the highest understory algal density, consisting mainly of *Pterygophora* and *Laminaria*, and the largest giant kelp thalli (Figure I-8). Understory algae was virtually absent from Cuyler (SMI), Scorpions (SCRI), Cat Canyon (SBI), Escondido and many of the breakwaters. Escondido is an urching removal/kelp restoration site. Macroinvertebrate density (Figure I-9) was lowest at some of the mainland sites (Cojo, La Jolla, Point Loma North and King Harbor). Invertebrate densities were typically dominated by urchins (Figures 9 and

10), with urchin barrens detected on 38% (25 of 65) of the reefs (Figure I-10), although macroinvertebrate density at Begg Rock was dominated by two species of anemones (*Metridium senile* and *Anthopleura elegantissima*) and included densities of *Crassedoma giganteum* and *Pisaster ochraceus* a full magnitude higher than on any other reef. Urchin barrens were not observed at San Clemente and Santa Catalina Islands, but were found in all other areas of the bight.

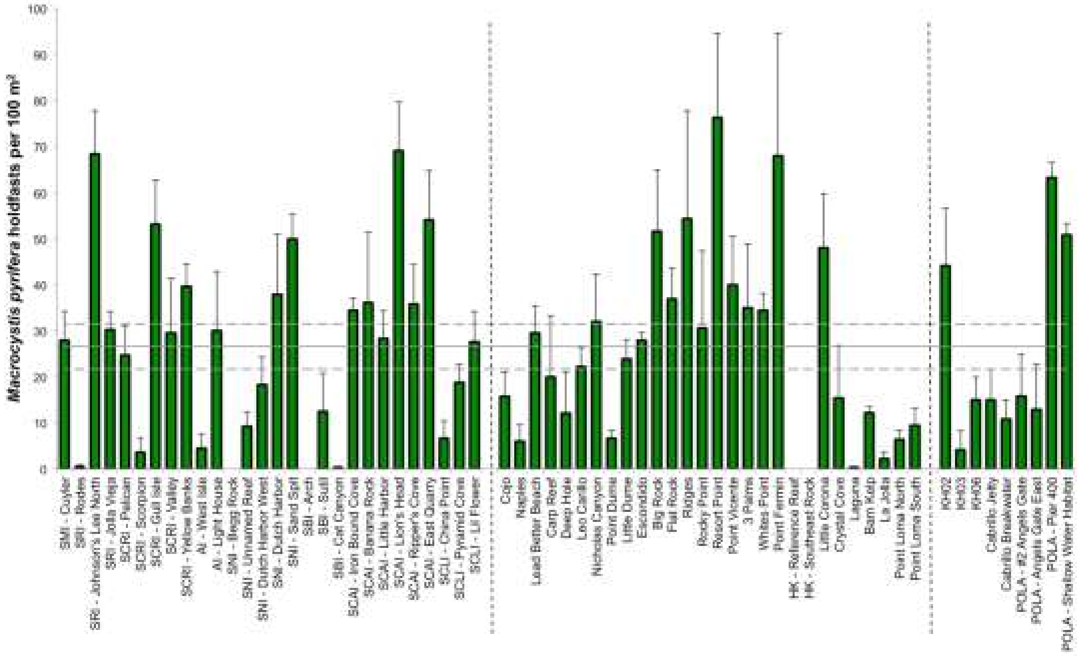

Figure I-6. Giant kelp (*Macrocystis pyrifera*) density (#/100 m^2) for island reefs (left), mainland reefs (middle) and breakwaters (right). Reefs were organized by latitude, north to south. Solid bar is the mean for the SCB and the dashed bars are the 95% confidence intervals.

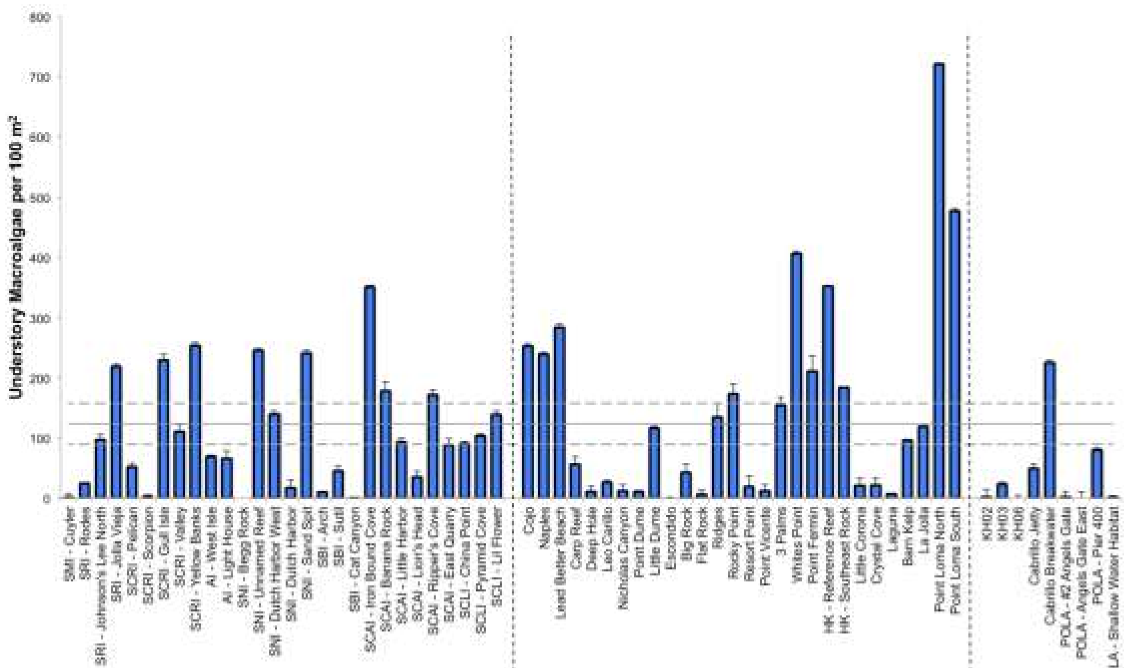

Figure I-7. Understory macroalgae density (#100 m^2) for island reefs (left), mainland reefs (middle) and breakwaters (right). Reefs were organized by latitude, north to south. Solid bar is the mean for the SCB and the dashed bars are the 95% confidence intervals.

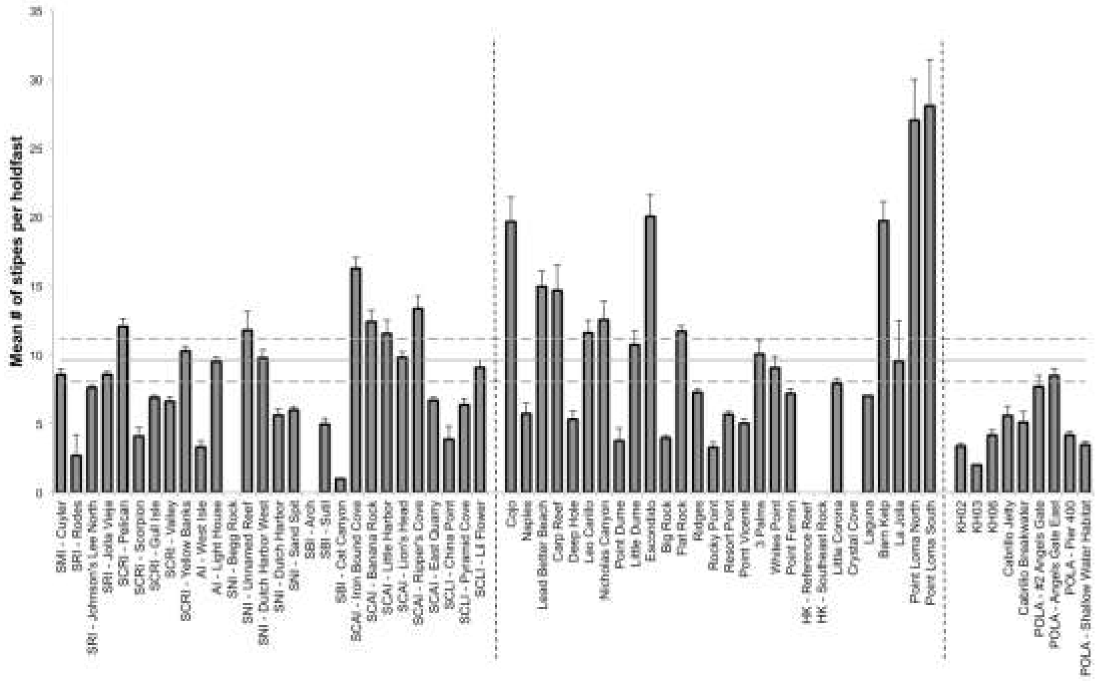

Figure I-8. Mean number (+1 SE) of *Macrocystis pyrifera* stipes for island reefs (left), mainland reefs (middle) and breakwaters (right). Reefs were organized by latitude, north to south. Solid bar is the mean for the SCB and the dashed bars are the 95% confidence intervals.

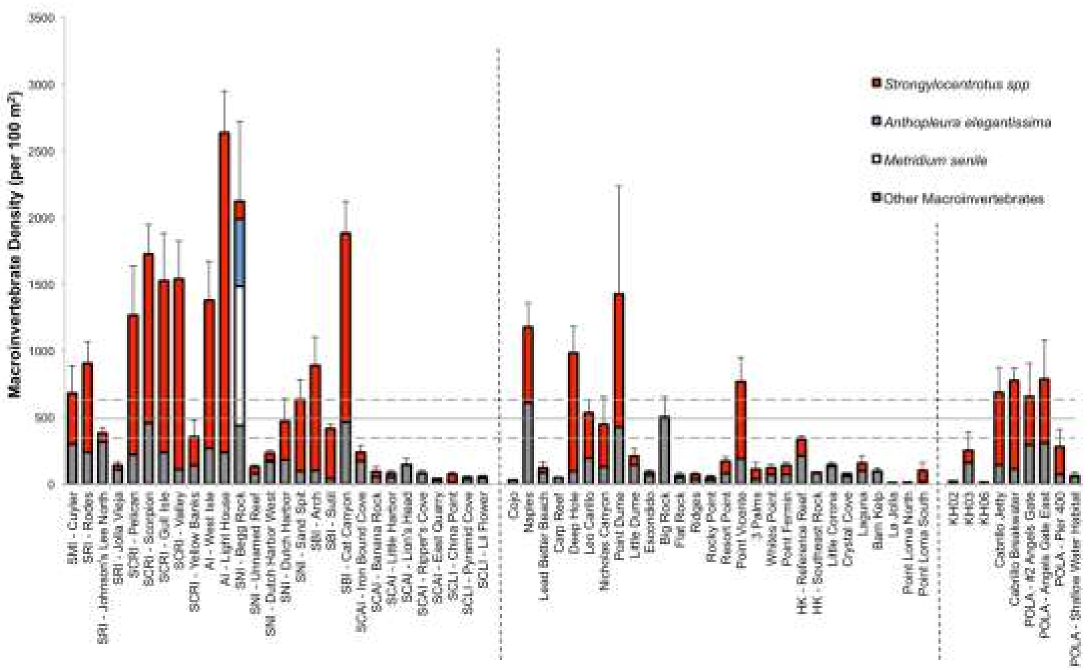

Figure I-9. Invertebrate density (#/100 m^2) for island reefs (left), mainland reefs (middle) and breakwaters (right). Reefs were organized by latitude, north to south. Solid bar is the mean for the SCB and the dashed bars are the 95% confidence intervals.

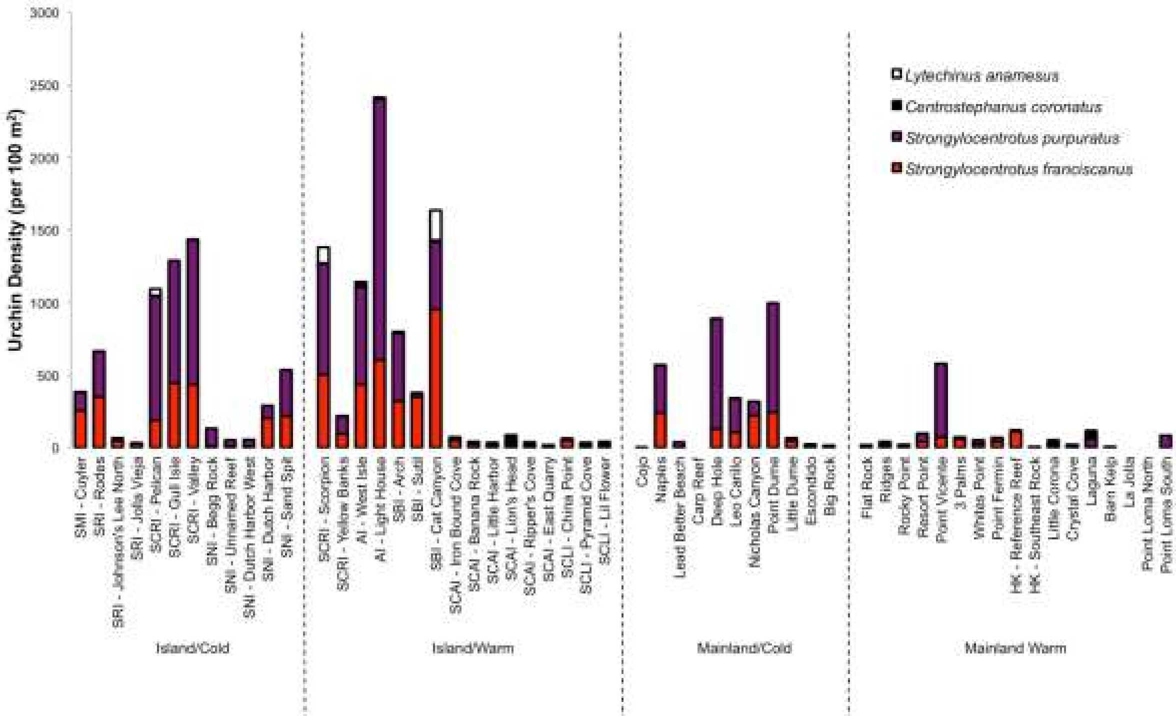

Figure I-10. Urchin density (#/100 m^2) for SCB reefs, organized by biogeographic province followed by latitude (north to south).

Fish Transects

Fish density (Figure I-11) and biomass (Figure I-12) varied substantially throughout the bight. The highest densities were found at the East Quarry, Santa Catalina Island (6.5/m^2) followed by Platform Ellen (5.2/m^2) and Platform Eureka (4.1/m^2). The lowest densities were observed at Carp Reef (0.03/m^2), Lead Better Beach (0.03/m^2) and Rodes, Santa Rosa Island (0.04/m^2). The density at the oil platforms also fluctuated appreciably. Substantial fractions of fish density were also observed in the midwater and canopy at some sites. For instance, 81% and 46% of the fish density at Lion's Head, Santa Catalina and East Quarry, Santa Catalina respectively, were in the midwater. At Nicholas Canyon, Malibu and Rippers Cove, Santa Catalina most of the fishes were distributed in the midwater and kelp canopy (69% and 79%, respectively). There does not appear to be a latitudinal trend in fish density among biogeographic regions. The stations with low fish densities had correspondingly low fish biomass. However, stations with high fish biomass did not necessarily correspond to stations with high fish densities. For instance, among the oil platforms, Platform Eva had the highest biomass (188 g/m^2), but relatively moderate density (0.4/m^2). Similarly Platforms Ellen and Eureka had low biomass density (41 and 33 g/m^2, respectively) and high fish density (5.3 and 4.1 /m^2, respectively). Big Rock, Malibu had the highest biomass density (552 g/m^2), followed by Nicholas Canyon (441 g/m^2) and Crystal Cove (412 g/m^2). Large fractions of biomass density were also observed in the water column and canopy. Examples of this are East Quarry (63%), Rocky Point (68%), and Pyramid Cove (76%).

A total of 78 fish species were observed across all sites. Bightwide, the most dominant fish species in terms of numerical density were the schooling blacksmith (0.20 /m^2) and senorita (0.12 /m^2) (Figure I-13), followed by kelp perch (0.04 /m^2). Other primarily schooling species in the top twenty were tubesnouts, opaleye, jacksmelt, topsmelt and blue rockfish. These species were observed throughout the water column, and they were primarily found in the midwater and canopy aspects of the kelp forest. Highly numerous benthic species (kelp bass, California sheephead, garibaldi and black perch) rounded out the top nine for fish density (Figure I-13). California sheephead had the highest biomass density (18 g/m^2) in the bight, followed by blacksmith, garibaldi, kelp bass, opaleye, barred sand bass, and giant sea bass (Figure I-13). However, giant sea bass are so relatively large that this ranking was due to only 4 individuals observed on a single transect at Light House, Anacapa.

Due to unequal sampling among sites fish richness was not depicted, however, Shannon-Wiener Diversity (this metric is also affected by unequal sampling) varied appreciably among sites (Figure I-14). In general the northern Channel Islands had high diversity, while Santa Barbara Island had low diversity. Platform Esther, Point Vicente and Leo Carrillo also had high diversity. The lowest diversity was observed at Platform Irene and Carp Reef. Carp Reef was a cobble reef with very low abundance of fishes. Only four species were reported for Platform Irene. The East Quarry, Santa Catalina Island had low diversity due to the high densities of blacksmith. While the northern Channel Islands performed strongly in terms of diversity, the warm island, Santa Catalina and San Clemente, had the highest fish guild values as they tended to have high densities of multiple fishes or in one case extremely high densities of a single species (*Chromis punctipinnis* at East Quarry, Santa Catalina). While diversity metrics are reduced by relatively extreme high densities of one or a few species, guild values increase with density regardless of the distribution among species or guilds. Also, since densities are additive across transect types, sites with high densities of fishes in the midwater and canopy (typically *Chromis punctipinnis* and *Oxyjulis californica*) also tend to have higher guild values. Other than these islands, fish guild value varied appreciably throughout the region (Figure I-15).

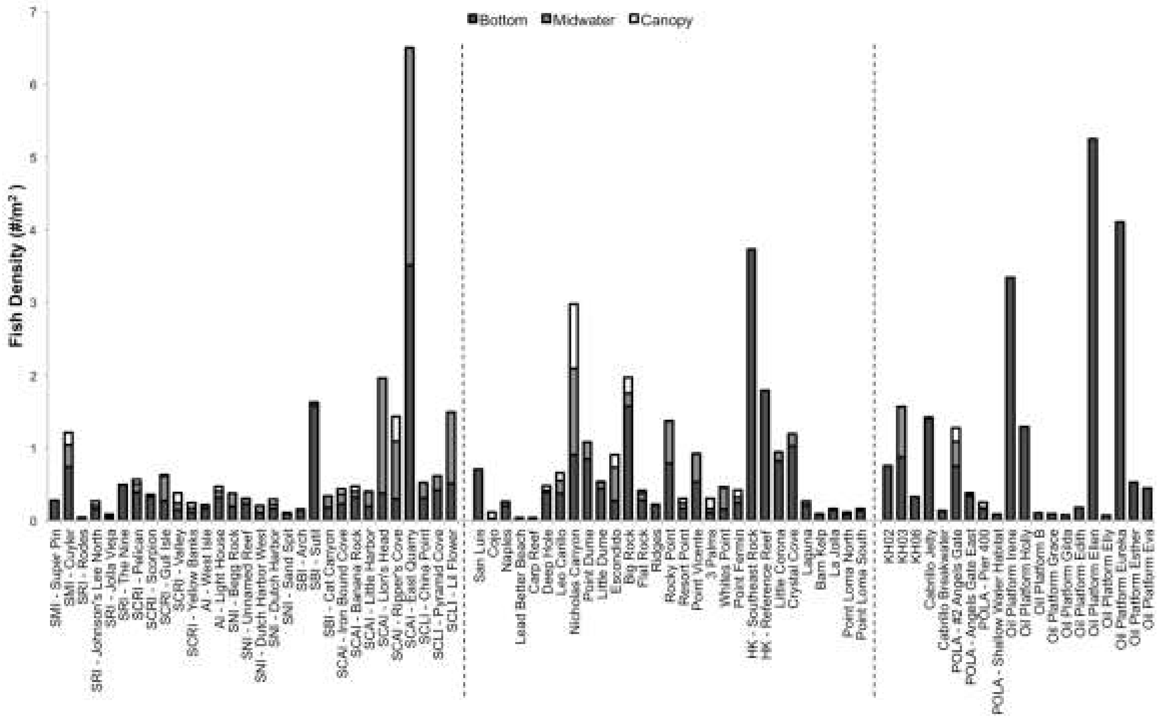

Figure I-11. Fish density (#/m^2) at island reefs (left), mainland reefs (middle) and breakwaters and oil platforms (right). Sites were organized by latitude, north to south.

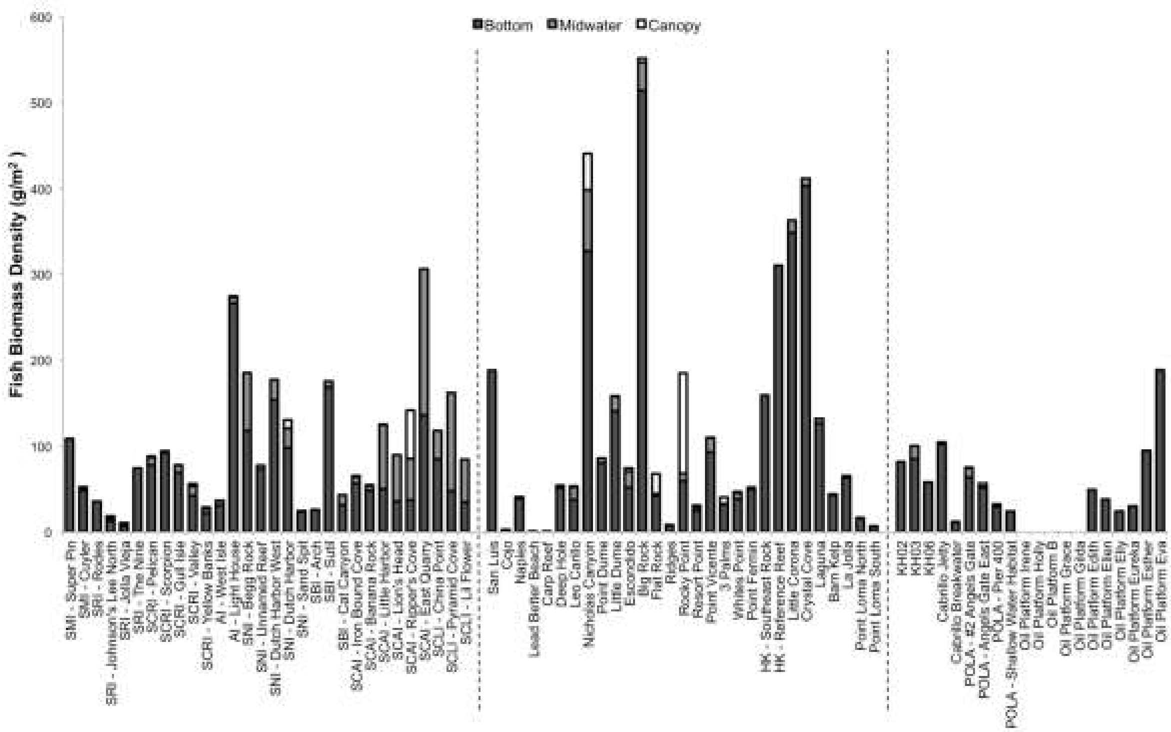

Figure I-12. Fish biomass density (g/m^2) at island reefs (left), mainland reefs (middle) and breakwaters and oil platforms (right). Sites were organized by latitude, north to south.

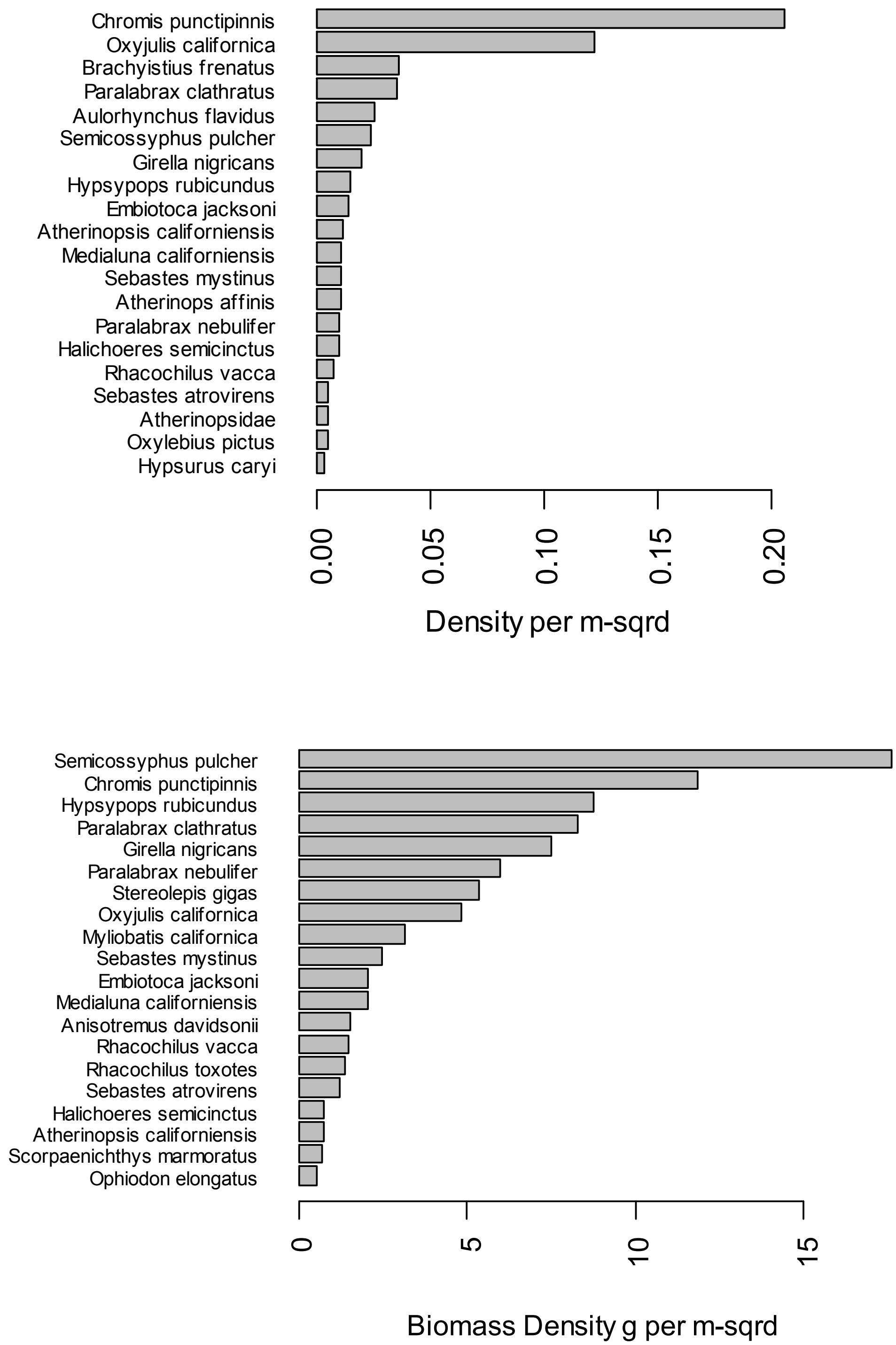

Figure I-13. Numerical density (above) and biomass density (below) for the top 20 fish taxa.

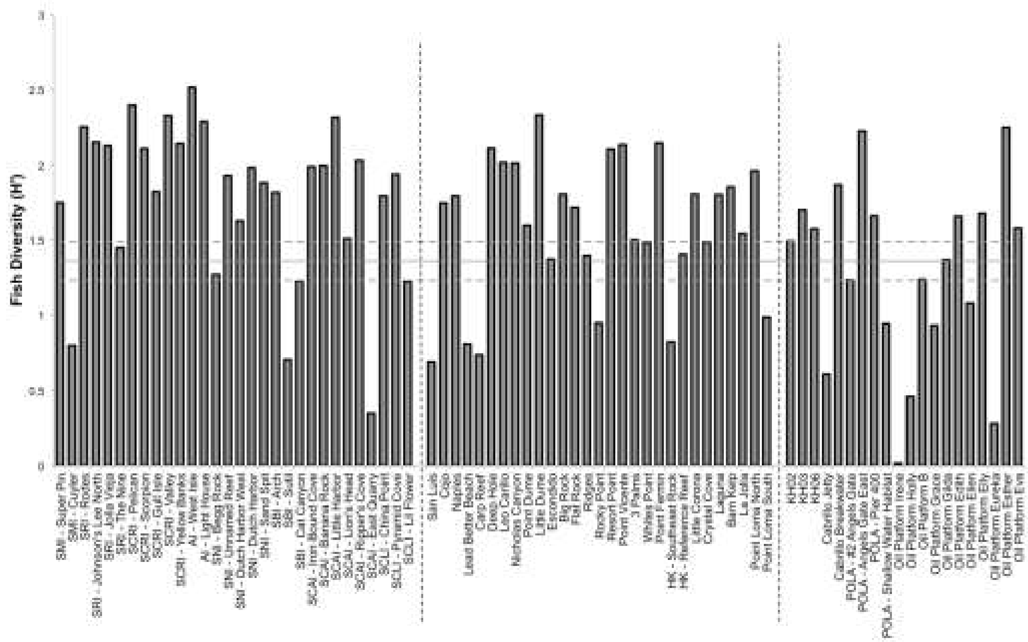

Figure I-14. Shannon-Wiener Diversity (H') for fishes at island reefs (left), mainland reefs (middle) and breakwaters and oil platforms (right). Sites were organized by latitude, north to south. Solid bar is the mean for the SCB and the dashed bars are the 95% confidence intervals.

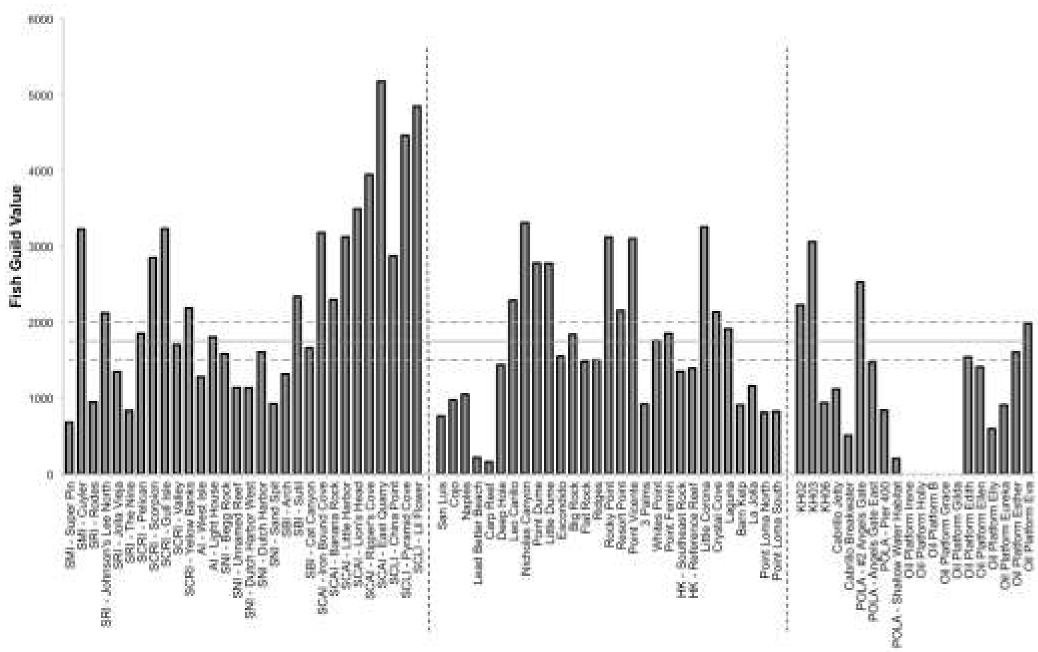

Figure I-15. Fish Guild Value for fishes at island reefs (left), mainland reefs (middle) and breakwaters and oil platforms (right). Sites were organized by latitude, north to south. Solid bar is the mean for the SCB and the dashed bars are the 95% confidence intervals. *Note:* Guild Values were not calculated for 5 oil platforms (Irene – Gilda) because fish sizes were not available.

Discussion

While the 120 natural reefs that were identified in the SCB spanned three orders of magnitude in size (6.2 to 2497.5 hectares), most were relatively large major reef complexes and they were distributed about equally between the San Diegan (warm temperate) and Oregonian (cold temperate) biogeographic regions. Island reefs tend to be higher relief, primarily bedrock with high proportions of algal cover. Mainland reefs tend to be lower relief, have more variable substrate composition and have higher proportion of abiotic cover relative to island reefs, but still moderate proportions of algal cover. We report that approximately a quarter of the nearshore (<30 m) habitat of the bight has rocky reefs. This is a percentage that is greater than would be expected from just analyzing the GIS layers available in 2008 (Kelner 2005). A substantial amount of the previously described soft bottom habitat was identified as reef by experts and over flight data of giant kelp canopy. Part of this difficulty is that side scan surveys are limited to the perimeter of kelp beds. More fine-grained reef mapping approaches have been and continue to be developed since this program (Pondella 2009) and we anticipate a more detailed mapping product in the future. Giant kelp was the dominant biogenic habitat structure on almost all reefs, although density was highly variable across mainland and islands reefs in both biogeographic regions and urchin barrens appear to be a potential problem in all regions except San Clemente and Santa Catalina Islands.

The extremely high fish biomass density (i.e. 300 to 550 g/m^2 or >3 to 5.5 mT/ha) at some reefs surveyed in this study is noteworthy as it is on par with fish biomass on some isolated coral reef ecosystem still dominated by large predators (Sandin et al. 2008), and in some cases double or triple the fish biomass found on rocky reefs in MPAs in the Mediterranean (Harmelin-Vivien et al. 2008) and Australia (Edgar and Stuart-Smith 2009). For the reefs in our study, the high biomass was largely due to high densities of relatively large bodied species that are common on rocky reefs in the SCB (i.e. *Anisotremus davidsonii, Girella nigricans, Hypsypops rubicundus, Paralabrax clathratus, Paralabrax nebulifer, Rhacochilus vacca*, and/or *Semicossyphus pulcher)*. Given that each site was only sampled on a single occasion, a large school of large bodied fishes observed on one or two transects can have a large influence on the site biomass density. However, at one site (East Quarry, Santa Catalina Island) the high biomass was due to hundreds of small *Chromis punctipinnis* or at Light House, Anacapa Island it was due to just 4 very large (~80 kg) *Stereolepis gigas*. Therefore, some caution should be taken when using the data resulting from this sampling scheme to examine site specific characteristics for general metrics such as total biomass. These data are probably better suited for exploring large-scale patterns across multiple sites or biogeographic regions. Continued studies of these reefs (i.e. increasing the sample size) will reduce the error estimates associated with site-specific values.

What is clearly evident is that the nearshore rocky reefs in the SCB are highly variable in terms of both abiotic and biotic reef structure, and metrics of the associated macroinvertebrates and fishes. Efforts need to be made to understand the influence of reef habitat characteristics on the associated biota. Classifying reefs by relief and substrate into six major reef structure categories was a good first step in this process, proving useful for controlling for habitat variation while examining biotic patterns associated with ASBS's and non-ASBS reference areas (see Chapter 2). The categorical scheme helped identify similarities among reefs across the various regions, while also pointing out those reefs that contained more unique combinations of habitat characteristics. Depth has also been shown to be a useful characteristic in modeling reef habitats (Claudet 2006); we did not use depth as a factor here, but note that depth components may be a significant factor in reef performance. For instance, some reefs were only distributed in the deepest strata (i.e. Horseshoe Kelp in Los Angeles County) while many others lacked a deep strata and some did not have a shallow strata. A finer scaled approach evaluating the influence of depth strata's on reef performance would be beneficial.

Ecological indicators are becoming mainstream tools for assessing impacts of human disturbance and general environmental 'quality' (Donnelly et al. 2007). Indicators are useful when they condense composite biological information into single measures, which might be more understandable for the general public and for non-scientific users, such as decision makers involved in environmental management. As indicators are used for different purposes in ecology and conservation, many argue that their selection depends on the issue at stake (Failing 2003; Heink and Kowarik 2010). However, any good 'indicator' must ultimately be related to the phenomena of interest that the indicator reflects (Heink and Kowarik 2010). In Southern California and elsewhere, there has been much success in developing indicators for marine habitats. These have focused primarily on soft bottom and estuarine ecosystems (Weisberg 1997; Borja 2000; Smith 2001). In southern California, the fish guild value metric we calculated for this study was developed for all subtidal marine habitats. While this metric has shown value in tracking and comparing reef by reef performance (Bond et al. 1999; Pondella 2009), it has not yet been expanded to assess an entire ecosystem feature. A great opportunity now exists to develop a regional assessment tool for nearshore rocky reefs given the amount of data now available between the CRANE 2004 SCB survey and the present study.

Conclusions

1) **At least 120 rocky reefs/reef complexes comprise approximately one-quarter (26%) of the subtidal habitat in the nearshore (<30m depth) SCB.**

   The mapping exercise undertaken in preparation of this study was the most exhaustive for its time. Data from multiple sources including side-scan sonar, aerial overflights, satellite imagery, and subtidal visual surveys were combined to create our estimates of habitat extent.

2) **Fish biomass density at some reefs surveyed in this study is on par with fish biomass at some isolated or protected ecosystems in other parts of the world.**

   Fish biomass densities of 300 to 550 g/m^2 in this study are noteworthy because they are similar to fish biomass densities on some isolated coral reef ecosystems still dominated by large predators (Sandin et al. 2008), and in some cases double or triple the fish biomass found on rocky reefs in Marine Protected Areas in the Mediterranean (Harmelin-Vivien et al. 2008) and Australia (Edgar and Stuart-Smith 2009). Our biomass densities were driven by a combination of either a large number of young recruits and/or fewer, but more large-bodied, fishes.

3) **The fish guild index was generally greatest in the southern (warmer) Channel Islands compared to the mainland and northern Channel Islands sites.**

The fish guild index used in this study takes into account trophic structure and abundance. While the range of fish guild index values was similar within each biogeographic region, the greatest index values were found at sites on Santa Catalina and San Clemente Islands. The lowest fish guild index values were observed at the northern end of the mainland SCB and at manmade structures such as breakwaters.

Recommendations

1) Since this study, more spatial data sets have become available and these should all be integrated into more fine-scaled reef maps.

Prior to this study, estimates of nearshore subtidal (<30 m) rocky reef habitat were inferred from the linear distribution of intertidal rock. While our estimates are dramatically improved, spatial data sets based on sidescan sonar, multibeam sonar, LIDAR, overflight and satellite imaging have become available. These newer data sets should be integrated with our existing data layers to create more fine-scaled reef maps. One improved asset will be to calculate the amount of reef habitat in various depth zones. These improved maps will aid in identifying where rocky habitat resources exist so they can be protected or augmented with restoration, if needed. This will become especially important as the State and Federal management agencies pursue marine spatial planning.

2) While this survey provided ideal information for assessing biological characteristics of subtidal rocky reefs, future surveys should be enhanced to maximize study designs for decision making.

This study introduced the various biological (abundance and biomass density) and structural components (amount of habitat) necessary to calculate stock sizes. However, we were reluctant to rely on these estimates because sites were sampled only once, which could introduce significant bias. Ideally, current and future management efforts will increase our nearshore fishery stocks and determining how to detect those changes will be important. Therefore, future surveys should contain scientifically robust study design elements for estimating stock size and examining trends.

3) Additional effort should be invested into developing an index of ecosystem health.

We used the fish guild index for this survey, which is based on trophic structure and fish density. However, this index does not take into account all of the ecosystem functions inherent to rocky reef systems. In addition, thresholds should be developed that indicate when a reef is in “good” or “poor” condition to provide ecosystem managers the information they need for stewarding our natural resources. Ideally, the relative impacts of natural (e.g., ocean temperature, recruitment) *versus* anthropogenic (e.g., fishing pressure, water quality) stressors should be evaluated either using (or built into) the index of ecosystem health. The data sets collected as part of this study will facilitate the development of this index.

4) **Method improvements could significantly enhance information needed for specific species of concern.**

There is some information that urchins could be better quantified (Schroeter 2009) and evaluating various means of better quantifying urchin density would be valuable. Various solutions could include: counting all red urchins (as this is a fishery species); subsample at a greater frequency (perhaps 5 m intervals versus 10 m intervals); increase the number of individuals counted in a subsample (currently that is set at 30, this could be increased to 50 or 100). In addition, increased information for other fishery-dependent species including Kellet's Whelk, (*Kelletia kelletii*), the Wavy Turban Snail (*Megastraea undosa*), several species of rock crab in the genus *Cancer*, spiny lobster (*Panulirus interruptus*) and abalone would likewise be useful. While there is currently density information from the Swath transects, size class information should be added (i.e., carapace length for lobster). Another option would be to add lobster density and size class to the fish transects.

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II. A PRELIMINARY INVESTIGATION INTO THE STATUS OF NEARSHORE ROCKY REEFS IN AREAS OF SPECIAL BIOLOGICAL SIGNIFICANCE IN THE SOUTHERN CALIFORNIA BIGHT

Introduction

Areas of special Biological Significance (ASBS) are designated water quality protected areas by the State of California. As such, the water quality standard for ASBS is "no discharge of waste" and "maintenance of natural water quality" (SWRCB 2005). Natural water quality can be an amorphous term, dependent upon time scale and relativity (Stoddard 2006). In the case of ASBS, natural water quality was defined as "any detectable human influence on water quality must not hinder the ability of marine life to respond to natural cycles and processes" (Dickson 2010). In essence, small anthropogenic perturbations to the chemical and physical composition of seawater are acceptable, so long as the biological community in an ASBS thrives.

A large amount of effort has been expended monitoring the chemical composition of ASBS receiving waters (Schiff 2011). After sampling 35 site-events, the geomean concentrations of total suspended solids, nutrients, total and dissolved trace metals, and polycyclic aromatic hydrocarbons in the ocean following storm events were similar between reference drainages and ASBS discharge sites. Concentrations of chlorinated hydrocarbons were nondetectable and no post-storm sample exhibited significant toxicity to the endemic purple sea urchin (*Strongylocentrotus purpuratus*) near ASBS discharge sites. Unfortunately, chemistry and toxicity do not tell a complete story of potential impacts to the ASBS. While these measures do well for assessing compliance using traditional regulatory approaches, it falls short of the natural water quality definition requiring a thriving biological community. For example, over one hundred chemical analytes were measured in the ASBS monitoring program, but not every chemical that could harm ASBS biota was measured. In addition, only a handful of storms were sampled at each site. This brings into question concentrations following unsampled storms or low-level, but chronic concentrations occurring during dry weather discharges.

Ultimately, it's the status of the biological community in ASBS that is fundamental to assessing ASBS condition. Regardless of chemical concentrations, impacts to the biological community will convince environmental managers that something should (or should not) be done. However, not all habitats are exposed to the same risks. For example, intertidal habitats are naturally variable responding to the daily stress of desiccation and wave energy (Thompson et al. 2002). Nearshore sandy habitats are known to have relatively low abundance and diversity compared to more stable habitats such as rock (Schiff 2003). In addition, rocky subtidal habitat has tremendous habitat value both in terms of abundance, diversity, and ecosystem services (Bond et al. 1999; Kildow 2009). One metric of the health of this habitat, giant kelp canopy, has fluctuated appreciably over the last 100 years (Figure II-1).

In addition to completing a characterization of fishes, invertebrates, algae and reef characteristics for all southern California ASBSs, there are several rocky reef metrics that potentially indicate past or current problems with water quality in the Southern California Bight. These metrics include the presence of urchin barrens, the presence/absence and density of giant kelp, understory and turf algae cover, tubeworm cover and the presence of bare rock (Figure II-2). Giant kelp is the hallmark species in this system and overall performance of giant kelp in the bight is related to a myriad of complex macro- and micro-scale oceanographic processes, including water quality (North 1964; Foster 2010). While understory algae and turf algae can be out competed for reef habitat by giant kelp through the process of shading, in poor habitat conditions urchins (white, purple and red) can overgraze these assemblages and create urchin barrens that can persist for years to decades (Figure II-2) (Steneck 2002). In areas of high turbidity, we find reefs dominated by tubeworms (Figure II-2). Also in highly turbid environs, reefs can become covered with sediment (Figure II-2) and in more extreme examples, completely devoid of cover (bare rock) or lost to burial (Pondella 2010).

The goal of this study was to characterize the rocky reef biological communities at sites inside ASBS and compare them to biological communities at sites outside of ASBS. This goal requires four tasks: 1) identify where and how much rocky habitat exists in southern California ASBS; 2) identify physical attributes that define natural differences among reefs; and 3) compare biological community parameters inside and outside of ASBS; and 4) examine specific metrics of importance to reef health. Ideally, biological measurements inside the ASBS are either as good as, or better than, biological measurements outside ASBS.

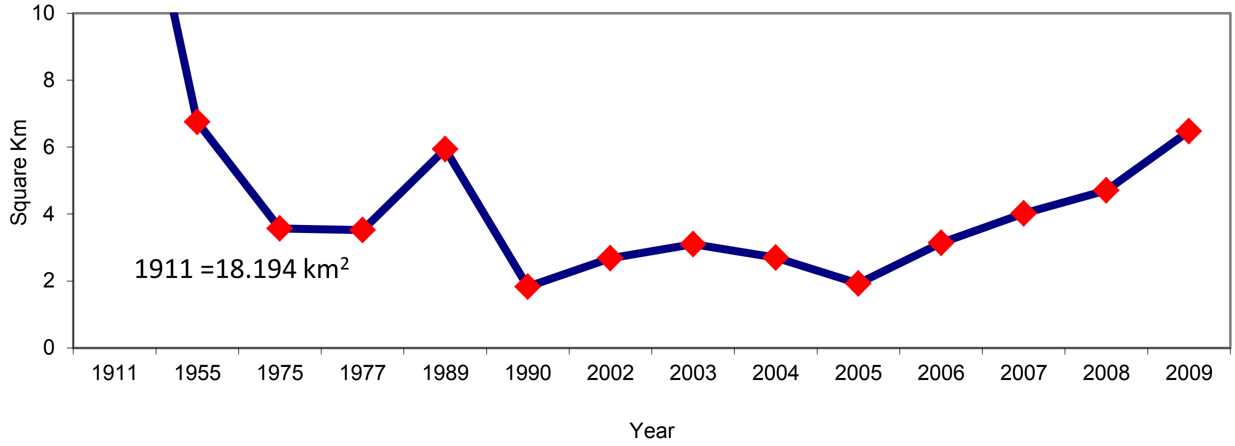

Figure II-1. Kelp canopy aerial extent for Ventura, Los Angeles and Orange Counties (MBC 2010).

Figure II-2. Examples (clockwise) of a healthy kelp bed, an urchin barren, sand tubeworms (*Phragmatopoma californica*) and reef inundated with sediment (Photos by J. Williams, VRG).

Methods

This reef assessment was completed independent of known locations of discharges in ASBSs. While there is detail about each ASBS in the bight, a more global assessment of ASBS performance relative to similar non-ASBS reef habitats was completed. Each potential water quality metric was tested within reef habitat types (high, middle and low relief reefs) against reference sites (non-ASBS). Our working hypothesis was that there would be no difference inside and outside of ASBSs, or potentially that ASBSs would perform better than non-ASBS sites.

Mapping-The best compilations of mapped rocky reef habitat in the Southern California Bight were assembled in GIS. These included maps of hard bottom habitats and kelp canopy (Kelner 2005). GIS spatial analysis techniques were used to integrate existing spatial data that characterizes bottom type, kelp cover, and bathymetry to create a preliminary habitat map. Using these data in GIS, we met with experts who have conducted multiple subtidal scuba research projects on various geographic areas of the SCB. These working groups delineated and categorized all reefs in the SCB. The size of each reef was calculated in GIS.

***Station Draw*-**Reefs were coded as island or mainland within each biogeographic realm, San Diegan (warm temperate) or Oregonian (cold temperate). Biogeographic realm was determined by biogeographic assessment of benthic fish assemblages studied during the 2003-04 CRANE survey (Tenera_Environmental 2006). In this biogeographic analysis young-of-year (YOY) fishes whose density is seasonal, and highly abundant pelagic species (*Engraulis mordax* and *Sardinops sagax*) present at only two sites were excluded from the data set. All statistics were run using PRIMER (version 6). The number of fishes observed by station were Log (x+1) transformed. A Bray-Curtis similarity matrix was then calculated and a hierarchical cluster analysis was performed. Using the similarity matrix, non-metric multi-dimensional scaling was performed and using 45% similarity ellipses calculated from the Bray-Curtis cluster the biogeographic regions were determined. Oil platforms, artificial reefs, breakwaters and jetties were not included in this mapping effort because they are well mapped and not part of the random station draw. For the spatial scale aspect of this program, 60 natural rocky reefs from this map were selected using the Generalized Random Tessellation Stratified (GRTS) Spatially-Balanced Survey Designs (Stevens and Olsen 2004), a probability-based design developed for Monitoring Aquatic Resources through EPA's Environmental Monitoring and Assessment Program (EMAP) (Stevens 1999). The advantage of the GRTS design is that it allows for random sampling in a way that provides good spatial coverage (without the clumping of sites often seen with simple random sampling). In addition, various strata or subpopulations can be defined and weighted proportionally to a host of subpopulation characteristics (e.g., the size of the resource, the size of the reef, variability in subpopulation estimates) so as to maximize efficiency when estimating population totals or comparing among subpopulations. In addition, nine breakwater habitats were sampled at King Harbor, Redondo Beach and six reefs at the Port of Los Angeles. Eleven of the 27 southern California oil platforms (B, Edith, Ellen, Elly, Esther, Eureka, Eva, Gilda, Grace, Holly and Irene) and three offshore pinnacle reefs (The Nine, San Luis, SuperPin) were sampled for fishes using a previously determined optimal sampling strategy due to their configuration (Love 2003). Only fish data was collected at these 14 sites and is not included in the habitat analyses in this report. Overall, 72 sites were sampled in the bight (Figure II-3).

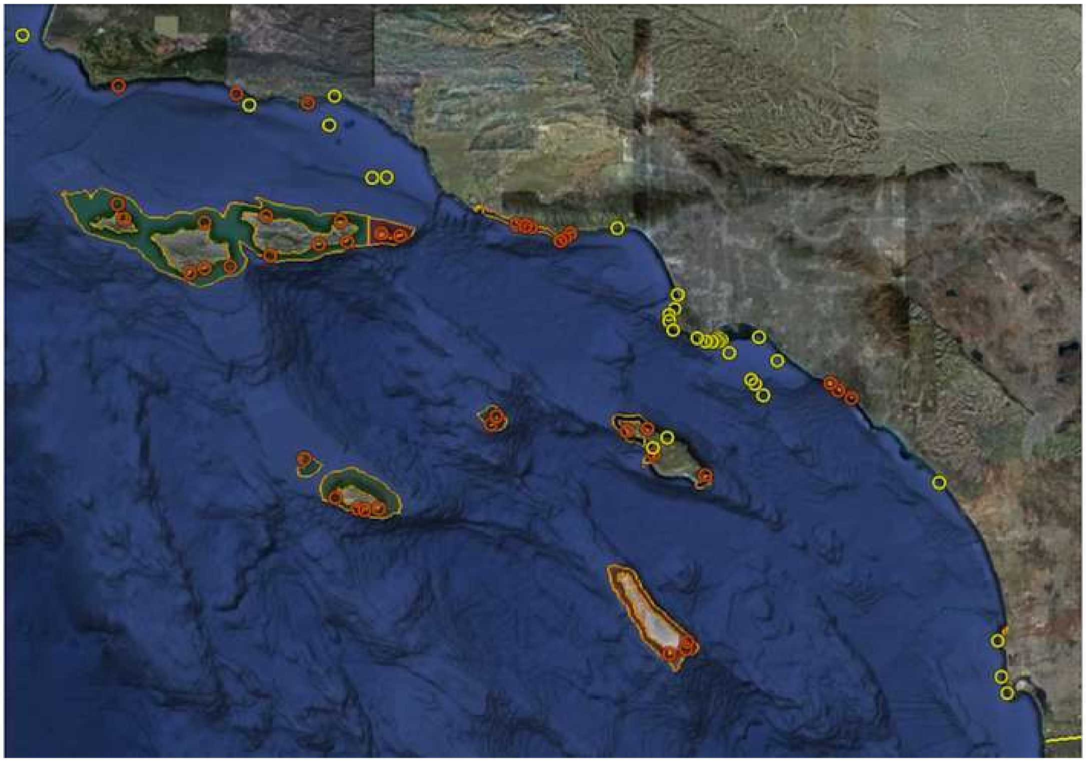

Figure II-3. 72 sites sampled in the Southern California Bight, ASBS's are shown in orange.

Figure II-4. Inner, middle, outer and deep depth strata used in Bight '08 rocky reef program.

Sampling Unit- A sampling cell consisted of at least 250m of reef habitat. Within each cell four depth strata (if present) were sampled and geo referenced. These strata are the inner (~5m), middle (~10m) and outer (~15m) and deep strata (~25m) portions of a natural reef or kelp bed (Figure II-4). Within each depth strata two benthic sampling protocols, Uniform Point Contact (UPC) and macro invertebrate and algae (Swath), were completed. All transects were 30m; Swath transects were 30m x 2m belt transects.

UPC- Percent cover of substrate type, substrate relief and benthic organisms were recorded at each meter mark along the 30 m transect tape. Substrate percentages in the following categories were estimated within each 10 m segment: bedrock (≥ 1 m), boulder (1 m), cobble (≤10 cm), and sand. Substrate relief was the maximum relief within a rectangle centered on the point that is 0.5 meter along the tape and 1 meter wide. To contact benthic organisms, the line is pushed down and the species under the tape is recorded. If the line could not contact the substrate, the diver's finger was used to mark the spot. Epiphytes, epizooids and mobile organisms were not recorded. If the contact point was on a blade of *Laminaria*, brittlestars or the sea cucumber *Pachythione rubra*, the organism under the point was recorded and it was noted that the point was under one of these organisms. The superlayer was also recorded. In addition to quantifying benthic organisms, the following types of bare substrate were recorded, if contacted: rock, sand, shell debris, and mud. Considering their paucity for the majority of the SCB the size and species of any abalone was recorded.

The percentage of each type of substrate category (bedrock, boulder, cobble or sand) was determined by pooling the number of contact points for all replicates at each site by category, and dividing the sum of each category by the total number of contact points at that site. Percentage of reef relief category (0-.1m, .1-1m, 1-2m or >2m) was calculated in the same manner. All benthic reef coverage was categorized into groups that roughly follow taxonomic divisions or appropriately named abiotic groups and densities for each group were calculated by site. Reef structure categories (% relief and substrate) were square root transformed and normalized prior to being clustered using Euclidean distances. Percent reef cover categories were square root transformed and then clustered using a zero-adjusted Bray-Curtis similarity index. These two hierarchical clusters were examined using the RELATE statistic, ρ, using the Spearman Rank Correlation with 999 permutations.

Swath-The purpose of the swath sampling was to estimate the density of conspicuous, solitary and mobile invertebrates as well as specific macroalgae. Individual invertebrates and plants were counted along the entire 30 m x 2 m transect. Transects were completed even if sand was encountered but when there was sand for more than 5 m, the direction of the transect was changed to the minimum necessary to remain on rocky habitat. Divers slowly swim one direction counting targeted invertebrates (from a pre-printed list on the data sheet) and then swim back along the transect counting targeted macroalgae. Cracks and crevices were searched and understory algae pushed aside. No organisms were removed. Any organism with more than half of its body inside the swath area was counted.

The following size criteria applied to counting macroalgal species: a) *Macrocystis* taller than 1 m (3.3 ft), and number of stipes per plant at 1 m above the substrate. *Macrocystis* is not subsampled; b) *Nereocystis, Pterygophora*, *Laminaria setchellii* and *Eisenia arborea* taller than 30 cm (11.8 in); c)

Laminaria farlowii with blade greater than 10 cm (3.9 in) wide; d) *Cystoseira osmundacea* greater than 6 cm (2.4 in) wide; and e) *Costaria* and *Alaria* no size restrictions.

Transects were divided into three 10-meter segments. Species that occurred in high densities (e.g., purple urchins) were sub-sampled if greater than 30 individuals occurred within any of the three 10 m segments on a transect. When 30 individuals of one species were counted, the diver recorded the meter mark at which the threshold abundance was reached and then stopped counting that species for the remainder of that segment. The species was then again counted at the start of each following segment and the same threshold abundance rule was applied. The subsampled abundances were then extrapolated per segment to calculate an estimated total abundance per transect. All swath taxa densities were estimated based on the count or estimate of the number of each taxa over the 60 m^2 area covered by a single transect and scaled to 100 m^2. Swath species were grouped into large taxonomic categories. Mean number of stipes per *M. pyrifera* holdfast was also calculated.

Analyses-Reef habitat quality metrics inside and outside of ASBSs were assessed with two-way ANOVAs. The independent variables for each model were ASBS (categorical: inside, outside) and reef relief (categorical: high, middle and low). Each site was assigned to a reef structure category and then these were further grouped into the reef relief categories (see results for details) to obtain adequate sample size for each group. Six potential habitat quality metrics that have been associated with known water quality problems (North 1964; Pondella 2010) were examined as the dependent variable in a model: (1) percent cover of bare rock, (2) percent cover of tube worms (i.e. *Phragmatopoma* and *Diopatra*), (3) density of giant kelp (*Macrocystis pyrifera*), (4) density of understory algae, (5) density of purple urchins (*Strongylocentrotus purpuratus*) and (6) density of red urchins (*Strongylocentrotus franciscanus*). Site means were Log (x+1) transformed prior to analysis to conform with model assumptions. Ninety-five percent confidence intervals were calculated to visualize among group differences.

In order to visualize these preliminary observations which may potentially explain patterns within ASBSs throughout the bight, six factors were graphed: urchin density (purple and white), kelp density, understory algae density, fish biomass, % bare rock and % tubeworms. Since factors were measured on difference scales (e.g. density, percent cover), values (bar heights) for all factors were standardized by scaling (from 0-1) as a proportion of the highest recorded value in an ASBS for a given factor. Kelp canopy over flight data from the Central Region Kelp Survey Consortium was also included (MBC 2010).

Results

Of the 48,221 ha of nearshore rocky reef in the bight, 28,791 ha (59.7%) are in ASBS (Table II-1). 28,044 ha of the 29,237 ha of island reefs are in ASBS. For the mainland, 747 ha out of a total of 18,984 ha are in ASBS with the greatest proportion in ASBS 24, Mugu to Latigo Point (659 ha). Island reefs were primarily composed of bedrock or boulders (85.9%) while mainland reefs had a more even mix of substrate types (Table II-2, Figure II-5). Nearly half (47.8%) of mainland reefs had a low (0-0.1 m) relief, more than double the percentage at the islands (23.3%). The percentages of 1-2 m and >2m relief at island reefs were 2 and 6 times higher than those on mainland reefs (Table II-2, Figure II-5). For relief, breakwaters were generally more similar to island reefs. The highest fraction of abiotic cover categories (bare rock, sand, detritus, mud and shell hash) was at the mainland reefs (26.3%) followed by breakwaters (20.2%) and islands (14.3%).

Reef structure, classified by relief and substrate (Figure II-6), varied from an oceanic pinnacle (Begg Rock), which was a sheer vertical structure composed of bedrock and an intertidal component, to mainland cobble reefs, such as La Jolla or Carp Reef, with large fractions of sand, abiotic cover and little or no relief (Figure II-5). Six reef types were found. Type I was a pinnacle reef (Begg Rock) and breakwaters comprised almost completely of bedrock or large boulders. The second grouping (Type II) was formed by two mainland pinnacle reefs (Pt. Dume and Southeast Rock), two breakwaters and three island reefs (Cat Canyon, SBI and Ripper's Cove and Banana Rock, SCAI). Type II reefs had high fractions of bedrock and boulder habitat, but had a much smaller fraction of sheer or wall (> 2m relief) components as opposed to Type I reefs. Type III reefs were predominantly island reefs with some exceptions (Big Rock, Cabrillo Breakwater, Point Loma North, Point Vicente and Little Corona). These reefs were characterized being almost completely bedrock high relief fractions (1-2m and > 2m). Alternatively, Type IV reefs were predominantly mainland high relief reefs with three island reefs (East Quarry, SCAI, Lil Flower, SCLI, and Lion's Head, SCAI). These reefs were comprised of bedrock and boulders, but had primarily 0-1m relief. Type V reefs were bedrock reefs that were primarily flat (0-0.1m relief). The last category (Type VI) were low relief and cobble reefs (Carp Reef and La Jolla) that had significant fractions of sand. Thus, reefs can be grouped into six major reef categories: low relief and cobble (Type VI), flat reefs (Type V), middle relief (Type IV), high relief (Type III), wall reefs (Type II), and pinnacles (Type I). Reefs were then grouped by more general reef relief and substrate categories: (1) high relief, primarily island reefs (Type I and III), (2) primarily middle relief mainland reefs (Type II, IV and V), and (3) low relief or cobble reefs (Type VI). The combining of categories increased sample size in order to increase the power to assess differences among ASBS and non-ASBS stations within these categories using ANOVA analyses.

Table II-1. ASBSs with nearshore (<30 m) rocky reefs and amount of reef habitat in hectares for the Southern California Bight.

ASBS	ASBS #	Hectares
Heisler Park Ecological Reserve	ASBS 30	0.5
Irvine Coast Marine Life Refuge	ASBS 33	87.5
Mugu Lagoon to Latigo Point	ASBS 24	658.7
San Clemete Island	ASBS 23	3593.2
San Diego-La Jolla Ecological Reserve	ASBS 29	0.7
San Miguel, Santa Rosa and Santa Cruz Islands	ASBS 17	17382.1
San Nicolas Island and Begg Rock	ASBS 21	5249.4
Santa Barbara Island and Anacapa Island	ASBS 22	1433.4
Santa Catalina Island-Subarea Four, Binnacle Rock to Jewfish Point	ASBS 28	1.6
Santa Catalina Island-Subarea One, Isthmus Cove to Catalina Head	ASBS 25	330.4
Santa Catalina Island-Subarea Two, North End of Little Harbor to Ben Weston Point	ASBS 26	53.8

Table II-2. Substrate type, relief and cover categories for island reefs, mainland reefs and breakwaters.

		Islands	Mainland	Breakwaters
Substrate	Bedrock	68.8%	40.8%	58.5%
	Boulder	17.1%	21.4%	25.7%
	Cobble	6.6%	18.3%	4.3%
	Sand	7.5%	19.4%	11.5%
Relief	0-.1m	23.3%	47.8%	16.6%
	0.1-1m	51.1%	43.8%	36.6%
	1-2m	12.3%	6.2%	27.5%
	>2m	13.2%	2.2%	19.3%
Cover	Abiotic	14.3%	26.3%	20.2%
	Algae and Seagrass	62.0%	57.1%	51.6%
	Invertebrate	23.7%	16.6%	28.3%

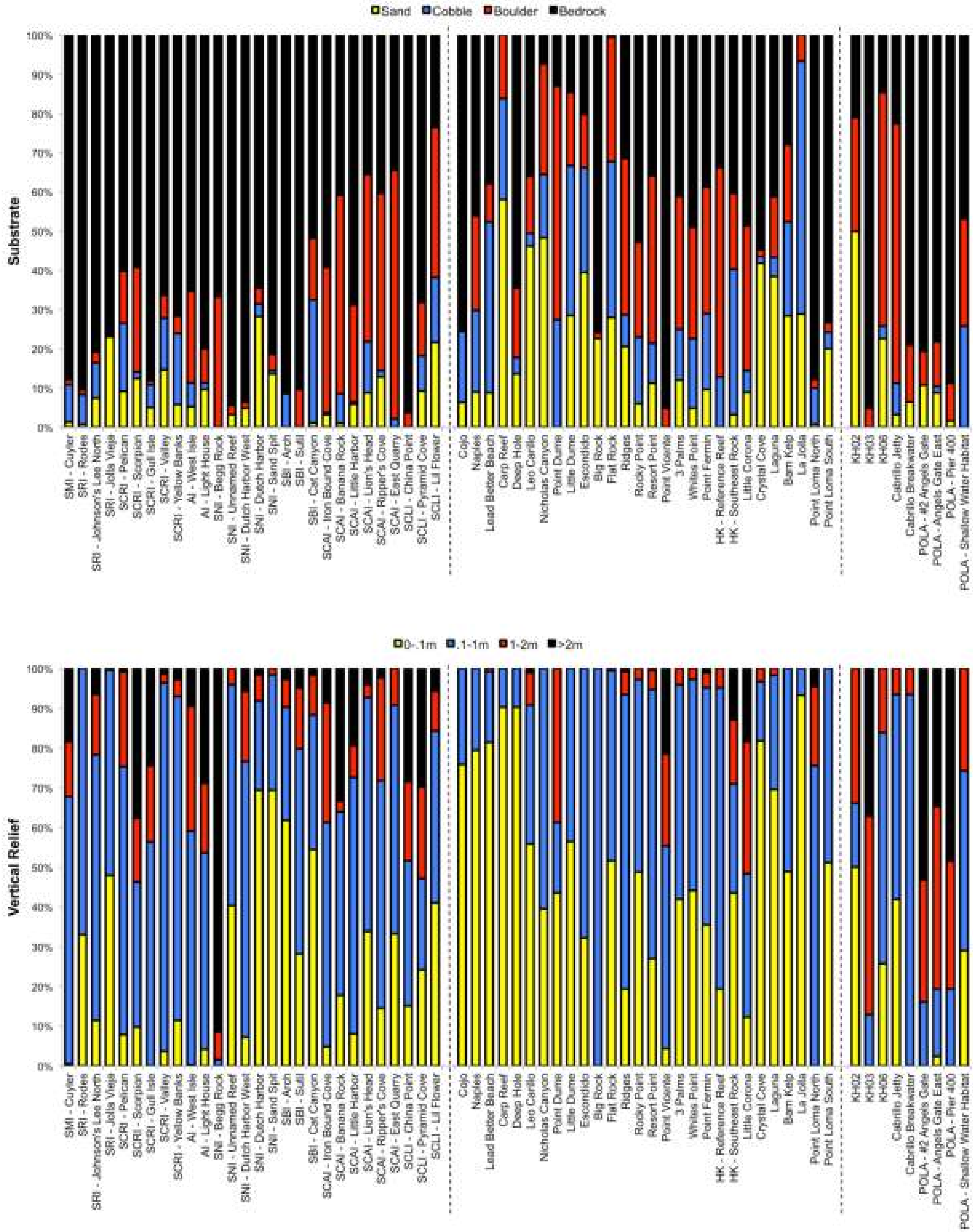

Figure II-5. Substrate type (above) reef relief (below) from south to north for island reefs, then mainland reefs, and then breakwaters-.

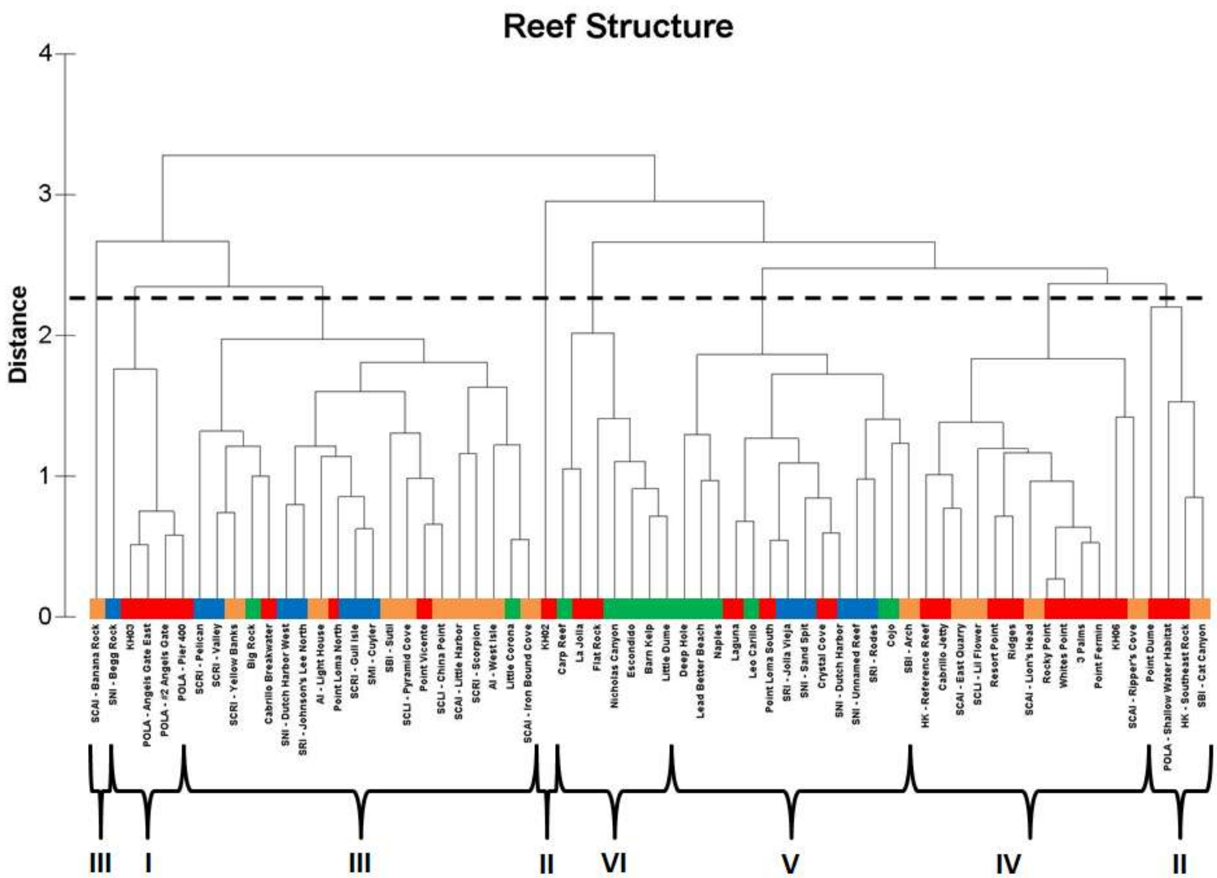

Figure II-6. Reef structure determined by clustered Euclidean distances from UPC substrate and relief measures. Habitat measures were square root transformed and normalized. Dashed line indicates reef clusters found in MDS. Colors refer to biogeographic provinces: blue = cold temperate islands, orange = warm temperate islands, green = cold temperate mainland, red = warm temperate mainland.

Table II-3. ASBS, ASBS number, Bight '08 Reef and the various potential water quality indicators.

ASBS	*ASBS Number*	*Bight '08 Reef*	purple urchin (#/100m²)	white urchin (#/100m²)	giant kelp (#/100m²)	understory algae (#/100m²)	% bare rock	% tubeworms
Malibu/Latigo	ASBS 24	Deep Hole	759.7	2.1	12.1	10.4	0.0%	0.8%
Malibu/Latigo	ASBS 24	Leo Carillo	232.5	0.6	22.2	25.8	0.5%	16.7%
Malibu/Latigo	ASBS 24	Nicholas Canyon	96.2	0.0	32.1	12.1	1.6%	31.5%
Malibu/Latigo	ASBS 24	Point Dume	754.2	0.0	6.7	10.8	8.1%	3.2%
Malibu/Latigo	ASBS 24	Little Dume	19.6	0.0	23.9	116.0	2.2%	10.8%
Malibu/Latigo	ASBS 24	Escondido	9.2	0.0	27.9	0.0	4.8%	16.1%
Newport Beach	ASBS 32	Little Corona	10.3	0.0	48.1	21.1	3.7%	0.0%
Irvine Coast	ASBS 33	Crystal Cove	2.1	0.0	15.4	21.7	0.8%	0.8%
Heisler Park	ASBS 30	Laguna	54.2	0.0	0.3	6.9	0.0%	0.5%
La Jolla	ASBS 29	La Jolla	0.0	0.0	2.2	119.2	3.9%	0.0%
San Miguel	ASBS 17	Cuyler	126.3	2.6	27.9	1.3	5.8%	8.1%
Santa Rosa	ASBS 17	Johnson's Lee North	20.3	0.0	68.5	97.0	3.9%	6.1%
Santa Rosa	ASBS 17	Rodes	315.4	0.0	0.4	24.9	3.8%	1.7%
Santa Rosa	ASBS 17	Jolla Vieja	4.0	0.0	30.3	219.1	7.7%	12.2%
Santa Cruz	ASBS 17	Pelican	856.6	45.1	24.7	51.4	11.9%	7.9%
Santa Cruz	ASBS 17	Scorpion	763.0	110.6	3.6	2.5	2.3%	11.8%
Santa Cruz	ASBS 17	Gull Isle	843.0	0.0	53.2	229.9	1.4%	5.0%
Santa Cruz	ASBS 17	Valley	994.2	0.1	29.6	110.5	12.5%	9.5%
Santa Cruz	ASBS 17	Yellow Banks	118.8	0.1	39.7	254.1	13.1%	4.2%
Anacapa	ASBS 22	West Isle	673.1	2.5	4.4	68.6	8.4%	13.6%
Anacapa	ASBS 22	Light House	1794.3	1.4	30.0	65.5	3.1%	13.4%
Santa Barbara	ASBS 22	Arch	468.0	5.0	0.0	10.3	26.3%	1.1%
Santa Barbara	ASBS 22	Sutil	25.8	0.0	12.5	45.4	21.8%	0.8%
Santa Barbara	ASBS 22	Cat Canyon	462.0	205.4	0.3	0.6	25.6%	4.4%
SCAI West End	ASBS 25	Iron Bound Cove	16.7	0.0	34.4	351.3	0.5%	0.0%
SCAI West End	ASBS 25	Lion's Head	0.0	0.0	69.2	35.0	4.0%	0.0%
SCAI East End	ASBS 28	East Quarry	0.0	0.0	54.2	88.3	0.5%	0.0%
SCAI Little Harbor	ASBS 26	Little Harbor	10.0	0.0	28.3	93.3	1.1%	0.0%
San Clemente	ASBS 23	China Point	11.4	0.0	6.7	90.4	5.9%	2.2%
San Clemente	ASBS 23	Lil' Flower	0.5	0.0	27.6	138.5	6.0%	5.1%
San Clemente	ASBS 23	Pyramid Cove	0.6	0.0	18.8	103.2	1.6%	1.3%
San Nicolas	ASBS 21	Begg Rock	123.1	0.0	0.0	0.0	0.0%	0.0%
San Nicolas	ASBS 21	Unnamed Reef	43.8	0.0	9.2	245.4	0.8%	0.0%
San Nicolas	ASBS 21	Dutch Harbor West	44.1	0.0	18.3	139.4	0.8%	12.1%
San Nicolas	ASBS 21	Dutch Harbor	86.7	0.0	37.9	17.1	0.8%	6.5%
San Nicolas	ASBS 21	Sand Spit	320.1	0.0	50.0	241.1	0.0%	0.0%

No significant differences (ANOVA; $F_{5,59}$=1.14; p= 0.35) were found in mean percentage of bare rock between ASBS and non-ASBS sites when pooled by major reef type categories (Figure II-7a). There was high variability among sites, from zero to nearly 50% at Cojo (Figure II-7b). Reasons for bare rock may vary from site to site, but it is a known indication of sediment scour and shading. Sites with high fractions of bare rock were found at Santa Barbara Island (all three sites), White Point, Point Loma South, and Barn Kelp. In ASBS, the range was 0-26.3% with the highest percentages found at Santa Barbara Island. The Santa Cruz Island sites (Pelican, Valley, Yellow Banks) and West Isle, Anacapa Island had relatively large fractions compared to other Type III reefs. Otherwise, ASBS reefs were within or at the lower end of the range of non-ASBS reefs for each reef type.

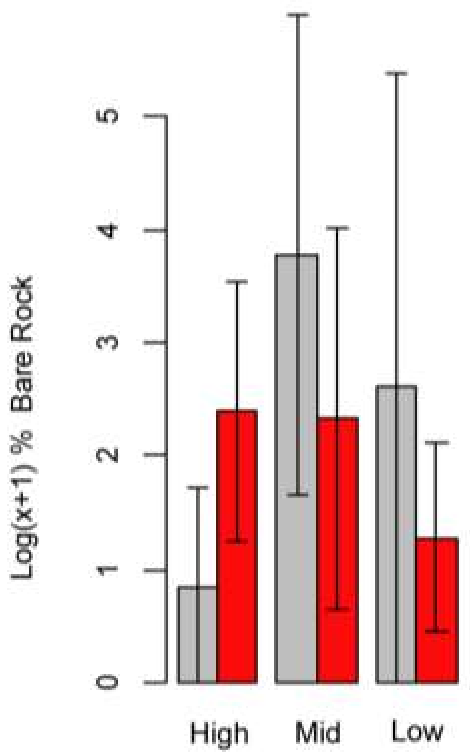

Figure II-7a. Log (x+1) percent cover of bare rock from UPC surveys for ASBS (red) vs. Non-ASBS (grey) sites grouped by reef type: high relief (Type I and III), middle relief (Type II, IV and V), low relief (Type VI); Figure II-6. Error bars are 95% confidence intervals.

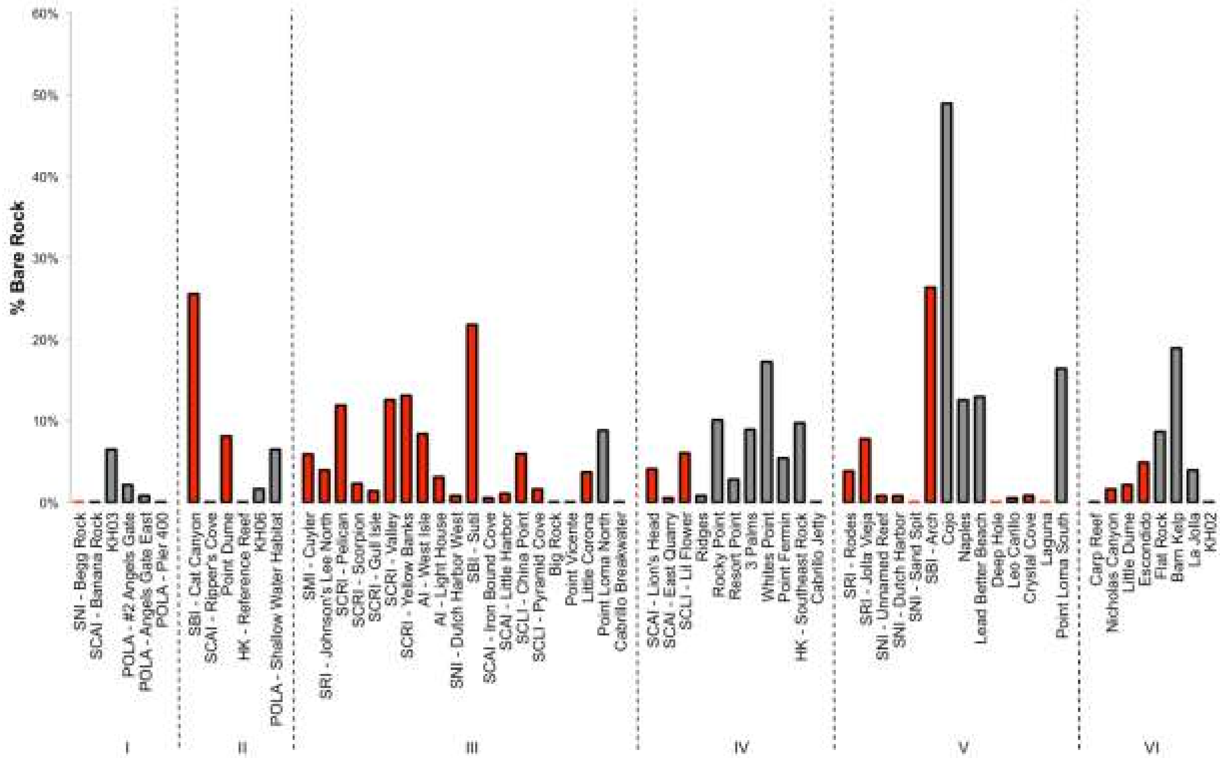

Figure II-7b. Percent cover of bare rock from UPC surveys by reef type (I-VI; Figure II-6) arranged latitudinally. ASBS sites are in red.

Tubeworms have been found in areas of high sediment loads. They can use the material for their tubes (i.e. *Phragmatopoma* and *Diopatra*) and may feed on particulate matter. There were significant differences (ANOVA; $F_{5,59}$=4.66; p= 0.001) in percent cover of tubeworms between ASBS and non-ASBS sites when pooled by major reef groupings (Figure II-8a). This difference was primarily between ASBS and non-ASBS type VI habitat (low relief) sites, due to the high % cover of tubeworms at the Malibu/Latigo ASBS sites (Little Dume and to a lesser degree Nicholas Canyon). There were also high % cover of tube worms at sites in that region in other relief categories, (Leo Carillo and a non-ASBS site, Big Rock). A Port of Los Angeles (POLA) site, the Cabrillo Jetty and Point Fermin also had high percent cover of tube worms potentially due to high turbidity and sediment loads associated with the Los Angeles River. For Type III reefs, the northern channel island sites and Dutch Harbor West, San Nicolas had higher tubeworm cover than all other Type III reefs (except Big Rock) (Figure II-8b).

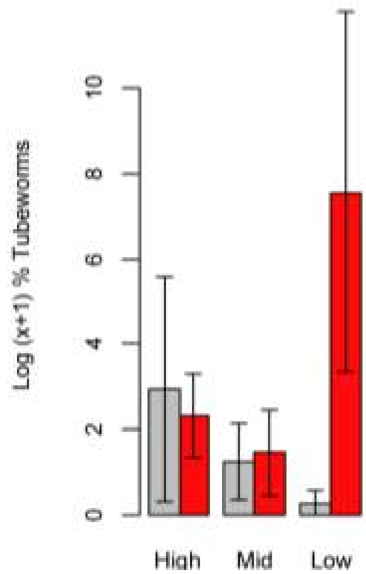

Figure II-8a. Log (x+1) percent cover of tube worms from UPC surveys for ASBS (red) vs. Non-ASBS(grey) sites grouped by reef type: high relief (Type I and III), middle relief (Type II, IV and V), low relief (Type VI); Figure II-6. Error bars are 95% confidence intervals.

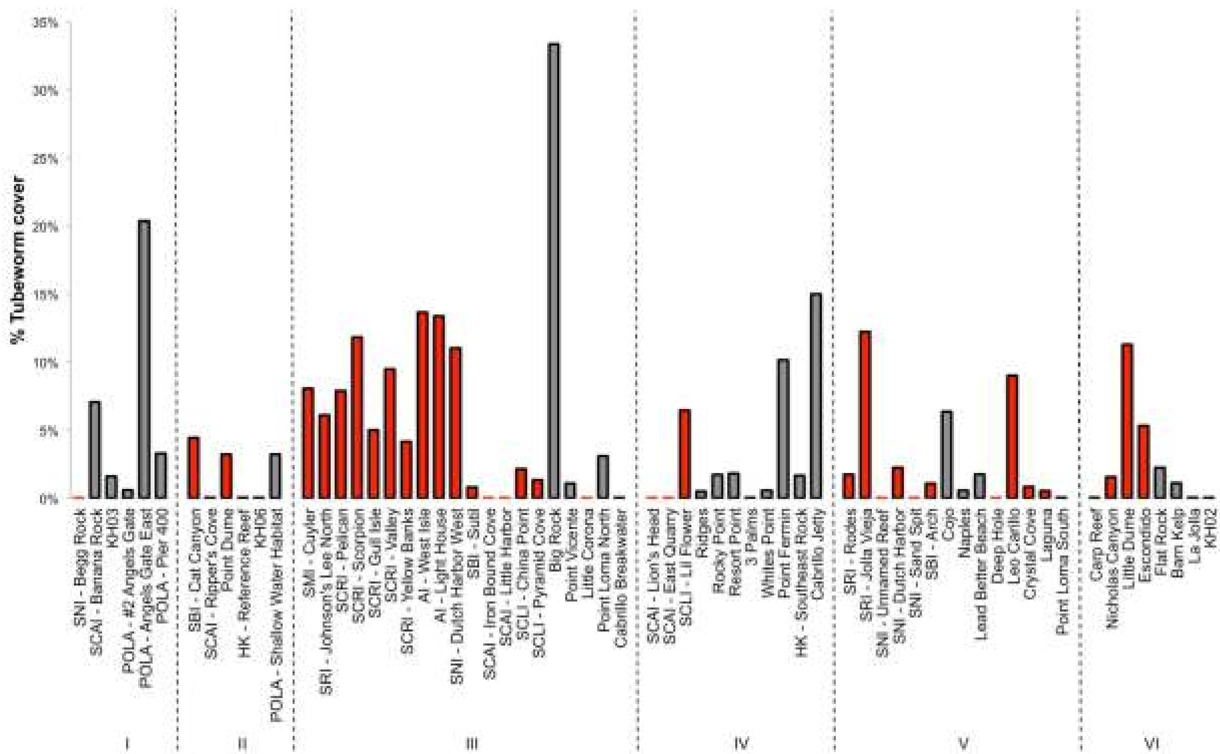

Figure II-8b. % cover of tubeworms from UPC surveys by reef type (I-VI; Figure II-6) arranged latitudinally. ASBS sites are in red.

Giant kelp (*Macrocystis pyrifera*) is a key habitat forming species on rocky reefs in Southern California. 2008 was a particularly strong year for kelp in many areas of the bight (MBC 2010). Major factors that affect giant kelp are pollution (sewage), sedimentation, oceanographic parameters, episodic events, and overgrazing by urchins. Kelp density is also a factor of the age of a kelp bed. Older kelp beds have lower density but larger plants (more stipes per plant) than younger kelp beds. Good examples of this are the Point Loma sites that have relatively low kelp density yet support a mature and dense kelp forest. However, when grouped by habitat types, there were no significant differences (ANOVA; $F_{5,59}=0.53$; $p= 0.75$) between ASBS and non-ASBS sites in log (x+1) density of giant kelp (Figure II-9a). It varied from high to low in all types (Figure II-9b). Sites with low density or absent kelp may have potential problems and need to be studied case by case. There are some exceptions, such as Begg Rock, which did not have any kelp, but it is a very unique habitat. Also, the horseshoe kelp sites are at a depth of ≥25 m and have not supported kelp in decades. Low kelp densities were found at Laguna, Arch and Cat Canyon (Santa Barbara Island), Scorpion (Santa Cruz Island), West Isle (Anacapa Island), and Rodes (Santa Rosa Island). It should be noted that giant kelp density is underestimated on mainland reefs where a deep component was surveyed (i.e. Ridges and Rocky Point) since few giant kelp can survive at depths greater than 20m.

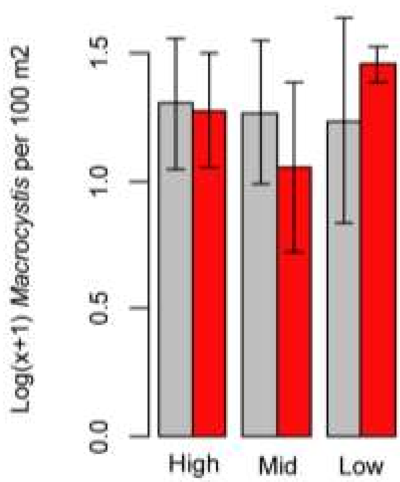

Figure II-9a. Log (x+1) density of giant kelp (*Macrocystis pyrifera*) from swath surveys for ASBS (red) vs. Non-ASBS (grey) sites grouped by reef type: high relief (Type I and III), middle relief (Type II, IV and V), low relief (Type VI); Figure II-6. Error bars are 95% confidence intervals.

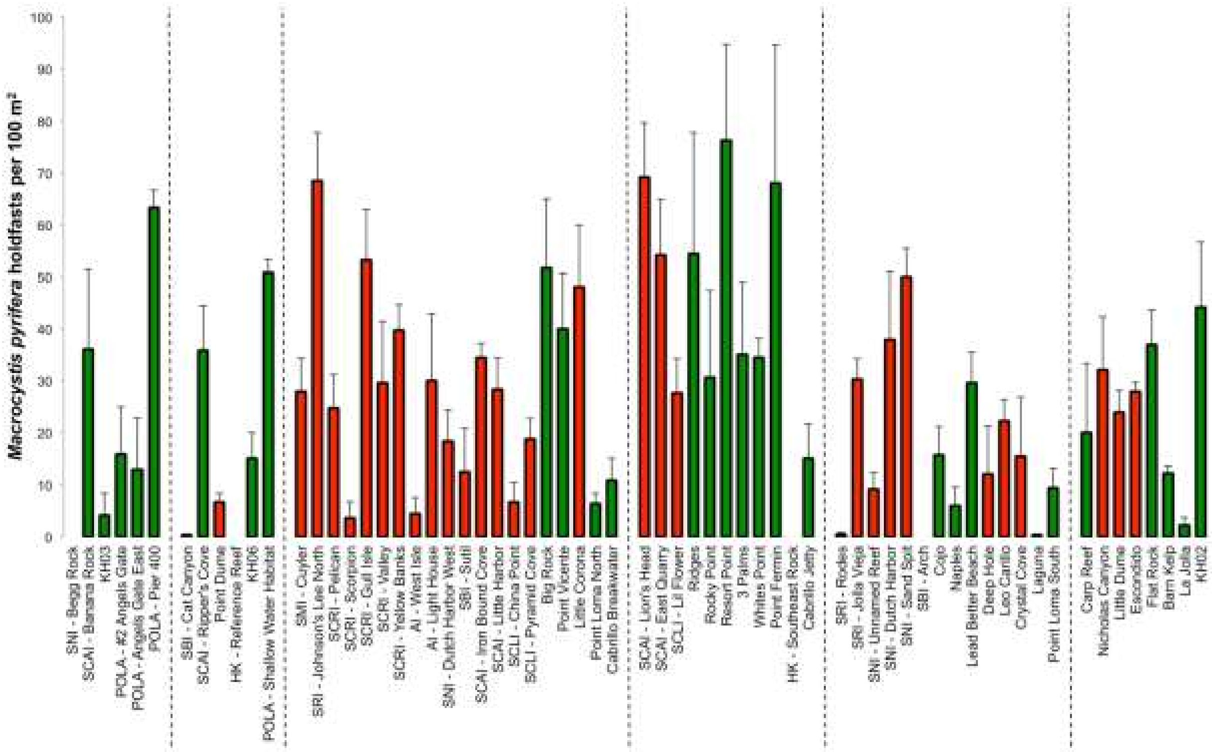

Figure II-9b. Density of giant kelp (*Macrocystis pyrifera*) from swath surveys by reef type (I-VI; Figure II-6) arranged latitudinally. ASBS sites are in red.

Like giant kelp, understory algae can be affected by a variety of environmental conditions and varied substantially within each habitat type (Figure II-10). When grouped by habitat types, there also were no significant differences (ANOVA; $F_{5,59}$=1.20; p= 0.32) between ASBS and non-ASBS sites in log (x+1) density of understory algae (Figure II-10a). For Type I and II reefs, there were generally low amounts of understory algae on breakwaters, it was absent at Begg Rock, and low at Point Dume (Figure II-10b). For Type III reefs, relatively low values were found at Cuyler (San Miguel Island), Scorpion (Santa Cruz Island), Point Vicente and Little Corona. Resort Point had a low density of understory algae for Type IV reefs. Type V and VI reefs had a mix of high and low values.

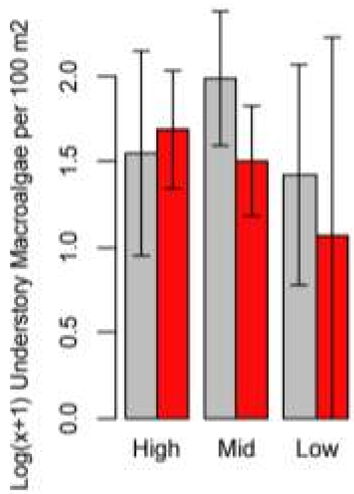

Figure II-10a. Log (x+1) density of understory algae from swath surveys for ASBS (red) vs. Non-ASBS(grey) sites grouped by reef type: high relief (Type I and III), middle relief (Type II, IV and V), low relief (Type VI); Figure II-6. Error bars are 95% confidence intervals.

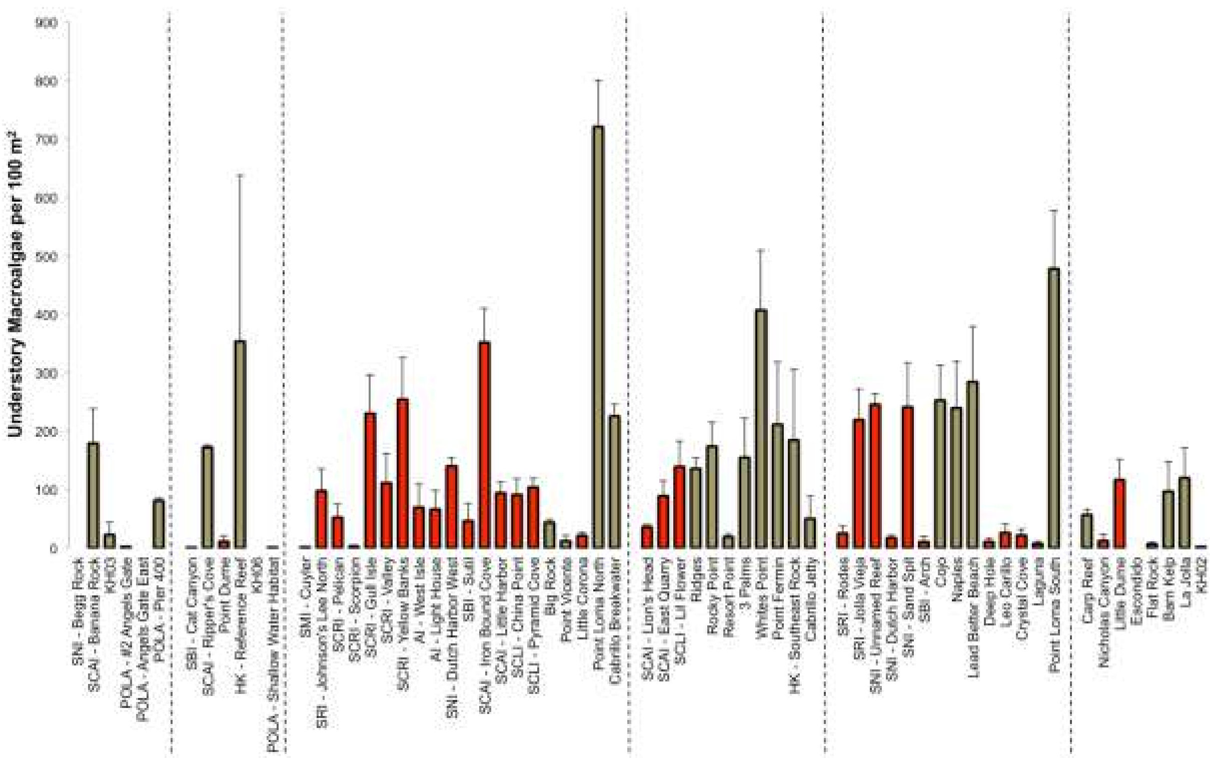

Figure II-10b. Density of understory algae from swath surveys by reef type (I-VI; Figure II-4) arranged latitudinally. ASBS sites are in red.

There were significant differences among ASBS and non-ASBS sites when grouped by reef types in both the density of purple (*Strongylocentrotus purpuratus*) (ANOVA; $F_{5,59}$=3.59; p= 0.006) and red (*Strongylocentrotus franciscanus*) (ANOVA; $F_{5,59}$=5.81; p< 0.001) urchins. For both species ASBS sites tended to have higher densities than non-ASBS sites (Figures II-11a, II-12a), however, densities varied dramatically among reefs within each habitat type (Figures II-11b, II-12b). We found urchin barrens in at least 20 of 65 reefs. Urchin barrens were found on both mainland and island reefs. Notably the northern Channel Islands had a high percentage of sites containing urchin barrens. Santa Barbara Island (other than Sutil Island) had urchin barrens as well.

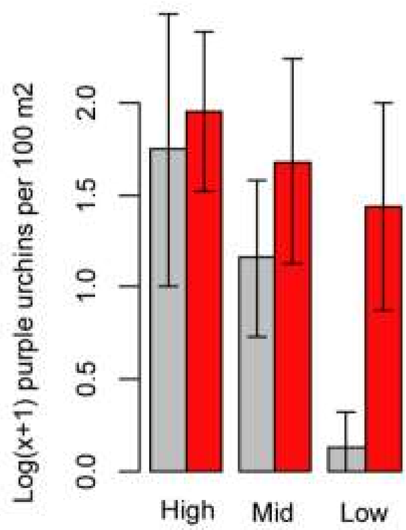

Figure II-11a. Log (x+1) density of purple urchins (*Strongylocentrotus purpuratus*) from swath surveys for ASBS (red) vs. Non-ASBS(grey) sites grouped by reef type: high relief (Type I and III), middle relief (Type II, IV and V), low relief (Type VI); Figure II-6. Error bars are 95% confidence intervals.

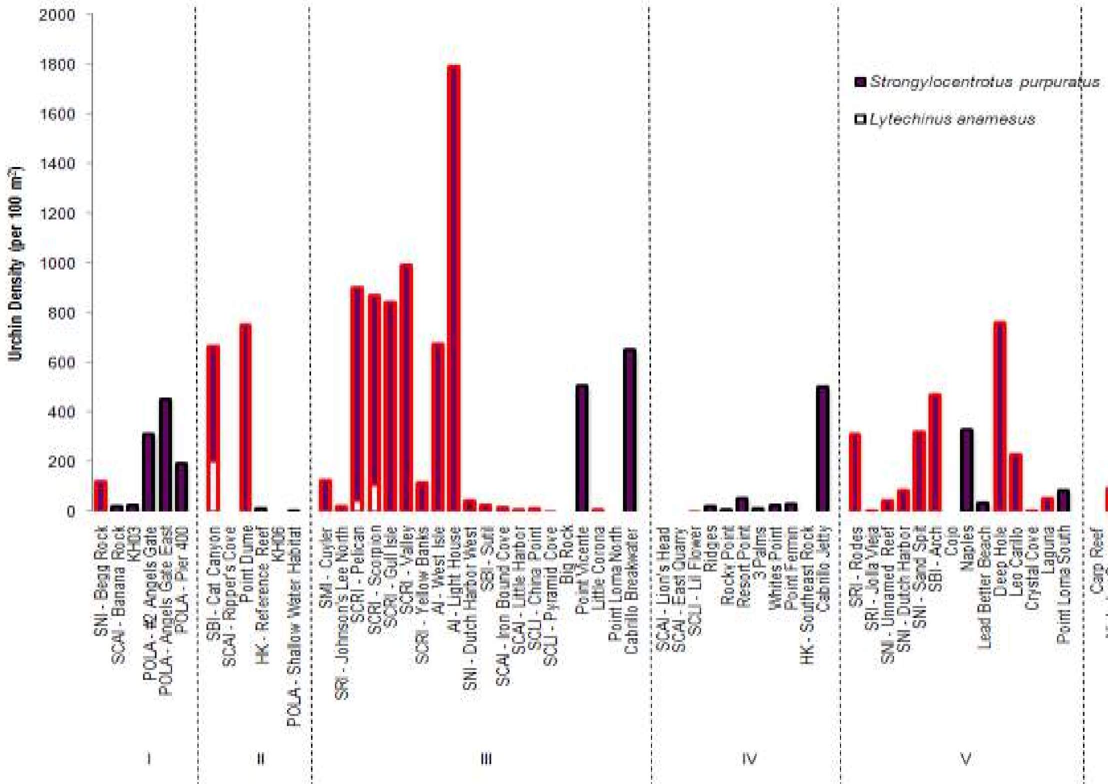

Figure II-11b. Density of purple urchins (*Strongylocentrotus purpuratus*) purple fill and white urchins (*Lytechinus anamesus*) white fill from swath surveys by reef type (I-VI; Figure II-6) arranged latitudinally. ASBS sites are outlined in red.

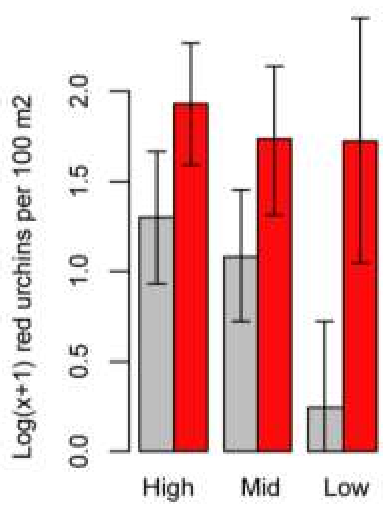

Figure II-12a. Log (x+1) density of red urchins (*Strongylocentrotus franciscanus*) from swath surveys for ASBS (red) vs. Non-ASBS(grey) sites grouped by reef type: high relief (Type I and III), middle relief (Type II, IV and V), low relief (Type VI); Figure II-6. Error bars are 95% confidence intervals.

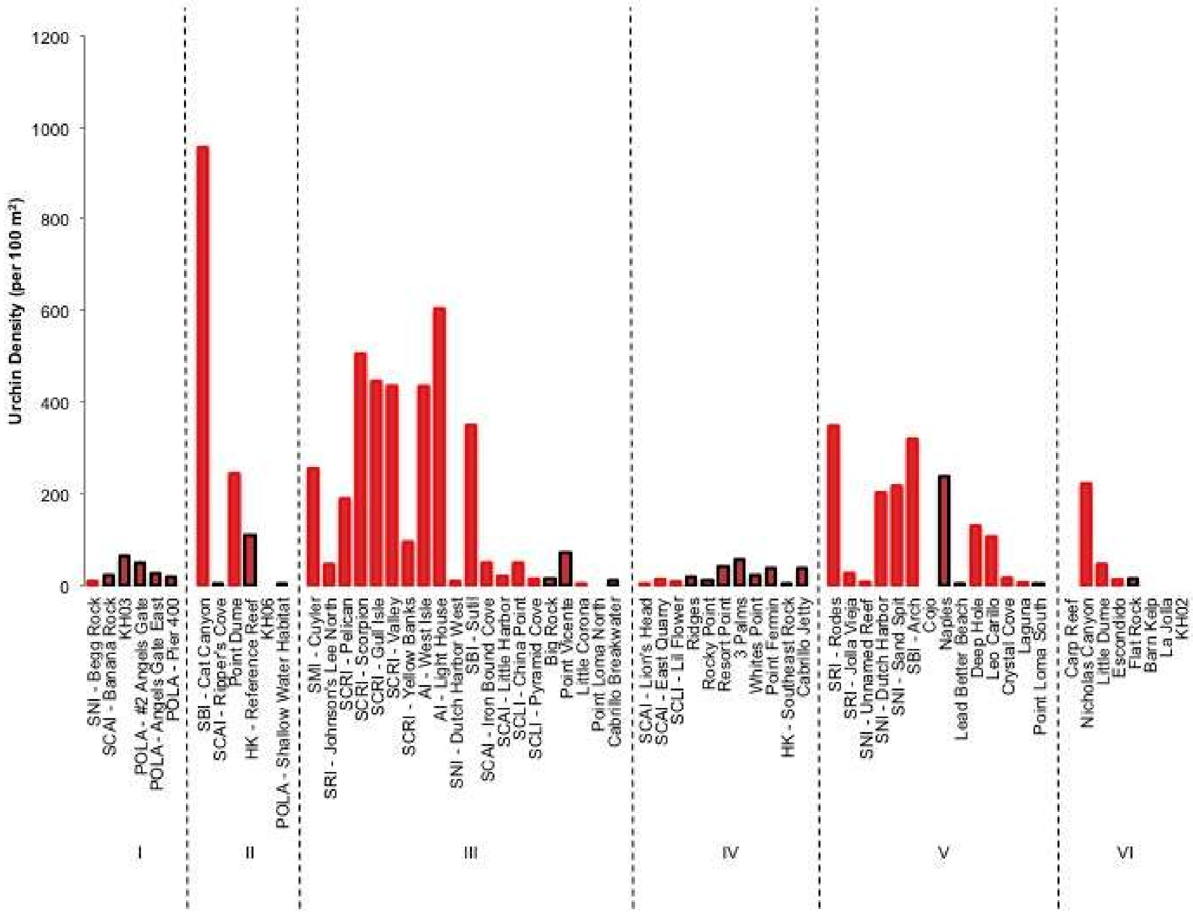

Figure II-12b. Density of red urchins (*Strongylocentrotus franciscanus*) from swath surveys by reef type (I-VI; Figure II-6) arranged latitudinally. ASBS sites are outlined in red.

Malibu/Latigo (ASBS 24)

Urchin barrens were found at Deep Hole and Point Dume. These were inversely related to kelp density and understory algae density. At the northern sites where urchin barrens dominate, high turbidity was also observed along this stretch of coastline (Burt Jones personal communication). There was also a high % cover of tube worms at 4 out of the 6 sites in this area, which also is suggestive of high sediment loads.

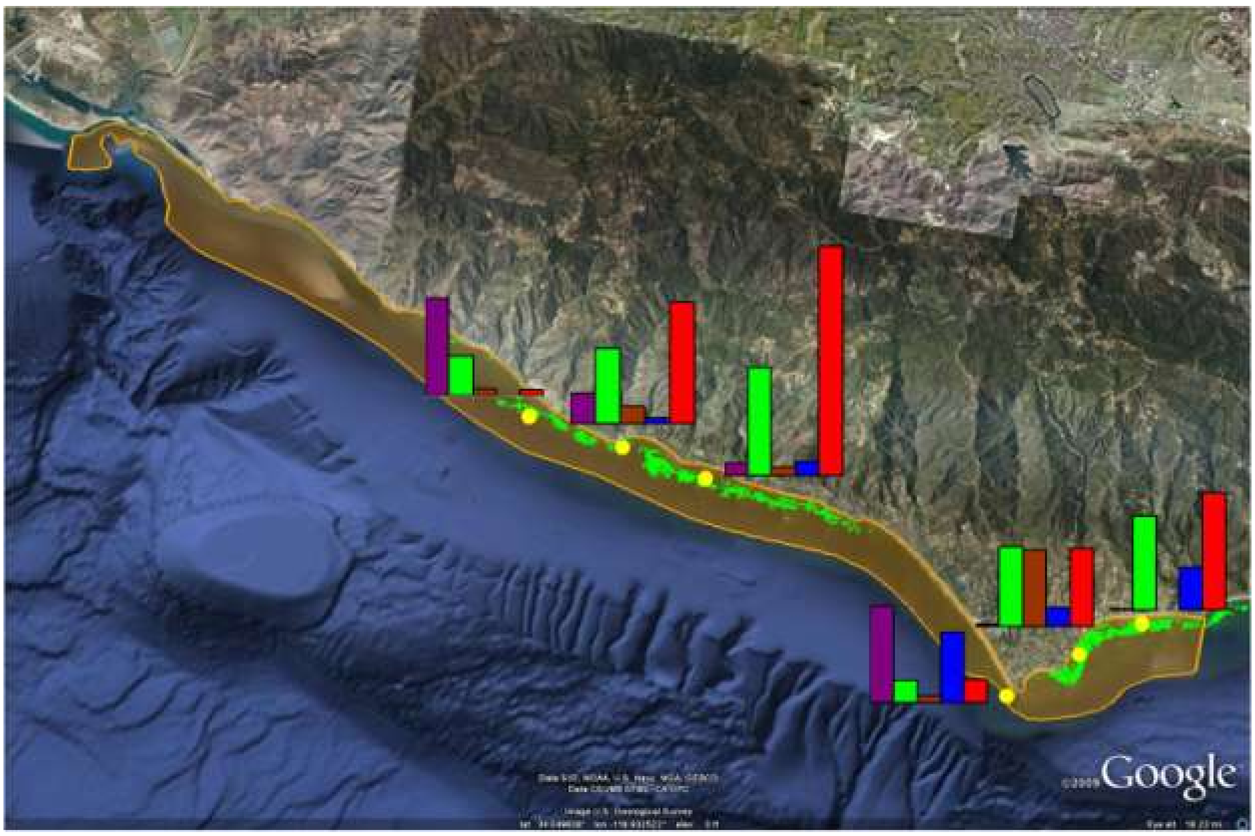

Figure II-13. The Malibu/Latigo ASBS, purple = urchin density, green = kelp density, brown = understory algae density, blue = % bare rock, red = % tubeworms, kelp canopy is in green. Bar heights for all factors were standardized by scaling (from 0-1) as a proportion of the highest recorded value in an ASBS for a given factor. Sampling locations are in yellow.

Newport Beach, Irvine Coast and Heisler Park (ASBS 32, ASBS 33 and ASBS 30, respectively)

Using these six metrics, the Newport Beach and Irvine Coast ASBSs, had good kelp canopy at 2 out of the 3 sites and no urchin barrens. All the reefs in this area are relatively shallow and kelp canopy was observed at the reefs in Newport Beach and Irvine Coast, but not in Heisler Park. Here kelp has been reduced or absent since 1993 and currently there is about 10% of the previous kelp canopy coverage. While purple urchin density was highest among these 3 sites at Heisler (54.2/100 m^2), this is a low value relative to other sites sampled in study (Table II-3).

Figure II-14. The Orange County ASBSs, purple = urchin density, green = kelp density, brown = understory algae density, blue = % bare rock, red = % tubeworms, kelp canopy is in green. Bar heights for all factors were standardized by scaling (from 0-1) as a proportion of the highest recorded value in an ASBS for a given factor. Sampling locations are in yellow.

La Jolla and San Diego-Scripps (ASBS 29 and ASBS 31)

There was not any rocky reef in the Scripps ASBS. The La Jolla ASBS is on the edge of the La Jolla kelp bed, sampling however did not occur in the ASBS proper, but did take place in the kelp bed. There was good kelp canopy and strong understory algae density.

Figure II-15. The La Jolla ASBSs, purple = urchin density, green = kelp density, brown = understory algae density, blue = % bare rock, red = % tubeworms, and kelp canopy is in green. Bar heights for all factors were standardized by scaling (from 0-1) as a proportion of the highest recorded value in an ASBS for a given factor.

San Clemente Island (ASBS 23)

Three sites were sampled at the east end of San Clemente Island. Sites genearlly had moderate kelp and understory algea density with relately low values for factors that may indicate water quality problems (i.e. urchin barrens, % bare rock and % tubeworms).

Figure II-16. The San Clemente Island ASBS, purple = urchin density, green = kelp density, brown = understory algae density, blue = % bare rock and red = % tubeworms. Bar heights for all factors were standardized by scaling (from 0-1) as a proportion of the highest recorded value in an ASBS for a given factor. Sampling locations are in yellow. Kelp canopy layer is in green (Kelner 2005).

Santa Catalina Island ASBSs (ASBS 25, ASBS 26 and ASBS 28)

Similar to the San Clemente Island ASBS, the Catalina Island ASBSs did not appear affected by the potential water quality indicators. In fact, we did not observe urchin barrens at this island at any site. Sites also had some of the highest kelp and understory algae densities of all ASBS sites surveyed.

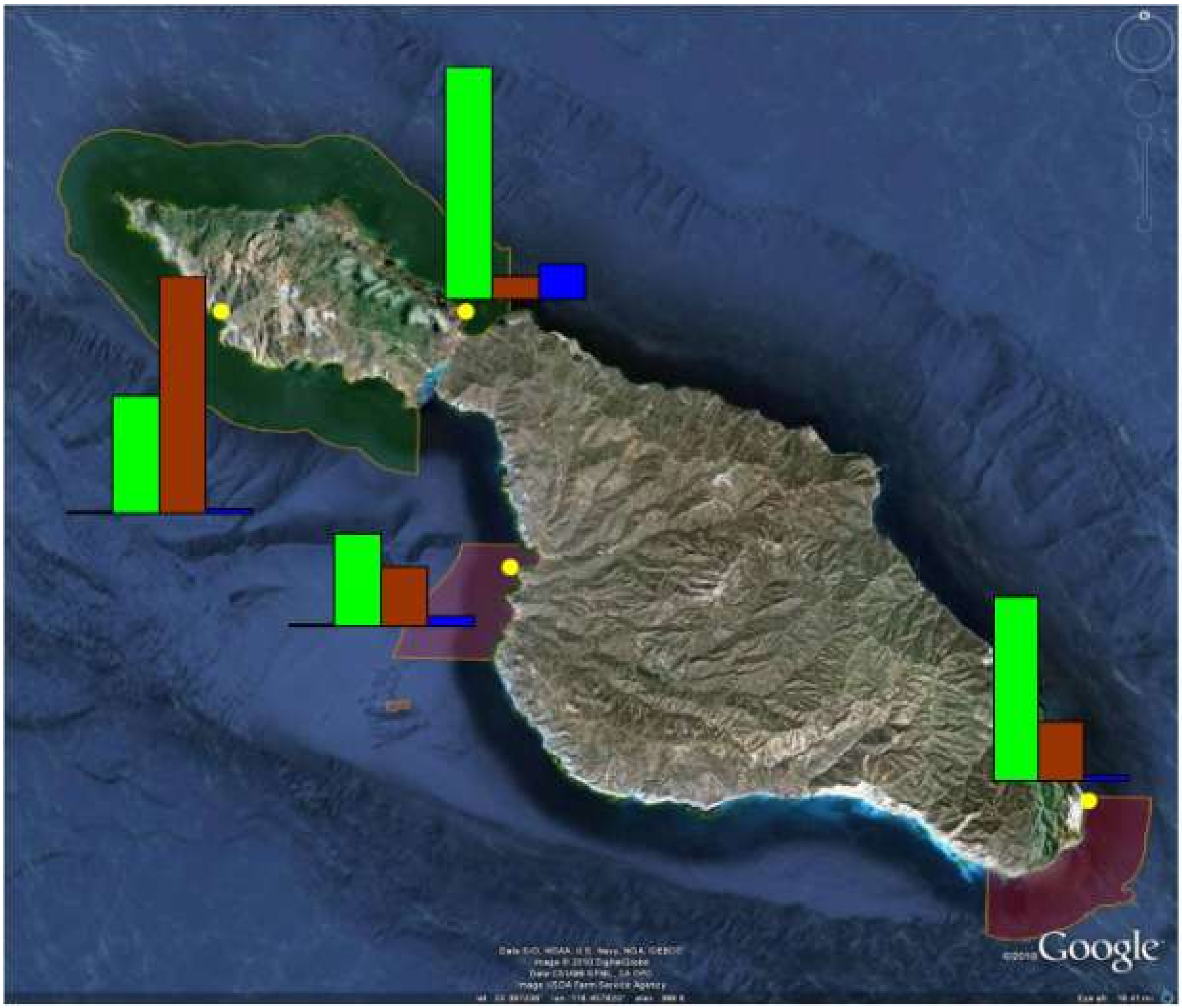

Figure II-17. The Santa Catalina Island ASBS, purple = urchin density, green = kelp density, brown = understory algae density, blue = % bare rock and red = % tubeworms. Bar heights for all factors were standardized by scaling (from 0-1) as a proportion of the highest recorded value in an ASBS for a given factor. Sampling locations are in yellow. Kelp canopy layer is in green (Kelner 2005).

San Nicolas Island (ASBS 21)

Of the five sites sampled at San Nicolas Island there was high kelp and/or understory algae density at all sites except for Begg Rock. Only one site on the east end of the island had a moderate urchin density, but this coincided with high kelp and algae levels. Two sites had moderate % cover of tube worms and it appears that there was also less kelp canopy coverage on the east end of the island as compared to previous years.

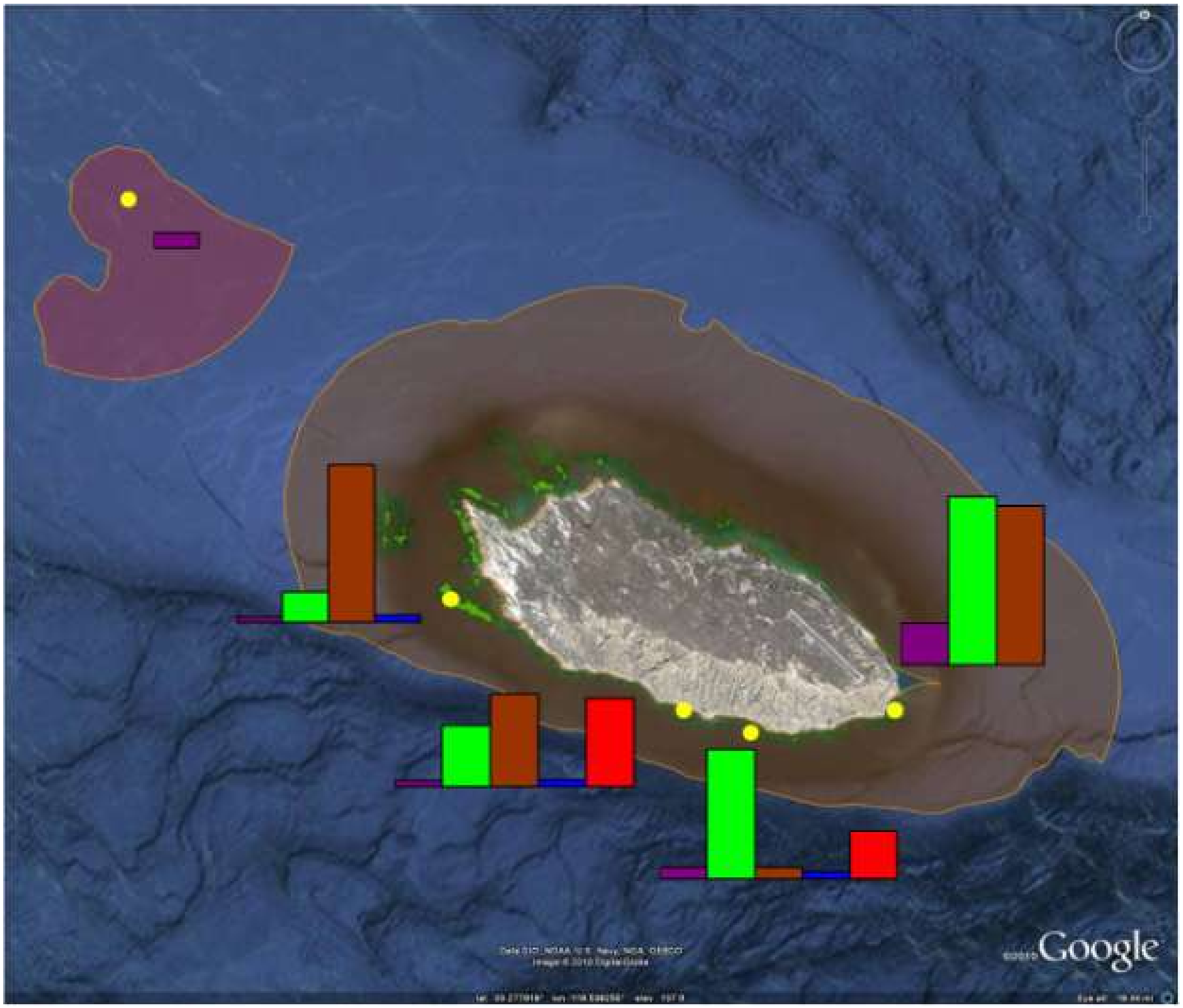

Figure II-18. The San Nicolas Island ASBS, purple = urchin density, green = kelp density, brown = understory algae density, blue = % bare rock and red = % tubeworms. Bar heights for all factors were standardized by scaling (from 0-1) as a proportion of the highest recorded value in an ASBS for a given factor. Sampling locations are in yellow. Kelp canopy layer is in green (Kelner 2005).

Santa Barbara Island (ASBS 22)

Santa Barbara Island has isolated high quality reefs, but the Island is dominated by high % cover of bare rock and 2 sties had moderate levels of urchin density. The reason for the % cover of bare rock is unknown as visual evidence of sediment scour was not prevalent during the time of the surveys.

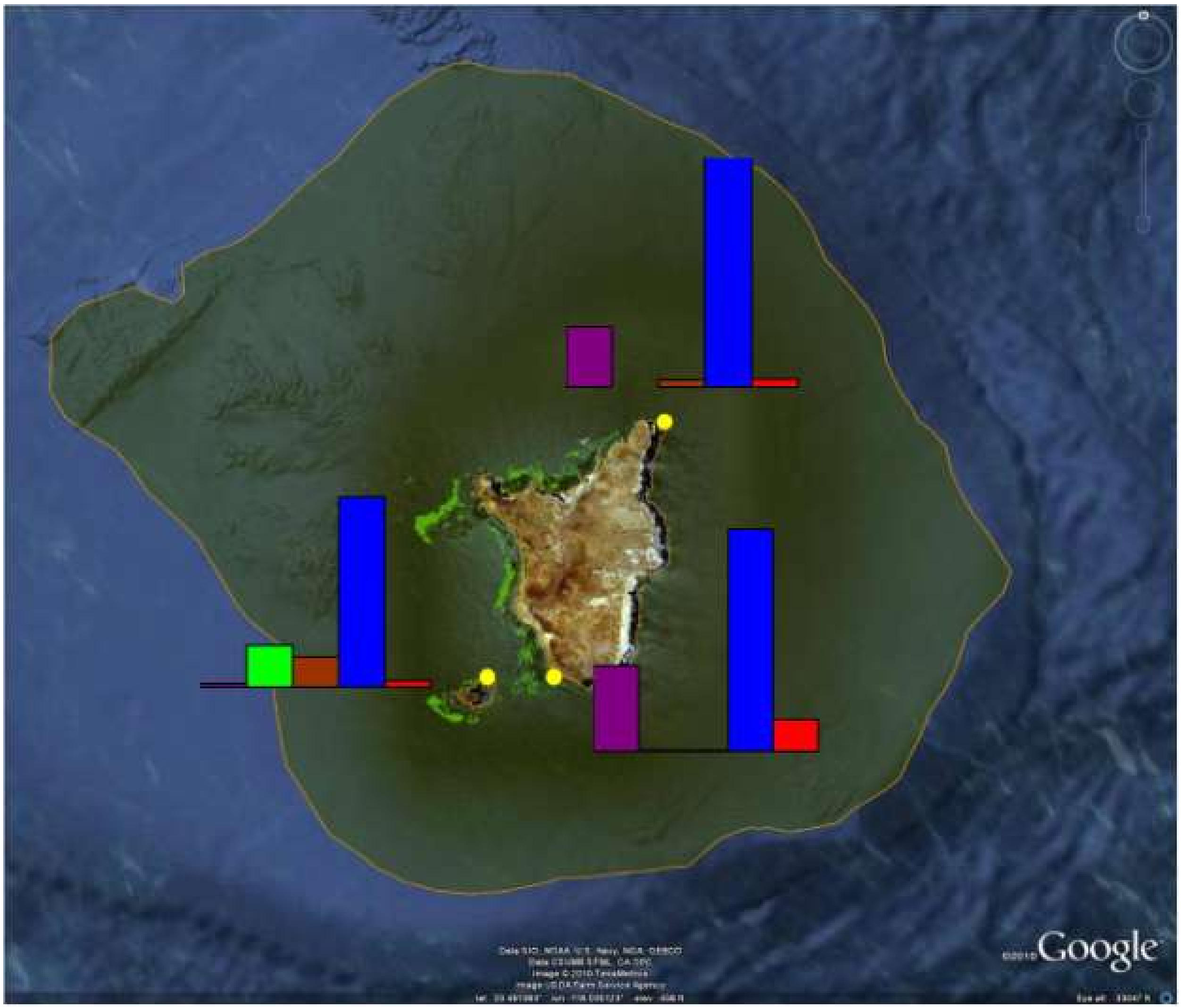

Figure II-19. The Santa Barbara Island ASBS, purple = urchin density, green = kelp density, brown = understory algae density, blue = % bare rock and red = % tubeworms. Bar heights for all factors were standardized by scaling (from 0-1) as a proportion of the highest recorded value in an ASBS for a given factor. Sampling locations are in yellow. Kelp canopy layer is in green (Kelner 2005).

Northern Channel Islands (ASBS 17 and ASBS 22)

Variability was high both within and among sites at these islands, presenting a mixed picture in terms of the water quality indicators utilized for this study. Sites contained both some of the highest densities of kelp and understory algae, and a high prevalence for urchin barrens. At times these co-occurred in a single site which is reflective of high variation in habitat characteristics at relatively small spatial scales (i.e. transect level). Some sites also had relatively high fractions of bare rock and tubeworms.

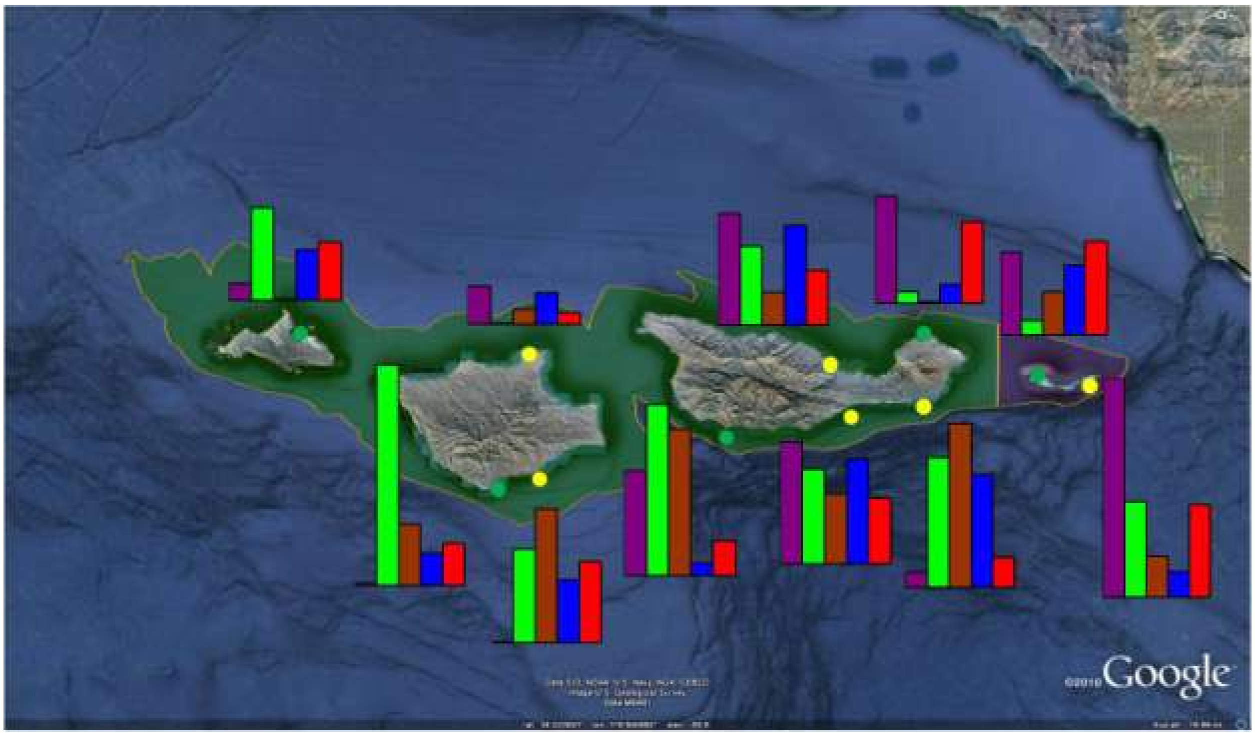

Figure II-20. The Northern Channel Island ASBSs, purple = urchin density, green = kelp density, brown = understory algae density, blue = % bare rock and red = % tubeworms. Sampling locations are in yellow; locations in marine reserves are in green. Bar heights for all factors were standardized by scaling (from 0-1) as a proportion of the highest recorded value in an ASBS for a given factor. Kelp canopy layer is in green (Kelner 2005).

Discussion

For many metrics associated with potential water quality impacts, rocky reefs in ASBS were similar to non-ASBS. These metrics included kelp canopy cover, understory algae, and the presence of bare rock. To contextualize this survey, 2008 was an excellent year for giant kelp growth primarily due to optimal oceanographic conditions and that growth has continued through 2009 (Figure II-1) (MBC 2010). However, evidence of anthropogenic impacts to giant kelp has been observed in the past (Stein 2009). These anthropogenic impacts stemmed from advanced primary treated wastewater discharges and no treated wastewater is discharged to ASBS studied herein (Schiff 2011).

There were some metrics that indicated a potential for water quality impacts in ASBS including the presence of tubeworms and urchin barrens. About a third of all rocky-reefs in Southern California appear to be impacted by urchin barrens. Urchin barrens are an indicator of a disturbed kelp ecosystem, where they may persist for years to tens of years as an alternative stable state (Steneck 2002). While in other ecosystems they have been linked to top down (loss of predators) forcing, this has been suggested (Steneck 2002), but not demonstrated in Southern California (Foster 2010). Nonetheless it is possible that variable fishing pressure among ASBSs influenced the presence/absence of urchin barrens. A surprising number of these are at the Channel Islands. However, spatial variation in these habitat characteristics was high, often differing substantially across transects within a single site. Unequivocally, urchins have been associated with pollution on mainland reefs (North 1964). Given this variability and the lack of an apparent causal factor for the increased density of urchins in ASBSs across all reef categories, further sampling over finer scales would be necessary to draw conclusions.

At sites in multiple regions in the SCB, both inside and outside of ASBS, a relatively high percent cover of tube worms may be suggestive of high sediment loads. These included sites in the vicinity of the Port of Los Angeles, potentially due to high turbidity and sediment loads associated with the Los Angeles River. Additionally, four of six sites in the Malibu/Latigo ASBS and at another non-ASBS site in the area had elevated levels. The Malibu/Latigo sites are south of the Santa Clara River (outside the ASBS), which is perhaps the greatest sediment generating river system in the SCB (Reifel 2009; Kniskern 2011). Additionally, measurements taken near ASBS discharges in the Malibu/Latigo ASBS also had TSS levels above reference thresholds following storms in 2009 (Schiff 2011). Similarly high percentages of tubeworms were seen at ASBS sites at Santa Cruz, Anacapa, Santa Rosa and San Nicolas Islands, which would not be expected to have the same potential sediment issues associated with sources as the mainland sites. This leads to the possibility that there are, or were, water quality issues at these islands that are currently not being studied (CINMS 2009). There is also the possibility that long-ranging, turbid runoff plumes from the mainland are affecting island reefs (Reifel 2009) or tube worm density is not strongly correlated with turbidity/sedimentation at all sites – more fine scale process studies might be necessary. Using tubeworms as a metric, Santa Catalina Island and San Clemente Island appeared to have reduced potential water quality impacts. Water quality measurements in both the Santa Catalina and San Clemente ASBS did not identify high TSS concentrations following storm events in 2009 (Schiff 2011).

Natural variability is a limiting factor in making strong conclusions about the health of ASBS subtidal rocky reefs. In this study, six unique habitat classifications were identified that correlated with reef relief, from steep bedrock pinnacles to flat cobble bottoms. These differences in abiotic factors drive large differences in the biotic assemblages that occupy a reef (Patton et al. 1985; Anderson 2004; Garcia-Charton et al. 2004; Graham 2004; Graham et al. 2008; La Mesa et al. 2011). Classifying reefs by relief and substrate into six major reef structure categories (and then three general categories: high, mid, low) controlled for habitat variation while testing for statistical differences in each potential water quality metric inside and outside of ASBSs. It is this variability that makes rocky reefs such a productive and valuable natural resource. This study identified that nearly 60% of the rocky reef in the Southern

California Bight exists in ASBS. The Channel Islands dominate most of this reef area (28,044 ha), which exemplifies the need to protect what little rocky habitat exists along mainland ASBS (747 ha).

The findings of this report do not necessarily indicate that ASBSs are suffering from greater water quality impacts than non-ASBS rocky reef habitats. Our goal was to simply apply established biological techniques to address potential water quality impacts. Hopefully, these results will open a discussion concerning reef quality throughout the Southern California Bight and explore the potential of various rocky reef metrics as water quality indicators. Ultimately, our knowledge of the impacts of runoff in the Southern California Bight can be greatly enhanced by integrative process studies of this phenomenon on various spatial scales. Considering that this program was not designed to detect specific water quality impacts, the techniques used appear sensitive enough to conduct future studies of water quality impacts.

Conclusions

1) **59.7% (28,791 ha) of Southern California Bight nearshore (<30 m) reef habitat are in ASBSs.**

   28,044 ha of the 29,237 ha of island reefs are in ASBS. For the mainland, 747 ha out of a total of 18,984 ha are in ASBS with the greatest proportion in ASBS 24, Mugu to Latigo Point (659 ha).

2) **Urchin density and tube worm density, two potential poor water quality indicators were significantly higher in ASBS than non-ASBS.**

   Urchin barrens were present on a third of the reefs in the Southern California Bight. A surprisingly high proportion of urchin barrens occur at the Northern Channel Islands and Santa Barbara Island (ASBS 17 and 22). They were also present at San Nicolas Island (ASBS 21) and at Malibu (ASBS 24). High urchin densities may have both natural and/or anthropogenic causes. High tube worm cover co-occurs on many of these reefs suggesting that turbidity is a factor. Other potential water quality metrics, including kelp density, understory algal cover, and bare rock did not show statistical differences between ASBS and non-ASBS reefs.

3) **The findings of this report do not necessarily indicate that ASBSs are suffering from greater water quality impacts than non-ASBS rocky reef habitats.**

   Our goal is that these analyses of potential water quality impacts open a discussion concerning reef quality throughout the Southern California Bight and explore the potential of various rocky reef metrics as water quality indicators. Our knowledge of the impacts of runoff in the Southern California Bight can be greatly enhanced by integrative process studies of this phenomenon on various spatial scales. Considering that this program was not designed to detect specific water quality impacts, the techniques used appear sensitive enough to conduct future studies of water quality impacts.

Recommendations

1) **Develop and improve reef health evaluation methods.**

   This study examined five potential metrics for assessing impacts. This is one of the simplest approaches to biological assessments. Multi-metric or multi-variate approaches have been demonstrated as useful approaches for detecting impacts in other marine habitats. Additional work should be undertaken to develop such tool(s) so ecosystem managers, including both regulated and regulatory sectors, can assess impacts in a scientifically robust and transparent way.

2) **Conduct strategic process studies to determine the effects of ASBS discharges, particularly storm drains, on rocky reef assemblages.**

   Runoff is not uniform throughout the Southern California Bight (i.e., Figure II-20). Thus, focused multi-disciplinary studies will be required to assess impacts of runoff discharges in ASBS. Chemistry, physical oceanography, toxicity, and ecology are all necessary tools in the toolbox that should be applied. This study identified specific metrics, some example constituents, and some general locations for conducting this focused research. The goal of such research should be to identify impacts stemming from specific ASBS discharge(s).

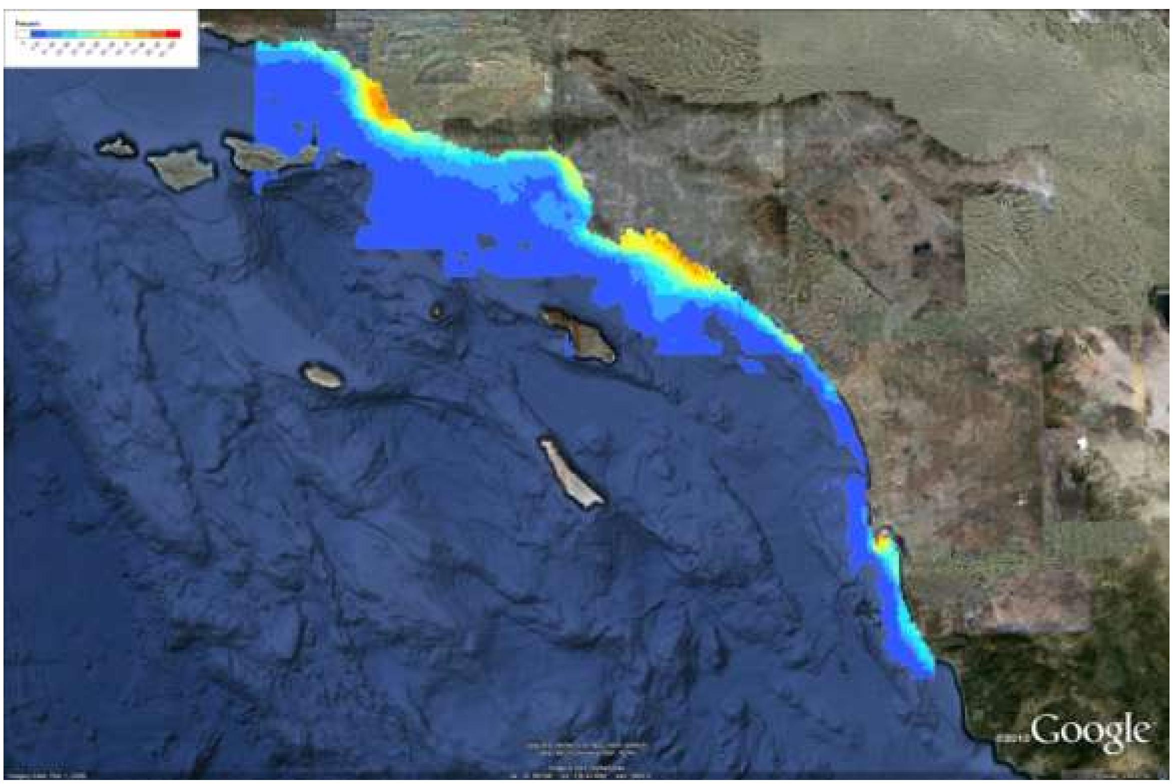

Figure II-20. Turbidity plumes observed by SeaWiFS radiometer for rain events (≥ 0.25 mm) (Nezlin 2005).

3) Determine the effects of other water quality stressors on reefs.

The metrics used in this study had a focal point on turbidity. Yet we know that turbidity is not the only potential water quality stressor on rocky reefs. For example, nutrient over-enrichment has led to eutrophication in many marine systems. Results have ranged from kelp growth enhancements when low level nutrient additions act as a type of fertilizer to harmful algal blooms and depressed oxygen levels that reverberate throughout the ecosystem. The discharge of toxics can be equally devastating, creating losses in biodiversity. In fact, standard laboratory toxicity tests use *Macrocystis* as a test organism. Since storm drains are known to discharge both nutrients and toxics, future work in this area is warranted.

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III. A PRELIMINARY INVESTIGATION INTO THE STATUS OF NEARSHORE ROCKY REEFS IN THE SANTA MONICA BAY REGION OF THE SOUTHERN CALIFORNIA BIGHT

Introduction

The Vantuna Research Group (VRG) at Occidental College, Santa Monica Baykeeper (SMBK) and the Los Angeles County Sanitation Districts (LACSD) partnered to quantitatively assess the nearshore rocky reef resources of Santa Monica Bay as part of the Bight '08 program during the 2008 sampling season. This field effort is part of an ongoing collaborative effort among these programs and the Santa Monica Bay Restoration Commission since 2007 in an effort to address the objectives (see below) of the SMBRCs Comprehensive Monitoring Program (SMBRC 2007; Pondella 2009).

Santa Monica Bay represents a unique nearshore biological habitat in the Southern California Bight. In this region, the coastline consists of long stretches of sandy beach broken up by rocky headland at Malibu and Palos Verdes. These headlands represent the confluence of the cold temperate (Oregonian) fauna from the north and the warm temperate (San Diegan) fauna from the south (Horn 1978; Horn 2006). It is also the most northern quiescent bay in the region facilitating the influence of the warm temperate fauna as well as heavy utilization by recreational fishers, primarily originating in Marina del Rey and King Harbor, Redondo Beach. As such, the major reef areas, the headlands at Palos Verdes and reefs along the Malibu coast, are intensively fished by both commercial and recreational fishers (Stull 1987) and is certainly the most popular locale for fishing in Los Angeles County.

The resources of the region have been studied intensively over the past few decades including long-term (1974-present) rocky reef monitoring of fishes (Terry 1976; Stephens 1984; Stephens et al. 1994; Pondella et al. 2002), kelp bed restoration at Palos Verdes and Malibu (Ford 2010), and NPDES monitoring at Palos Verdes (LACSD 2010). In this program we have coordinated these long-term studies to address spatial scale questions both within the reefs of the bay and among the reefs of the bight. Our goal was to address the following objectives (SMBRC 2007):

1) Determine the status of algal, invertebrate, and fish communities throughout the Bay within the shallow water (< 90 feet) portion of the habitat
2) Track changes over time in the status of algal, invertebrate and fish communities throughout the Bay within shallow water (< 90 feet) high relief and low relief habitat types
3) Conduct reconnaissance of conditions in deep-water (> 90 feet) habitat, including banks, canyons, and rocky outcrops along the shelf edge
4) Track changes over time at a set of fixed reefs in shallow water
5) Estimate changes in abundance of key commercial and recreational rocky subtidal fishes
6) Assess the effectiveness of the current Areas of Special Biological Significance (ASBS) at Malibu and any future marine protected areas at protecting and/or restoring algal, invertebrate, and fish communities

Methods

Mapping-The best compilations of mapped rocky reef habitat in the SCB were assembled in GIS. These included maps of hard bottom habitats and kelp canopy (Kelner 2005). GIS spatial analysis techniques were used to integrate existing spatial data that characterizes bottom type, kelp cover, and bathymetry to create a preliminary habitat map. Using these data in GIS, we met with experts who have conducted multiple subtidal scuba research projects on various geographic areas of the SCB. These working groups delineated and categorized all reefs in the SCB (Figure III-1). The size of each reef was calculated in GIS and categorized as large, medium or small based upon the distribution of reef sizes. In more well-studied regions (i.e. Palos Verdes, Catalina etc.) investigators tended to identify reefs on a finer scale, which would bias the sampling draw to these regions. Similarly, large reef tracks would be deemphasized. Thus, reef designations were adjusted to be as consistent as possible in size and distribution throughout the bight. At Horseshoe Kelp in Los Angeles County and Point Loma, the large reef areas were broken into two and three reefs, respectively, for the sampling draw.

Station Draw-Reefs were coded as island or mainland within each biogeographic realm, San Diegan (warm temperate) or Oregonian (cold temperate). Biogeographic realm was determined by biogeographic assessment of benthic fish assemblages studied during the 2003-04 CRANE survey (Tenera_Environmental 2006). In this biogeographic analysis young-of-year (YOY) fishes whose density is seasonal, and highly abundant pelagic species (*Engraulis mordax* and *Sardinops sagax*) present at only two sites were excluded from the data set. All statistics were run using PRIMER (version 6). The number of fishes observed by station were Log (x+1) transformed. A Bray-Curtis similarity matrix was then calculated and a hierarchical cluster analysis was performed. Using the similarity matrix, non-metric multi-dimensional scaling was performed and using 45% similarity ellipses calculated from the Bray-Curtis cluster the biogeographic regions were determined. Oil platforms, artificial reefs, breakwaters and jetties were not included in this mapping effort because they are well mapped and not part of the random station draw. For the spatial scale aspect of this program, 60 natural rocky reefs (Figure III-1) from this map were selected using the Generalized Random Tessellation Stratified (GRTS) Spatially-Balanced Survey Designs (Stevens and Olsen, 2004), a probability-based design developed for Monitoring Aquatic Resources, through EPA's Environmental Monitoring and Assessment Program (EMAP) (Stevens 1999). The advantage of the GRTS design is that it allows for random sampling in a way that provides good spatial coverage (without the clumping of sites often seen with simple random sampling). In addition, various strata or subpopulations can be defined and weighted proportionally to a host of subpopulation characteristics (e.g., the size of the resource, the size of the reef, variabilities of subpopulation estimates, etc.) so as to maximize efficiency when estimating population totals or comparing among subpopulations.

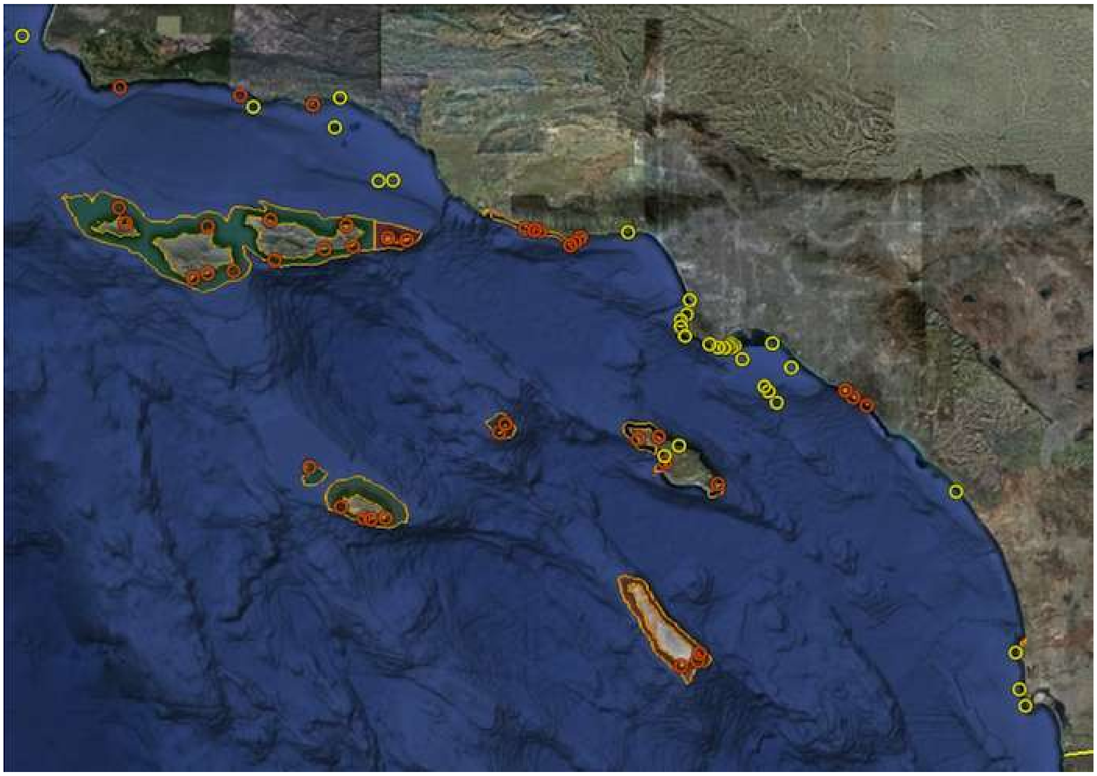

Figure III-1. 72 sites sampled in the Southern California Bight, ASBS's are shown in orange.

Figure III-2. Inner, middle, outer and deep depth strata used in Bight '08 rocky reef program.

Sampling Unit-A sampling cell consisted of at least 250m of reef habitat. Within each cell four depth strata (if present) were sampled and geo referenced. These strata are the inner (~5m), middle (~10m) and outer (~15m) and deep strata (~25m) portions of a natural reef or kelp bed (Figure III-2). Within each depth strata two benthic sampling protocols, Uniform Point Contact (UPC) and macro invertebrate and algae (Swath) were completed. All transects were 30m; swath transects were 30m x 2m belt transects.

UPC- Percent cover of substrate type, substrate relief and benthic organisms were recorded at each meter mark along the 30 m transect tape. Substrate percentages in the following categories were estimated within each 10 m segment: bedrock ($\geq$ 1 m), boulder (1 m), cobble ($\leq$10 cm), and sand. Substrate relief was the maximum relief within a rectangle centered on the point that is 0.5 meter along the tape and 1 meter wide. To contact benthic organisms, the line is pushed down and the species under the tape is recorded. If the line could not contact the substrate, the diver's finger was used to mark the spot. Epiphytes, epizooids and mobile organisms were not recorded. If the contact point was on a blade of Laminaria, brittlestars or the sea cucumber *Pachythione rubra*, the organism under the point was recorded and it was noted that the point was under one of these organisms. The superlayer was also recorded. In addition to quantifying benthic organisms, the following types of bare substrate were recorded, if contacted: rock, sand, shell debris, and mud. Considering their paucity for the majority of the SCB the size and species of any abalone was recorded.

The percentage of each type of substrate category (bedrock, boulder, cobble or sand) was determined by pooling the number of contact points for all replicates at each site by category, and dividing the sum of each category by the total number of contact points at that site. Percentage of reef relief category (0-.1m, .1-1m, 1-2m or >2m) was calculated in the same manner. All benthic reef coverage was categorized into groups that roughly follow taxonomic divisions or appropriately named abiotic groups and densities for each group were calculated by site. Reef structure categories (% relief and substrate) were square root transformed and normalized prior to being clustered using Euclidean distances. Percent reef cover categories were square root transformed and then clustered using a zero-adjusted Bray-Curtis similarity index. These two hierarchical clusters were examined using the RELATE statistic, ρ, using the Spearman Rank Correlation with 999 permutations.

Swath-The purpose of the swath sampling was to estimate the density of conspicuous, solitary and mobile invertebrates as well as specific macroalgae. Individual invertebrates and plants were counted along the entire 30 m x 2 m transect. Transects were completed even if sand was encountered but when there was sand for more than 5 m, the direction of the transect was changed to the minimum necessary to remain on rocky habitat. Divers slowly swim one direction counting targeted invertebrates (from a pre-printed list on the data sheet) and then swim back along the transect counting targeted macroalgae. Cracks and crevices were searched and understory algae pushed aside. No organisms were removed. Any organism with more than half of its body inside the swath area was counted.

The following size criteria applied to counting macroalgal species: a) *Macrocystis* taller than 1 m (3.3 ft), and number of stipes per plant at 1 m above the substrate. *Macrocystis* is not subsampled; b) *Nereocystis, Pterygophora*, *Laminaria setchellii* and *Eisenia arborea* taller than 30 cm (11.8 in); c) *Laminaria farlowii* with blade greater than 10 cm (3.9 in) wide; d) *Cystoseira osmundacea* greater than 6 cm (2.4 in) wide; and e) *Costaria* and *Alaria* no size restrictions.

Transects were divided into three, 10-meter segments. Species that occurred in high densities (e.g., purple urchins) were sub-sampled if greater than 30 individuals occurred within any of the three 10 m segments on a transect. When 30 individuals of one species were counted, the diver recorded the meter mark at which the threshold abundance was reached and then stopped counting that species for the remainder of that segment. The species was then again counted at the start of each following segment and the same threshold abundance rule was applied. The subsampled abundances were then extrapolated per segment to calculate an estimated total abundance per transect. All swath taxa densities were estimated based on the count or estimate of the number of each taxa over the 60 m^2 area covered by a single transect and scaled to 100 m^2. Swath species were grouped into large taxonomic categories. Mean number of stipes per *M. pyrifera* holdfast was also calculated.

Urchins- In order to gain a more accurate estimate of the size frequency distribution of local sea urchins populations, specimens were collected and measured in the areas on and around each transect. In areas where urchins were abundant at least 100 red and 100 purple urchins were collected and their test diameters measured to the nearest millimeter. Specimens were collected from each depth zone and multiple areas of the site, if possible. To avoid bias in size measurements, all emergent urchins were collected from each patch unless the patch is very large, in which case only a portion of the patch was completely collected. Urchins were measured on the boat. Very small urchins (< 1 cm) under the spine canopy of larger urchins are not measured. If it is not possible to collect 100 of each species within a total dive time of one hour, the search for urchins was suspended. Mean test size and standard error for red (*S. franciscanus*) and purple (*S. purpuratus*) urchins were calculated along with 95% confidence intervals.

Fish-The purpose of the fish sampling was to estimate fish density and length frequency distributions by species at each site. A minimum of 3 m of horizontal visibility was the acceptability cutoff. Divers swim in the pre-arranged compass direction for a distance of 30 m while counting and estimating the sizes of the fish along an isobath. All conspicuous fishes encountered along the transects were recorded. Divers count and estimated total length (TL) of small fish (< 15 cm TL) to the nearest cm, and larger fish (> 15 cm) to the nearest 5 cm interval. If a school of fish (>10 fish) is encountered, the number of fish is estimated within each size group. The observer censused fishes within the boundaries of an imaginary observation “box” slightly ahead of them as they swim along, sometimes stopping, scanning and searching within discrete areas of the “box” that is delimited by the 2 m transect width and natural features such as kelp plants or large boulders. If there is an intervening obstacle, the transect continued over it so long as the depth change was less than 2.5 m. If the obstacle is greater than 2.5 m in height, the transect circumvented it. Transects are completed even if sand is encountered. When there was sand for more than 5 m and it appeared that the habitat continued primarily as sand, the transect direction was changed to the minimum necessary to remain on rocky habitat. Physical data collected on each transect included observation depth (m), water temperature (C^o), horizontal visibility (m), surge (0-4 relative scale), and kelp canopy cover (%). Transects were completed in 3-6 minutes depending on the number of fishes and the complexity of the habitat. Upon completing a transect, the divers then swim to the starting point of their next replicate transect within the same zone by choosing a haphazard direction along a similar depth contour. The preferred distance between transects is at least 10 m.

By dividing the number of individuals by the surface area covered on a transect (typically 60 m^2), the mean density (abundance/m^2) of fishes were calculated for each site and for each bottom, midwater and canopy transect type at each site. In addition, the total length (TL) estimates were converted to biomass using species-specific length-weight conversion power equations of the form:

$Wt = aTL^b$,

where weight (g) is calculated from the total length (TL) estimate and a and b are species-specific constants. These constants were obtained from the literature, calculated in the laboratory or, when these two avenues were not available, adapted from the most similar morphological or proxy species. For some species only standard length (SL) to weight conversion equations were available. In these cases, TL was converted to SL using the linear function:

$TL = aSL + b$,

where a and b are species-specific parameters of the line. After the length-to-weight conversions were made, biomass density (g/m^2) was calculated in a similar fashion for each site. Site specific density and biomass were plotted with the values for benthic, midwater and canopy transects indicated separately.

Prior to statistic calculation, filter criteria were applied to remove fish species or size classes that would disproportionately weight the data toward a certain site for certain statistics. Pelagic species that are not characteristic of rocky reef habitats were excluded from the data set for all analyses because they occurred infrequently, but when they were present, they generally occurred in very large numbers. These included unidentified pelagic species (i.e. “Baitball") and the following species: *Engraulis mordax, Sarda chiliensis, Sardinops sagax, Scomber japonicas, Sphyraena argentea*, and *Trachurus symmetricus*. Additionally, because sites were sampled over a time period of several months, young-of-the-year (YOY) were removed prior to density calculations because they could numerically dominate the assemblage at some sites sampled early during the sampling season but decline later in the year as a result of natural mortality. YOY were generally defined as fishes <10 cm for all species except*: Aulorhynchus flavidus, Brachyistius frenatus, Cymatogaster aggregata, Gibbonsia elegans, Gibbonsia* sp., *Lethops connectens, Micrometrus minimus, Rhinogobiops nicholsii,* and *Syngnathus* sp. (YOY were < 5 cm) and Gobiidae sp. and *Lythrypnus dalli* (YOY were <1.5 cm). YOY were not excluded from biomass calculations as their small size would tend to have a more minimal impact.

A guild value (model adapted from Bond et al. 1999) was calculated for each site. This is a three parameter model where fish assemblages are quantified based upon feeding guilds (Table X) using mean size (TL), density (D: per hectare), and fidelity (F). Thus, the model incorporates trophic levels (feeding guilds), a diversity factor (# of guilds), density, size and fidelity. Fidelity, defined as the proportion of occurrence of a guild at a site per sampling period, was set to 1 as there was only a single sampling period for this study. The three parameters are treated equally such that for each guild, the guild value is the square root of the product of the three parameters. The guild values are then summed to yield a guild value (GV) for each depth zone as follows:

$$GV = \sum \sqrt{mean(TL) * F * D}$$

A GV was calculated for each depth zone sampled in the survey and then summed across all depth zones to yield a guild value for each site. Density was calculated by summing the density across the three transects types (bottom, mid water and canopy) per depth zone (inner, middle, outer, deep), with the aforementioned pelagic species excluded, but YOY were included as their impact would be mitigated by mean (TL) in the model.

Analyses of Commercial and Recreational Species - Site-specific density and biomass was also plotted for the following important commercial and recreational species, kelp bass (*Paralabrax clathratus*), barred sand bass (*Paralabrax nebulifer*), sheephead (*Semicossyphus pulcher*). To gain insight into the status of mean size and population size structure, which can provide insight into effects of fishing local populations when these are compared to the legal size limit, size frequencies were plotted for each of these 3 species observed at rocky reef sites (artificial reefs were excluded for this analysis). Sites were pooled within three groups (Santa Monica Bay, Mainland non-Santa Monica Bay and Islands) to obtain appropriate sample sizes for statistical analysis. Mean size for each species was compared among the 3 groups of sites using a 1-way ANOVA. YOY (TL <10cm) were excluded from these analyses to reduce the influence of temporal recruitment variability with respect to when individual sites were sampled. Site-specific density of red sea urchins (*Strongylocentrotus franciscanus*) was also plotted and size frequencies were plotted for urchins observed at rocky reef sites (artificial reefs excluded) pooled within Santa Monica Bay, Mainland non-Santa Monica Bay sites and Island sites. Mean urchin test size was also compared for each species among the 3 groups of sites using a 1-way ANOVA.

Results

Substrate-Substrate composition in rocky reefs within Santa Monica Bay is generally similar to that of the rest of the mainland SCB, though substrate at sites in the northern half of SMB was composed more of sand and cobble than the southern half, which is composed more of bedrock and boulders (Figure III-3). In particular, the substrate at Point Vicente is nearly entirely composed of bedrock, which is similar to island reefs and other pinnacle/point reefs.

Vertical Relief-Vertical relief in SMB was typical of mainland SCB rocky reefs, composed on average of approximately 40-50% no/low relief (Figure III-4). Notable exceptions include Point Dume and Point Vicente, which are mostly moderate to high relief reefs, much like island and artificial reefs. Big Rock, which is a small patch reef with many large bedrock formations and sand channels, is classified almost entirely as moderate relief reef.

Benthic Cover-Abiotic cover at rocky reefs was generally higher in Santa Monica Bay than the rest of the SCB, with the exception of Point Vicente which had almost no abiotic cover, likely due to the high relief nature of the reef (Figure III-5). Abiotic cover can often be associated with either destructive ocean processes, such as bare rock on vertical faces or when shell hash is created near an exposed mussel bed. It can also be a product of high runoff from land, as is common in Santa Monica Bay, or simply a patchy reef. Some of the areas in SMB with the highest amount of abiotic cover are on the west coast of Palos Verdes Peninsula, which is a vast area of continuous, somewhat protected rocky reef with several point sources of urban runoff. Invertebrate and algal coverage is highly variable throughout SMB, yet typical for the entirety of the SCB.

Macroinvertebrates-Macroinvertebrate densities in the northern half of Santa Monica Bay were at or above the average for the entire SCB, particularly at Point Dume, which had the highest macroinvertebrate density of all mainland SCB sites (Figure III-6). In the Palos Verdes region, macroinvertebrate densities were much lower than average overall, again with the exception of Point Vicente. The large, bedrock dominant, high relief, nearshore pinnacle reefs at Point Dume and Point Vicente are prime habitats for sea urchins (*Strongylocentrotus* spp), which indeed comprise the vast majority of each site's macroinvertebrate population. This composition is similar to other sites in the northern half of SMB (Deep Hole, Leo Carillo, Nicholas Canyon), and is most similar to artificial breakwaters and jetties, as well as some of the Channel Islands.

Big Rock, a small, isolated reef at the far east end of Malibu, was the lone anomaly in SMB. While sites like Point Dume and Point Vicente have high densities of macroinvertebrates, dominated by sea urchins (*Strongylocentrotus* spp), sea stars (*Patiria miniata* and *Pisaster* spp), and solitary green anemones (*Anthopleura sola*), Big Rock is almost completely devoid of these species. Instead, the macroinvertebrate landscape is dominated by the solitary stalked tunicate (*Styela montereyensis*) and the California golden gorgonian (*Muricea californica*).

Purple sea urchins (*Strongylocentrotus purpuratus*) densities in the northern half of Santa Monica Bay (from Deep Hole to Point Dume) were among the highest along mainland SCB and similar to densities at the Port of Los Angeles artificial breakwaters and jetties (Figure III-7). Reefs at Palos Verdes Peninsula had relatively low densities of purple urchins, similar to the rest of mainland SMB and the southern Channel Islands. Once again, the lone exception at Palos Verdes is at Point Vicente, which had the third highest density of purple urchins in SMB. Test sizes for purple urchins in Santa Monica Bay increased almost uniformly from north to south, with test sizes at Deep Hole and Leo Carillo being smaller than average for the SCB, and test sizes at 3 Palms, White Point, and Point Fermin being larger than average (Figure III-8). Significant differences in mean size were found for purple urchins (ANOVA; $F_{2,3473}$=251.5, p <0.00), with Santa Monica Bay sites having a larger mean size at 42 mm (95% CI: 41, 43) than the other site groupings. However, there was no difference between Mainland non-SMB sites at 31 mm (95% CI: 30, 33) and Island sites at 31 (95% CI: 30, 31) (Figure III-9).

Abalone-Given the paucity of abalone in the Southern California Bight, it should be no surprise that only a single individual was recorded on transect in Santa Monica Bay (Table III-B). However, it should come as a great surprise that the one abalone was a white abalone (*Haliotis sorenseni*), a federally endangered species, typically assumed to be at depths greater than the scope of this work, and at a well-known and well-hunted reef (Ridges at Palos Verdes).

Table III-B. Number and location of abalone (*Haliotis* spp) recorded on swath transect in the Southern California Bight. SMB reefs and records in blue.

Station	*Haliotis corrugata*	*Haliotis fulgens*	*Haliotis rufescens*	*Haliotis sorenseni*
Point Loma South	1			
HK - Reference Reef		1		
SCAI - Ripper's Cove		2		
SCAI - Little Harbor		3		
SCAI - Banana Rock		1		
SCAI - Iron Bound Cove	1	8		
Ridges				1
SMI - Cuyler			1	
SRI - Johnson's Lee North			11	
SRI - Jolla Vieja			1	
Bightwide	3	15	13	1

Macroalgae-Understory macroalgae is a large component of the benthic landscape in the Palos Verdes region of SMB, but is nearly absent in the Malibu region with the lone exception of Little Dume (Figure III-10). Giant kelp (Macrocystis pyrifera) holdfast densities on reefs at Palos Verdes Peninsula are among the highest in the SCB, with densities on Malibu reefs being lower but still average for the rest of the SCB (Figure III-11). One site well inside King Harbor has one of the highest densities of giant kelp holdfasts in Santa Monica Bay, most likely because of the artificial protection from the breakwater, and despite issues of pollution, sedimentation, and heat retention. It should be noted that giant kelp density is underestimated on mainland reefs where a deep component was surveyed (i.e. Ridges and Rocky Point) since few giant kelp can survive at depths greater than 20m.

As the density of giant kelp holdfasts only tells a portion of the story, it is important to consider the number of stipes per holdfast (Figure III-12). The number of stipes per holdfast in SMB was lower than the rest of the mainland SCB, and varied greatly from reef to reef. Interestingly, the reef with the highest number of stipes per holdfast in Santa Monica Bay was the Santa Monica Baykeeper kelp restoration site at Escondido, while the lowest was at Rocky Point, Palos Verdes Peninsula.

General fish results-There was high variation in total density and biomass of fishes among sites within the Santa Monica Bay and across the SCB (Figures 13, 14), however two sites within the Santa Monica Bay had the highest total fish Biomass of all sites surveyed in the SCB. Big Rock had the highest total fish biomass of any site at 552 g/m^2 and Nicholas Canyon had the second highest at 442 g/m^2. The extremely high biomass at Big Rock, a small, relatively isolated high relief reef, was almost exclusively due to very high biomass of large opaleye (*Girella nigricans*) (44% of total biomass) and sargo (*Anisotremus davidsonii*) (40% of total biomass). Additionally, Big Rock covers a small area relative to most other reefs in the survey and therefore had only a single depth zone (Inner) and only 4 transect replicates were performed at the site. This may help explain why these two species dominated the total site biomass compared with other sites that included multiple depth zones where these species may tend to be less abundant. At Nicholas Canyon the high biomass was largely due to numerous large (35 to 40 cm TL) barred sand bass (*Paralabrax nebulifer*) (52% of total biomass). Also note that 21% of total biomass was kelp bass (*Paralabrax clathratus*), although these were primarily smaller individuals <30 cm TL. However, repeated surveys would be required to determine if this was the case or if this is a resident population.

Fish guild value varied appreciably throughout the SCB with values at Santa Monica Bay sites being just below to well above the SCB average (Figure III-17). As has been the case with other abiotic and biotic metrics, Point Dume, Little Dume and Point Vicente also had well above average Fish Guild Values relative to the SCB and to values for other Santa Monica Bay sites. Sites closest to King Harbor (Flat Rock and Ridges) were relatively low, possibly indicating the negative influence of recreational fishing. Finally, while the value at Rocky Point was one of the highest in the Bay, this was partially due to an abnormally high number of fishes in the midwater at the time of the survey. Since there was only a single sampling period for this study, the fidelity parameter in the Guild Value Model was set to 1 thus negating the potential influence that variation over time may have on a site guild values and therefore these values should be interpreted with some caution.

Commercial and Recreational Species-The highest biomass and density of kelp bass (*Paralabrax clathratus*) in the entire SCB was observed within the Santa Monica Bay at Nicholas Canyon. In the southern part of Santa Monica Bay (i.e. Flat Rock North to Point Fermin), kelp bass exhibited a clear decrease in biomass and density with proximity King Harbor, consistent with what appears to be localized effects of fishing (Figures 18, 19). Significant differences in mean size were found for kelp bass (ANOVA; $F=93.3_{2, 1661}$, p <0.001), with Mainland non-SMB sites having the largest mean size at 30 cm TL (95% CI: 29, 31), followed by Santa Monica Bay at 25 cm TL (95% CI: 24, 26) and Island at 22 cm TL (95% CI: 21, 22) (Figure III-22). The larger mean size at mainland sites outside of Santa Monica bay was largely due to four sites in the south, Little Corona, Crystal Cove, Laguna and La Jolla. These sites had size structures with the highest proportions of individuals at the 2 size classes (30-35 and 35-40 cm TL) just above the 30 cm TL legal size limit, likely due protection from recreational fishing at these sites.

California sheephead (*Semicossyphus pulcher*) had a relatively low but consistent biomass (5 to 20 g/m^2) among sites within Santa Monica Bay (Figures 20, 21). Biomass was highest at Little Dume, which was the 8^{th} highest biomass of all sites across the SCB. Significant differences in mean size were found for sheephead (ANOVA; $F=14.3_{2, 1245}$, p <0.00), with Mainland non-SMB sites having a larger mean size 34 cm TL (95% CI: 33, 36) than the other site groupings. However, there was no difference between Santa Monica Bay sites at 30 cm TL (95% CI: 28, 31) and Island sites at 30 cm TL (95% CI: 29, 31) (Figure III-22). This is also likely due to fishing pressure, with the larger mean size at mainland sites outside of Santa Monica bay largely due to higher proportions of larger (30 - 40 cm TL) sheephead at the four protected sites in the south, Little Corona, Crystal Cove, Laguna and La Jolla.

The highest biomass and density of barred sand bass (*Paralabrax nebulifer*) within Santa Monica Bay and the entire SCB were observe at Nicholas Canyon (Figures 15, 16). However, repeated surveys would be required to determine if this was the case or if this is a resident population. No sand bass were observed at Island sites and there was no significant difference in mean size for sand bass between Santa Monica Bay and Mainland non-SMB sites (F=1.1, DF: 1, 260, p=0.29) (Figure III-22). Individuals larger than the legal limit in the Santa Monica Bay were primarily at Nicholas Canyon, possibly due to the presence of a spawning aggregation at that site during the survey.

Red sea urchin (*Strongylocentrotus franciscanus*) densities in the northern half of Santa Monica Bay (from Deep Hole to Point Dume) were among the highest along mainland SCB, while areas on the west side of Palos Verdes Peninsula were among the lowest (Figure III-23). Test sizes for red urchins in Santa Monica Bay were consistently at or near average in comparison to the entire SCB, though test sizes from sites in the Malibu region of Santa Monica Bay were smaller than those in the Palos Verdes region (Figure III-24). Significant differences in mean test size were found for red urchins (F=120.6, DF 2, 3450, p <0.001), with Santa Monica Bay sites having a larger mean size at 69 mm (95% CI: 67, 70) than the other site groupings. There was only a slight difference between Mainland non-SMB sites at 55 mm (95% CI: 52, 58) and Island sites at 52 mm (95% CI: 51, 53) (Figure III-25).

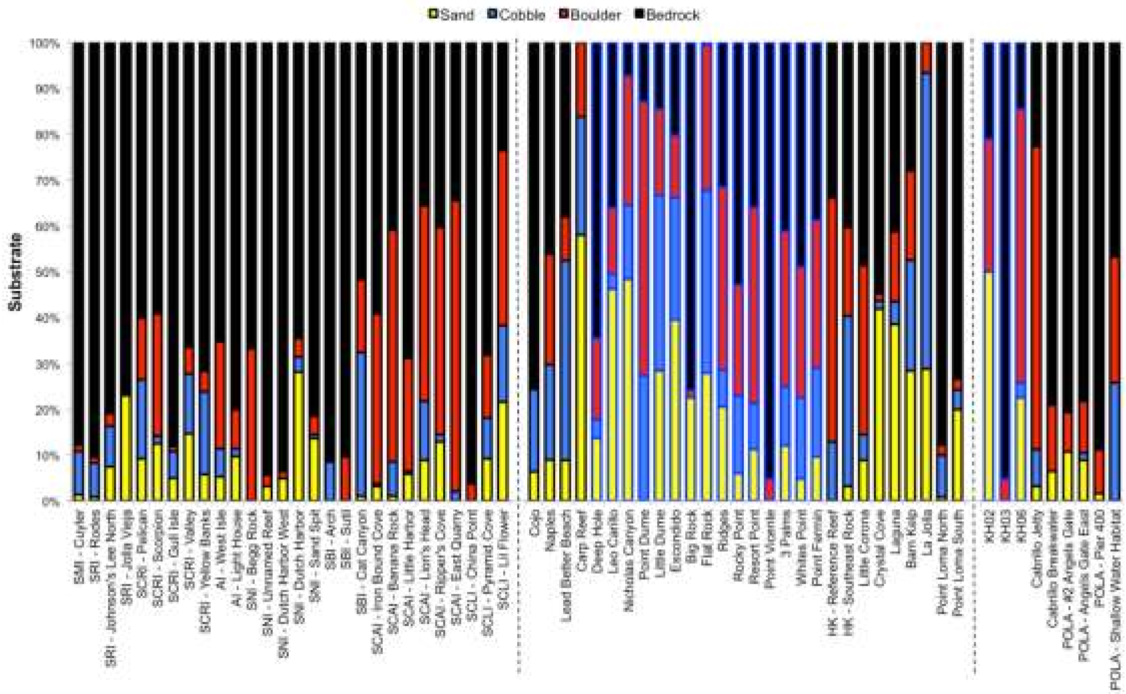

Figure III-3. Percentage of each type of substrate (bedrock, boulder, cobble, sand) by site. Bars outlines are blue for Santa Monica Bay sites.

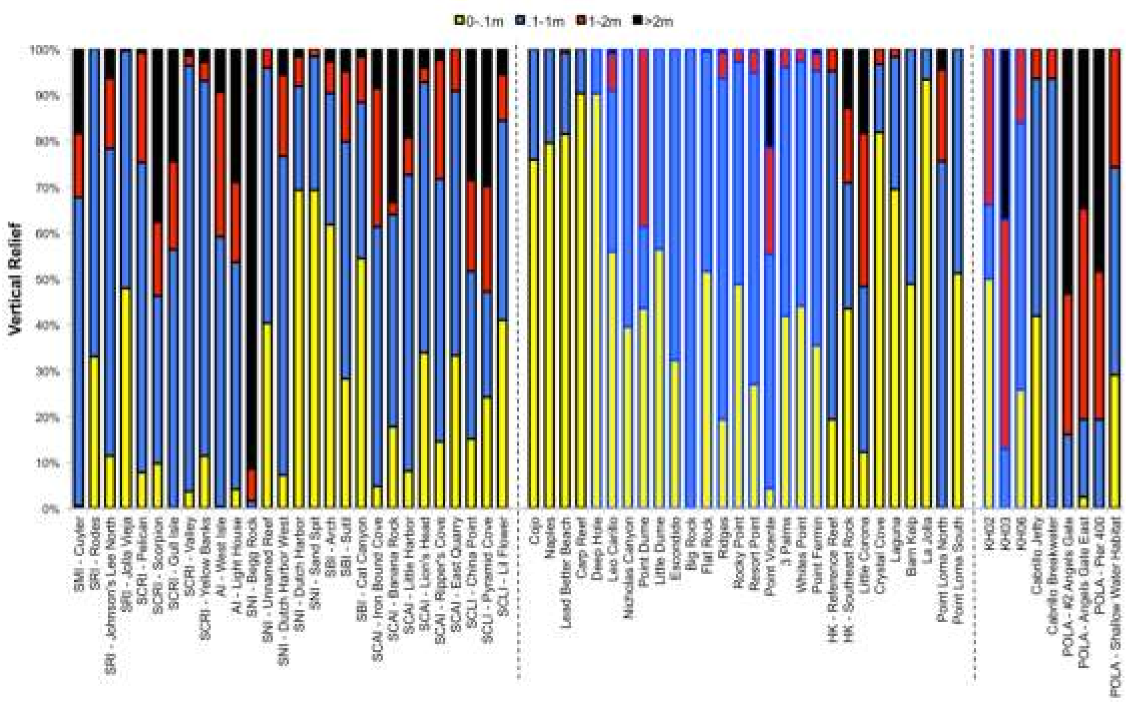

Figure III-4. Percentage of each category of vertical relief by site. Bars outlines are blue for Santa Monica Bay sites.

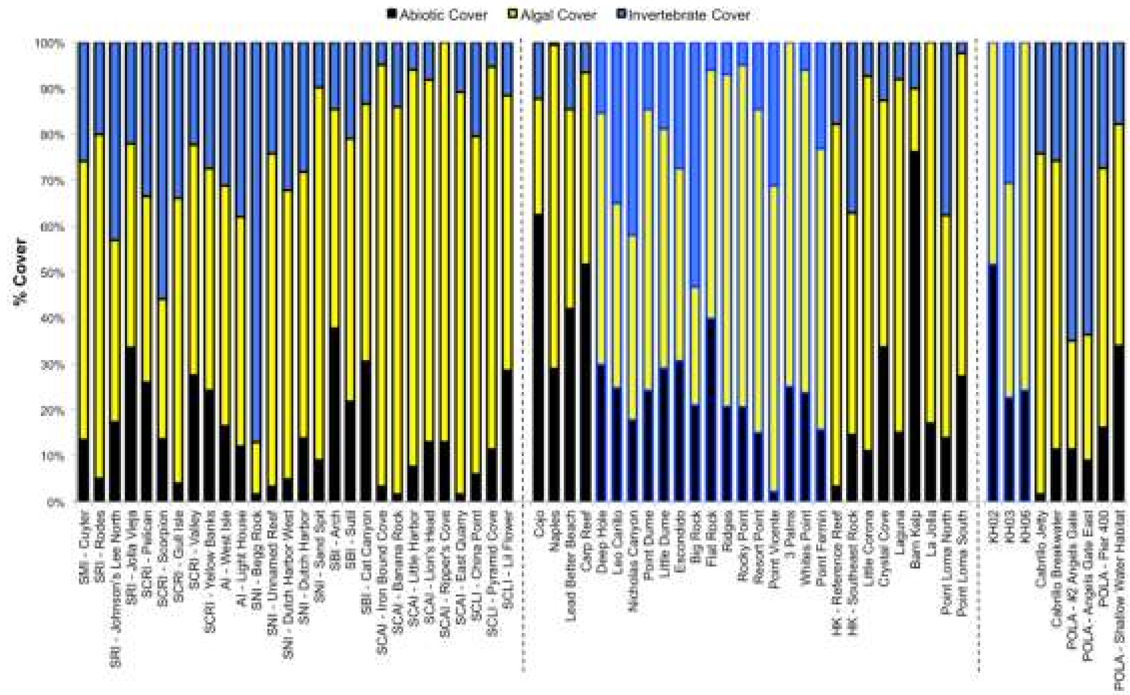

Figure III-5. Percent invertebrate, algal, and abiotic cover on each SCB reef. Bars outlines are blue for Santa Monica Bay sites.

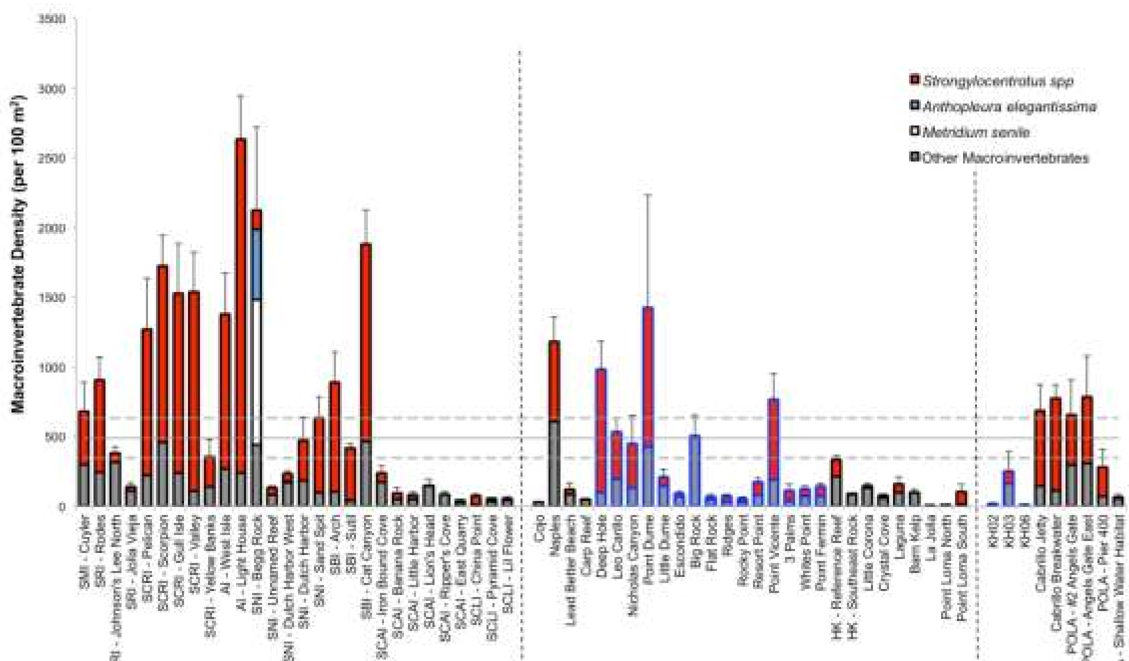

Figure III-6. Macroinvertebrate density (number/100 m^2) at each SCB site. Solid line represents mean test size throughout the Southern California Bight; dashed lines represent 95% confidence intervals. Bar outlines are blue for Santa Monica Bay sites.

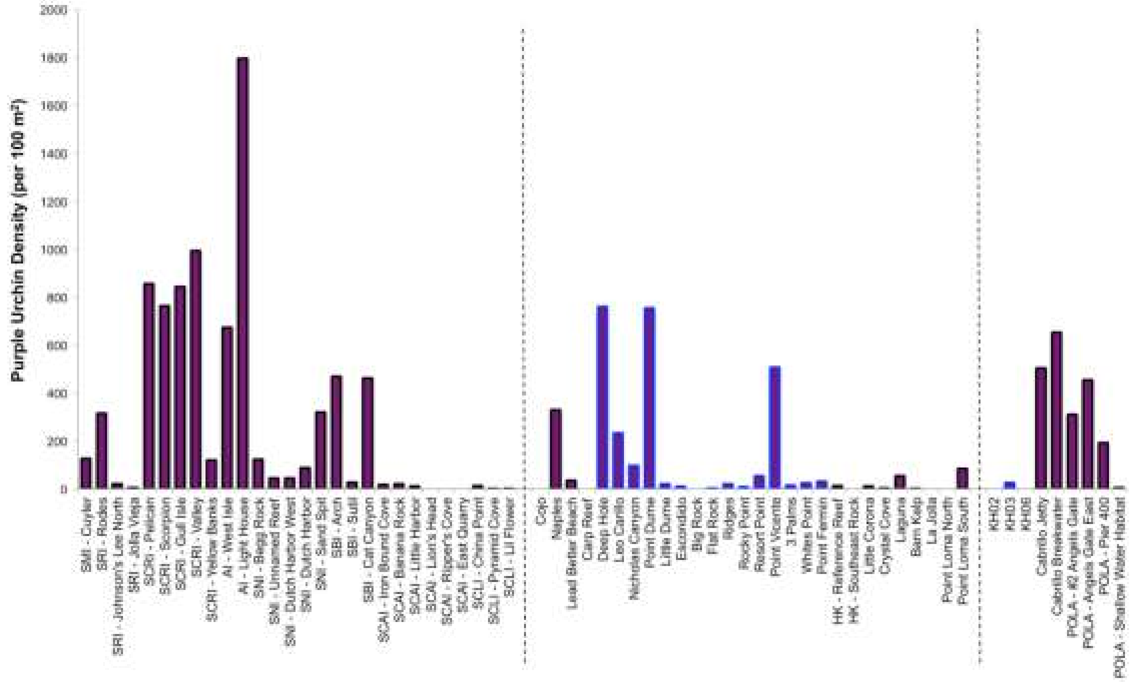

Figure III-7. Density (abundance/100 m^2) of purple sea urchins (*Strongylocentrotus purpuratus*) by site. Bar outlines are blue for Santa Monica Bay sites.

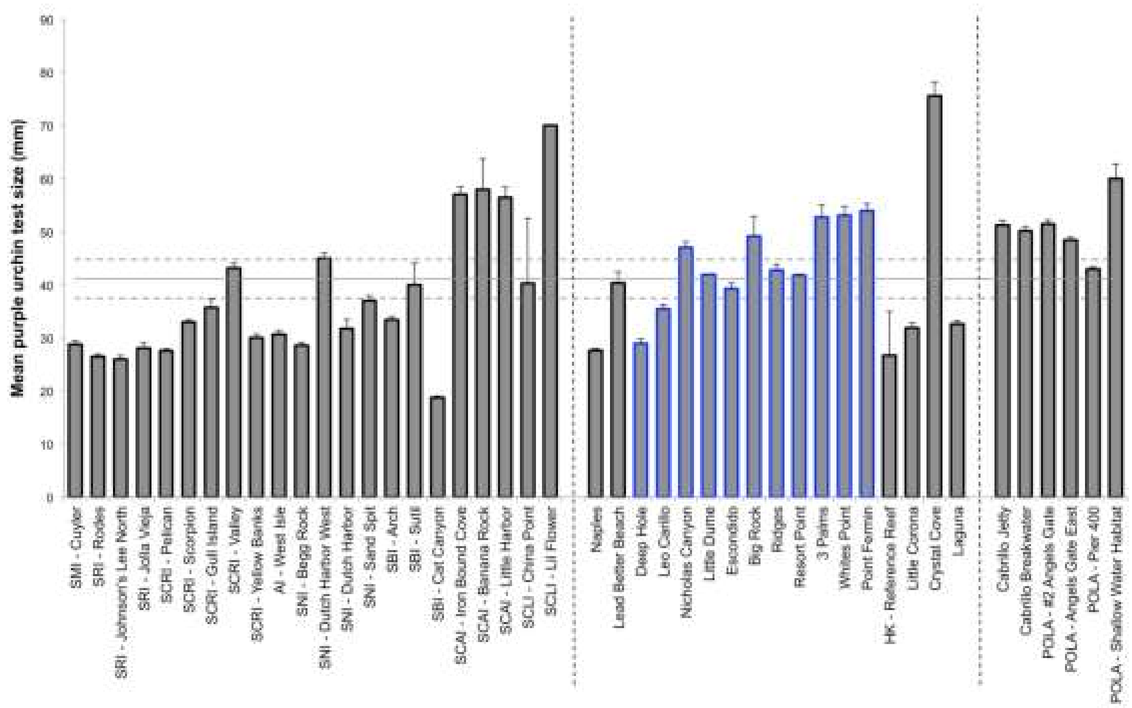

Figure III-8. Mean test size of purple sea urchins (*Strongylocentrotus purpuratus*) by site. Solid line represents mean test size throughout the Southern California Bight; dashed lines represent 95% confidence intervals. Bar outlines are blue for Santa Monica Bay sites.

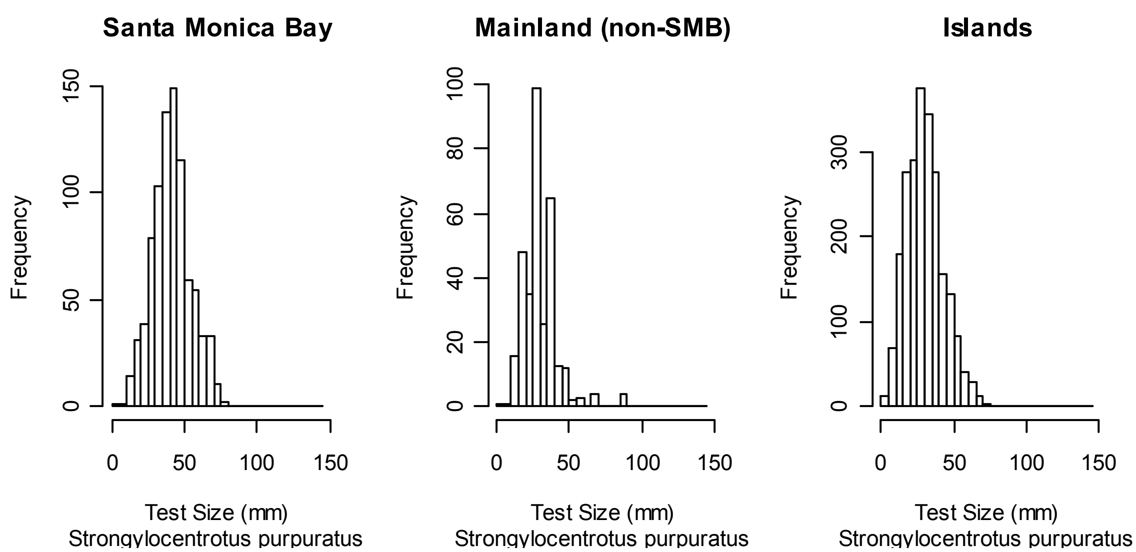

Figure III-9. Size frequency distributions for purple sea urchins (*Strongylocentrotus purpuratus*).

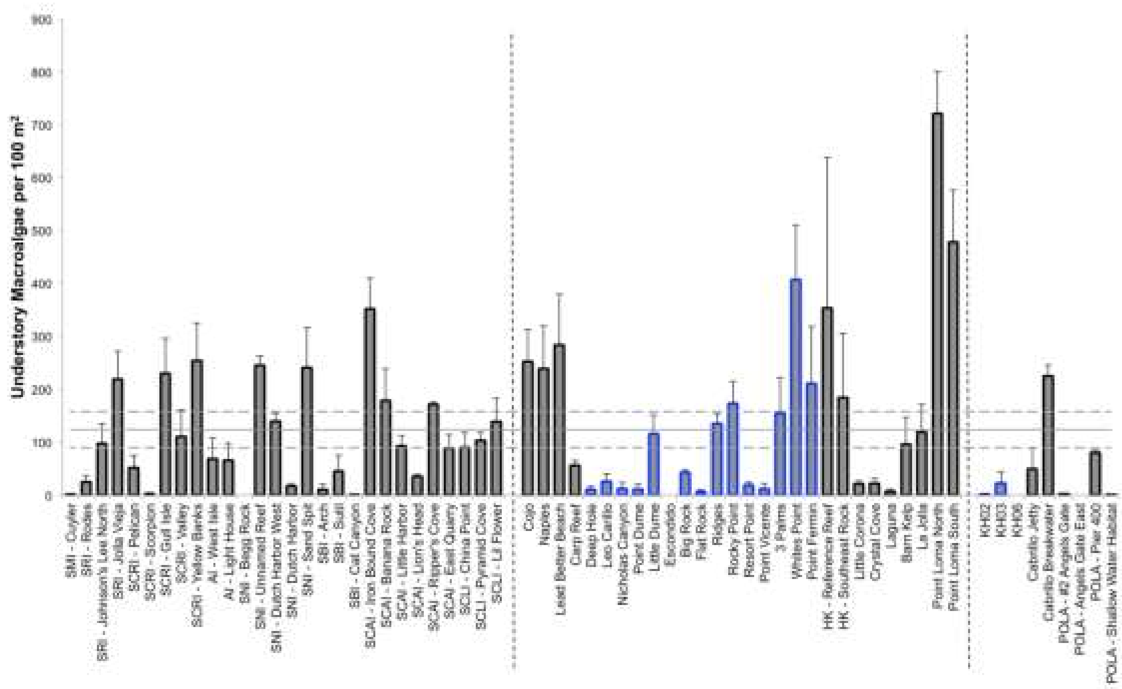

Figure III-10. Density (abundance/100 m^2) of understory macroalgae by site. Bar outlines are blue for Santa Monica Bay sites.

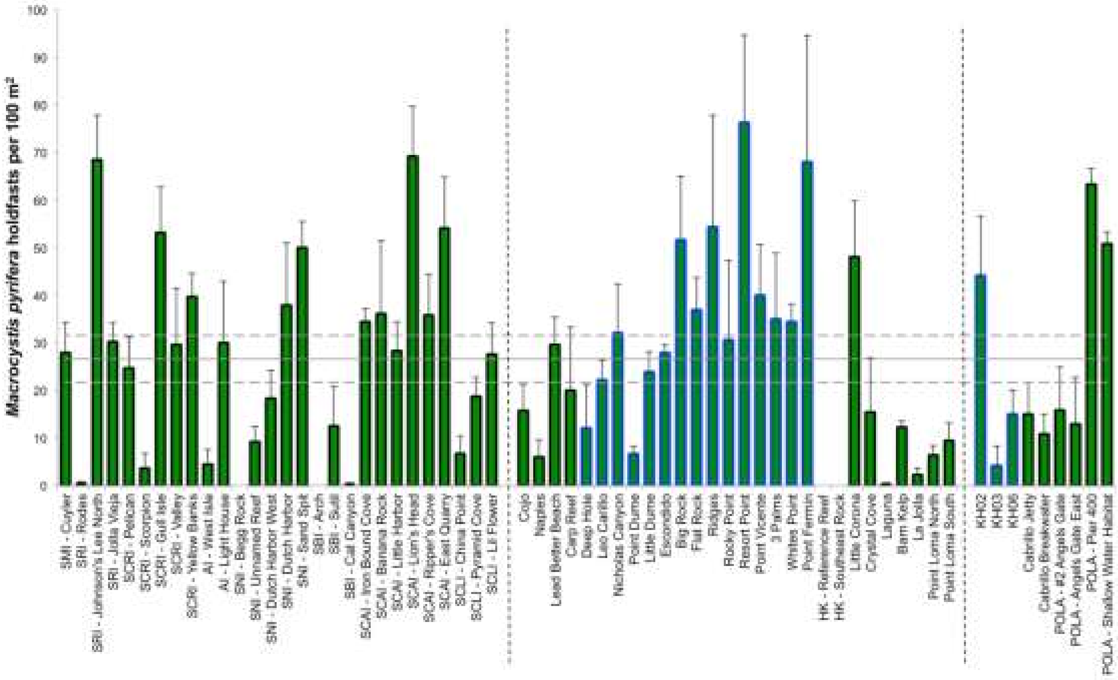

Figure III-11. Density (abundance/100 m^2) of giant kelp (*Macrocystis pyrifera*) holdfasts by site. Bar outlines are blue for Santa Monica Bay sites.

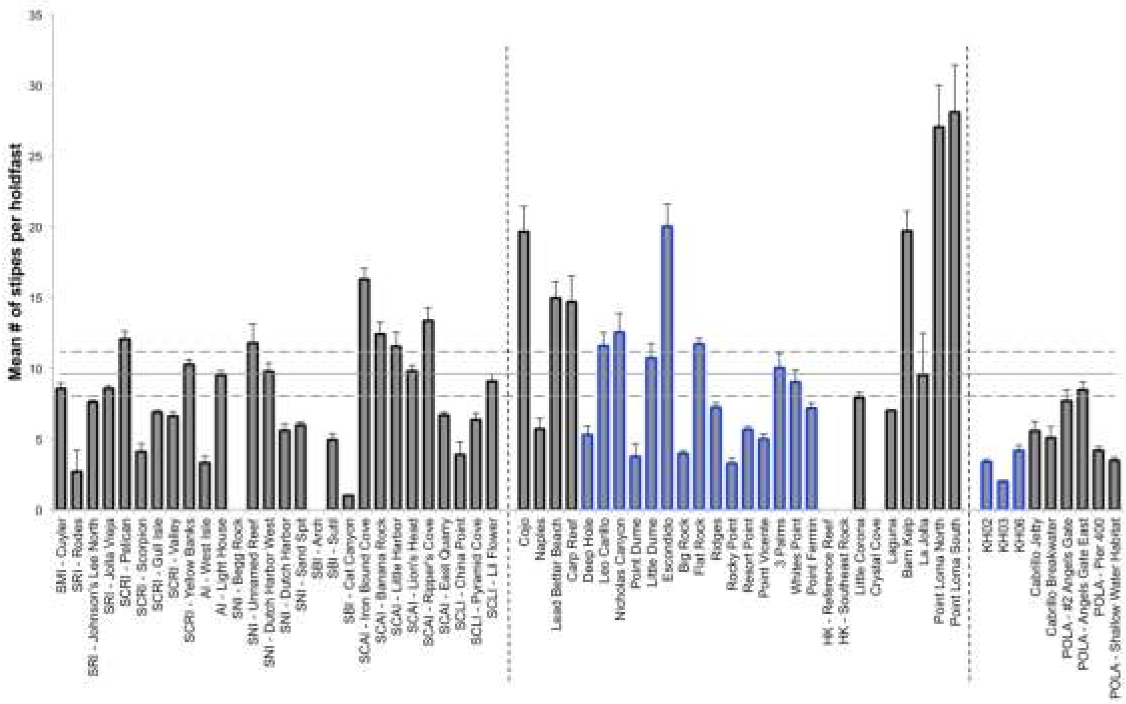

Figure III-12. Mean number of giant kelp (Macrocystis pyrifera) stipes per holdfast by site. Bar outlines are blue for Santa Monica Bay sites.

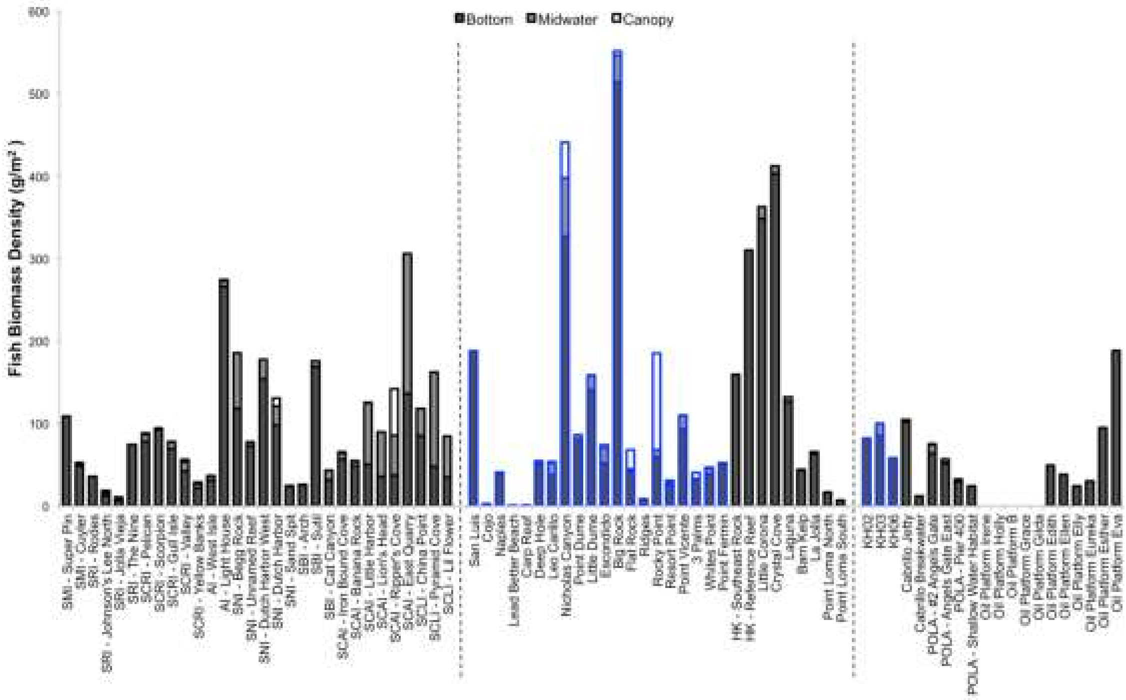

Figure III-13. Biomass (g/m^2) of fishes by transect type. For Santa Monica Bay sites bar outlines are in blue. Non-reef pelagic species were removed before plotting.

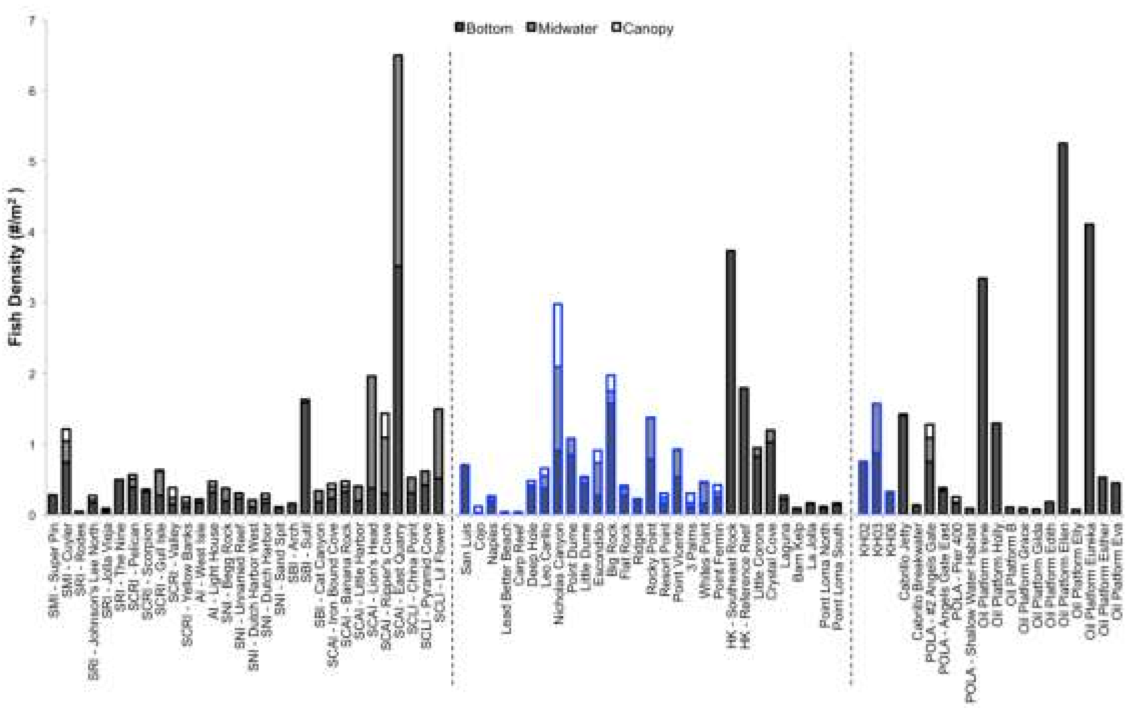

Figure III-14. Density (abundance/m^2) of fishes by transect type. For Santa Monica Bay sites bar outlines are in blue. Non-reef pelagic species and young of the year (for most species this was individuals <10cm TL) were removed before plotting.

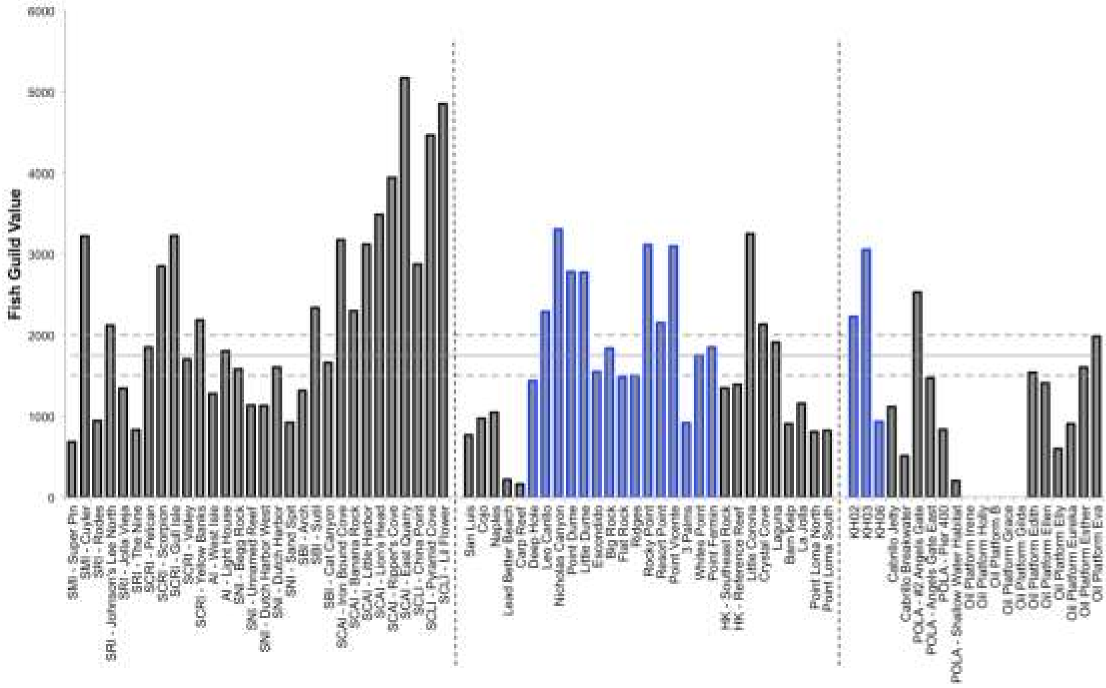

Figure III-17. Fish Guild Value for fishes at island reefs (left), mainland reefs (middle) and breakwaters and oil platforms (right). Sites were organized by latitude, north to south. Solid bar is the mean for the SCB and the dashed bars are the 95% confidence intervals. Bar outlines are blue for Santa Monica Bay sites. Note: Guild Values were not calculated for 5 oil platforms (Irene – Gilda) because fish sizes were not available.

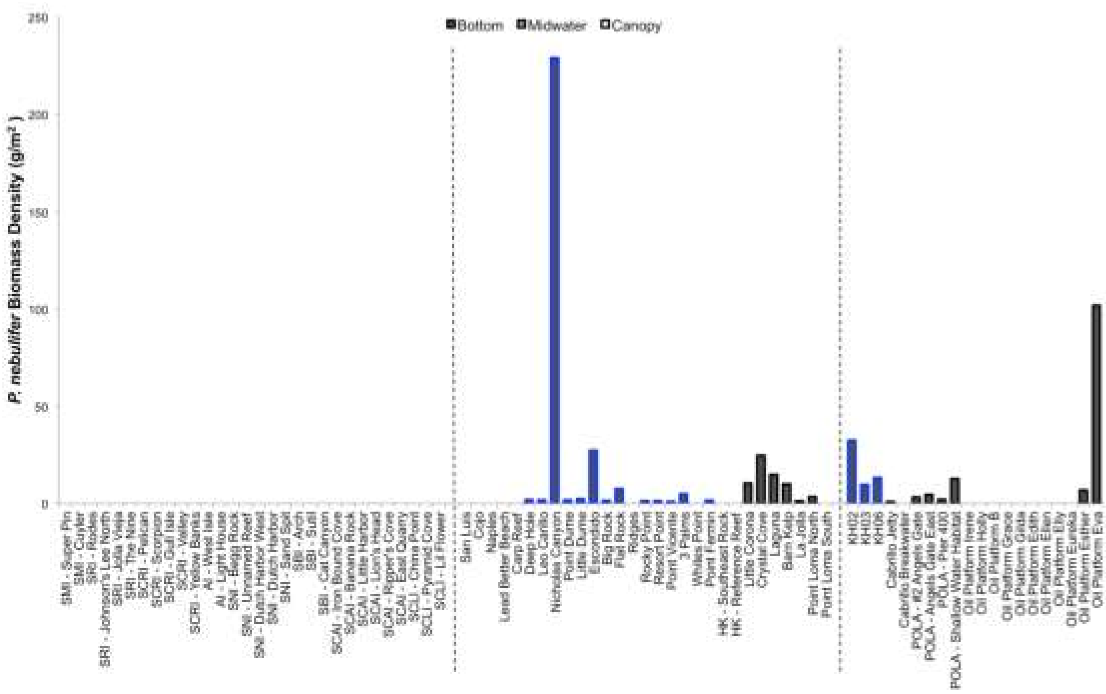

Figure III-15. Biomass (g/m^2) of *Paralabrax nebulifer* by transect type. For Santa Monica Bay sites bar outlines are in blue.

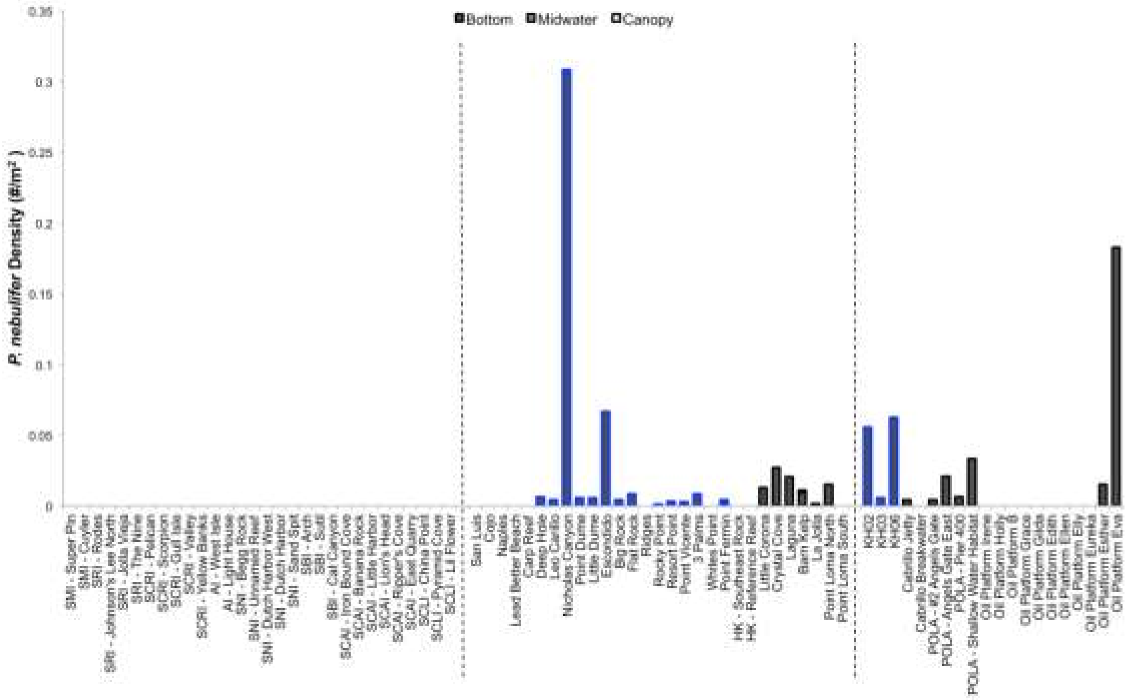

Figure III-16. Density (abundance/m^2) of *Paralabrax nebulifer* by transect type. For Santa Monica Bay sites bar outlines are in blue. Young of the year (individuals <10cm TL) were removed before plotting to reduce the influence of recruitment variability relative to the timing of the survey at each site.

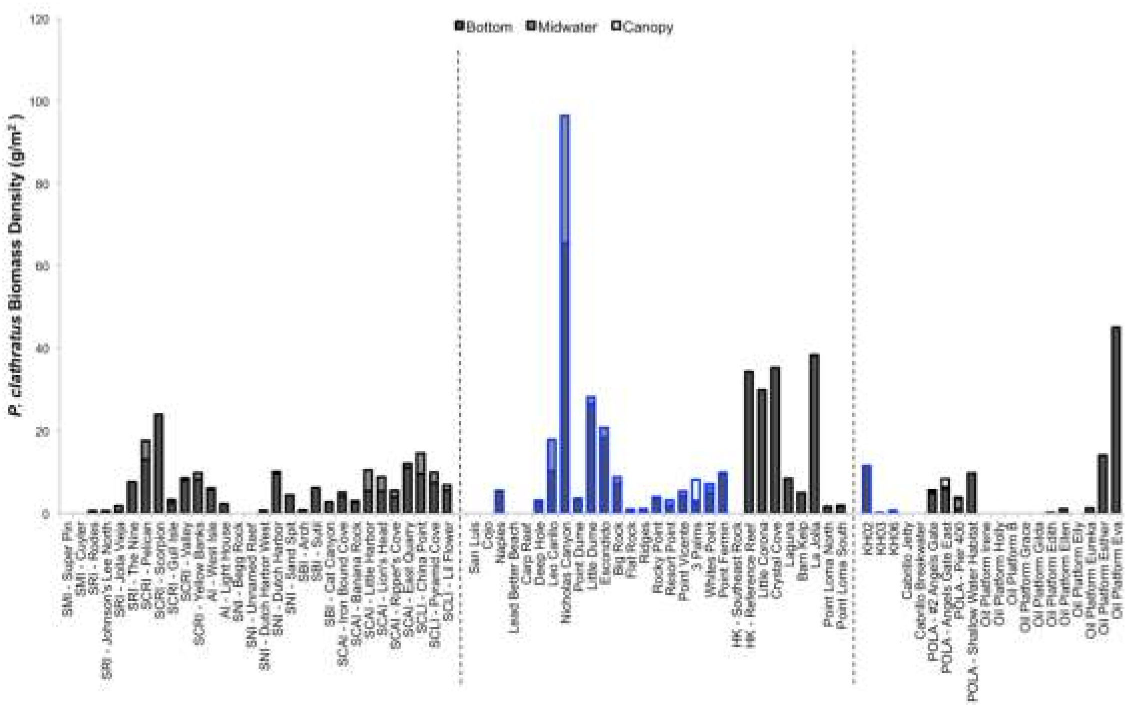

Figure III-18. Biomass (g/m^2) of *Paralabrax clathratus* by transect type. For Santa Monica Bay sites bar outlines are in blue.

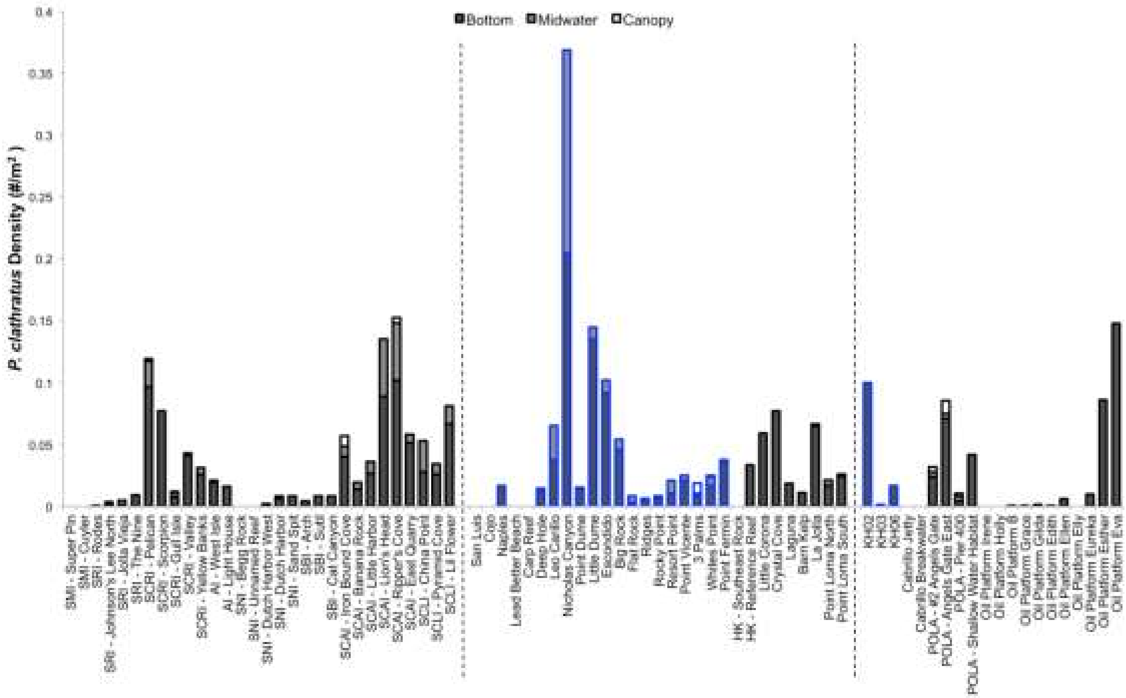

Figure III-19. Density (abundance/m²) of *Paralabrax clathratus* by transect type. For Santa Monica Bay sites bar outlines are in blue. Young of the year (individuals <10cm TL) were removed before plotting to reduce the influence of recruitment variability relative to the timing of the survey at each site.

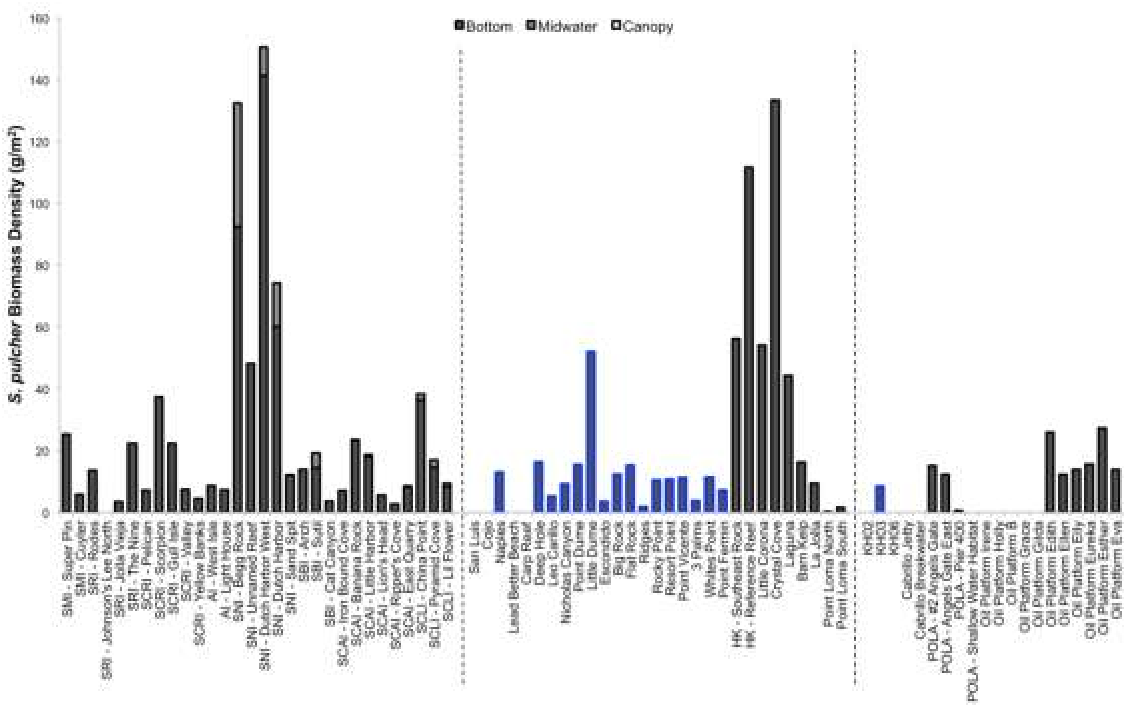

Figure III-20. Biomass (g/m²) of *Semicossyphus pulcher* by transect type. For Santa Monica Bay sites bar outlines are in blue

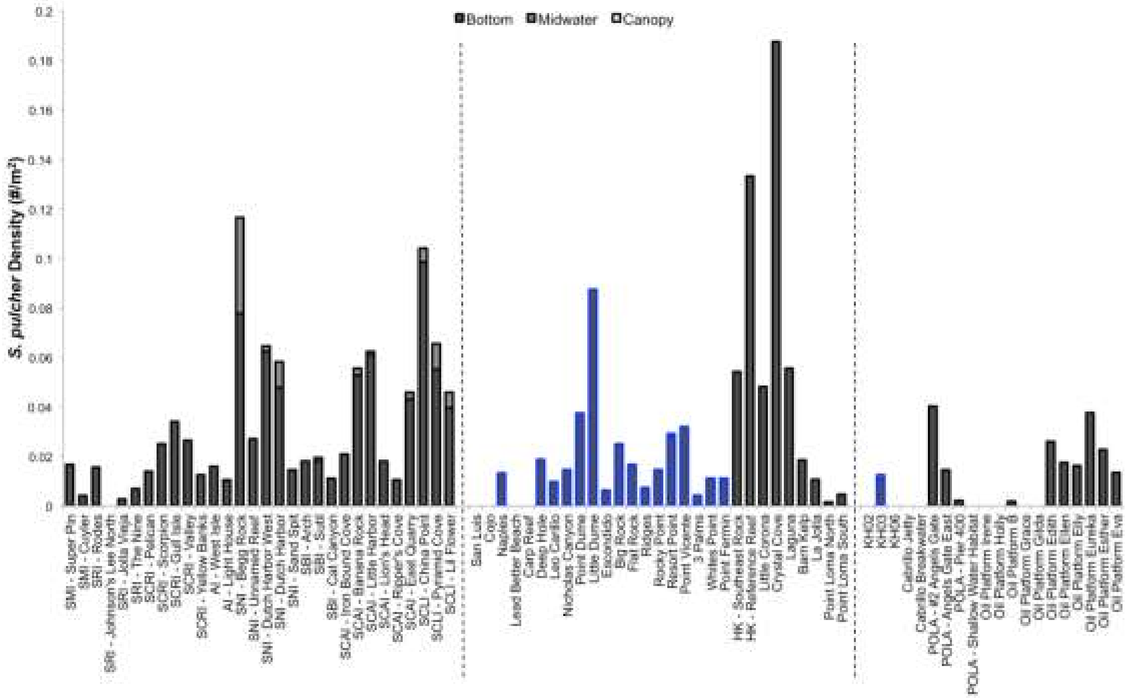

Figure III-21. Density (abundance/m^2) of *Semicossyphus pulcher* by transect type. For Santa Monica Bay sites bar outlines are in blue. Young of the year (individuals <10cm TL) were removed before plotting to reduce the influence of recruitment variability relative to the timing of the survey at each site.

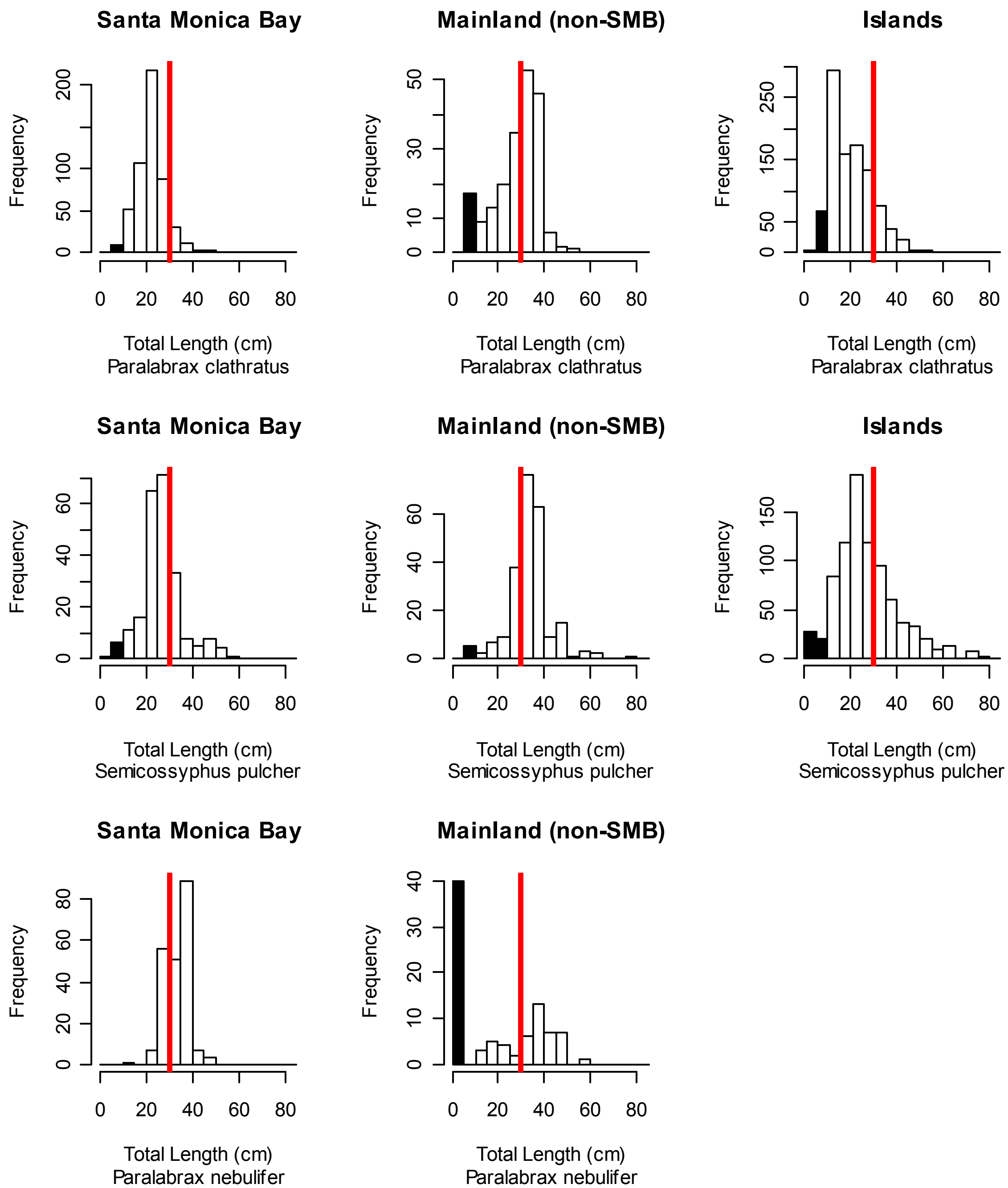

Figure III-22. Size frequency distributions for 3 economically important species. Red lines indicate the recreational fishing minimum size limit. YOY (TL <10cm) are indicated in black and were excluded from the analyses to reduce the influence of temporal recruitment variability with respect to when individual sites were sampled.

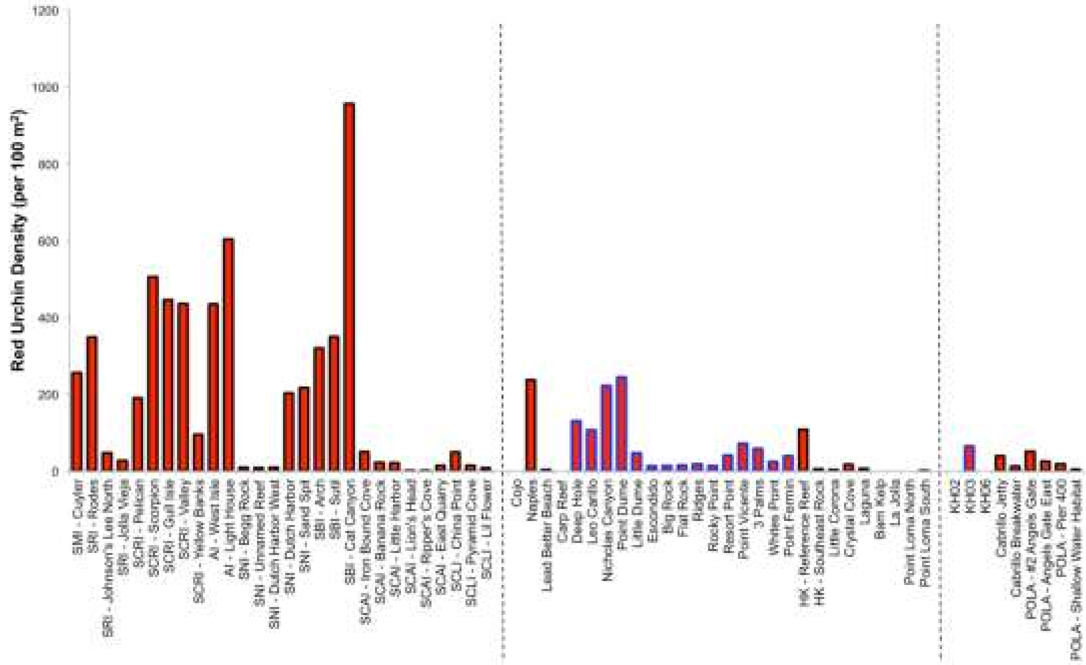

Figure III-23. Density (abundance/100 m^2) of red sea urchin (*Strongylocentrotus franciscanus*) by site. Bar outlines are in blue for Santa Monica Bay sites.

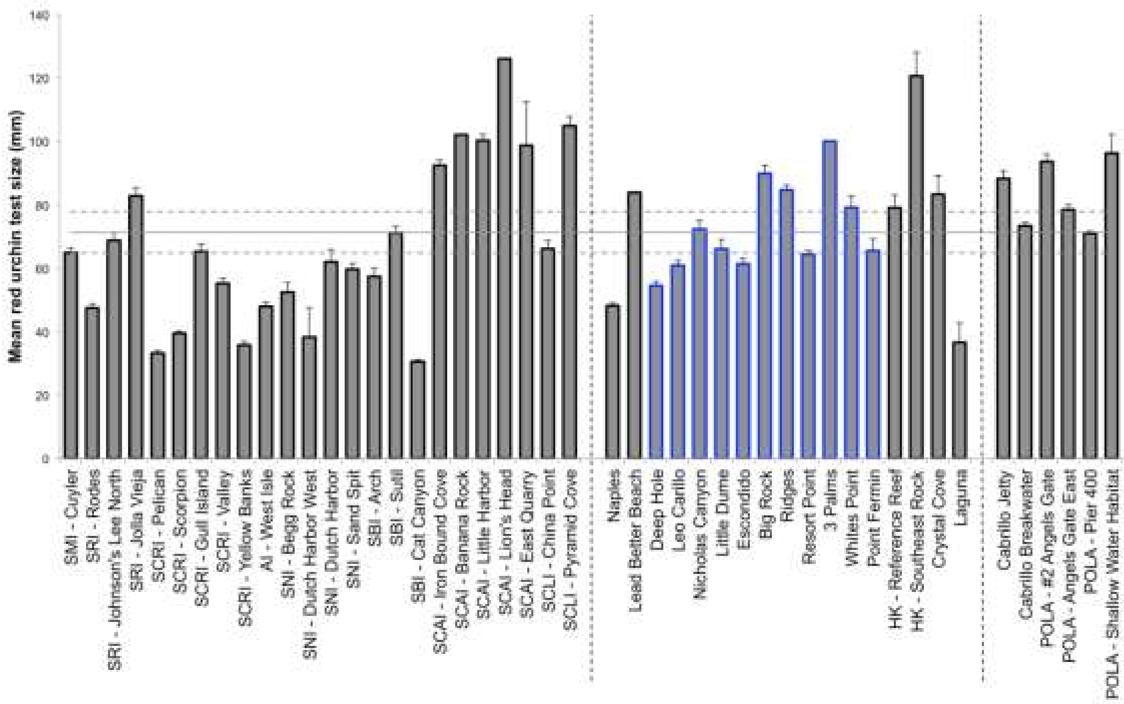

Figure III-24. Mean test size of red sea urchins (*Strongylocentrotus franciscanus*) by site. Solid line represents mean test size throughout the Southern California Bight; dashed lines represent 95% confidence intervals. Bar outlines are blue for Santa Monica Bay sites.

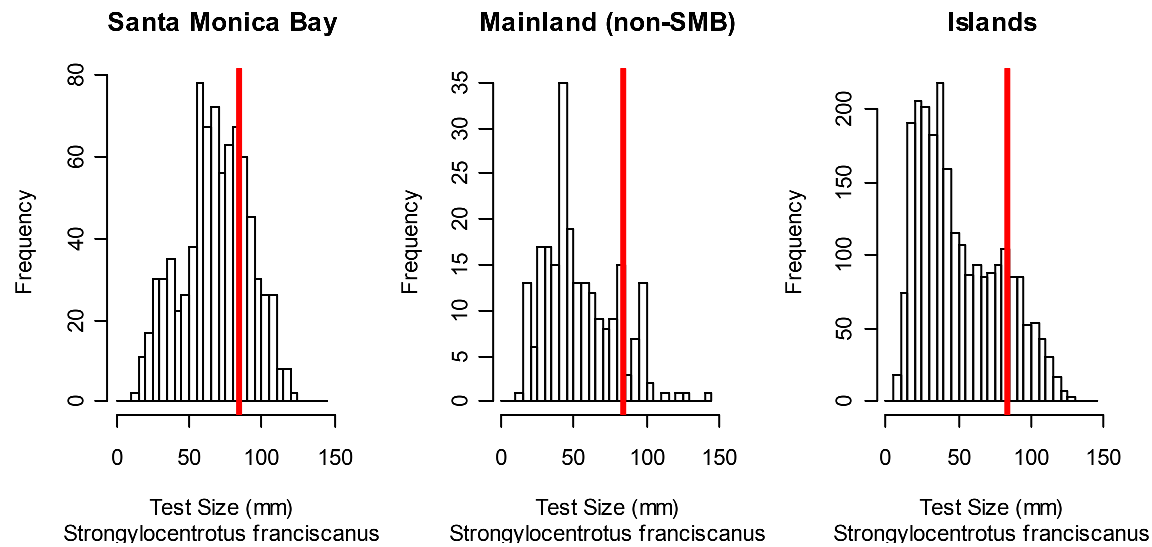

Figure III-25. Size frequency distributions for red sea urchins (*Strongylocentrotus franciscanus*). Red lines indicate the commercial minimum size limit.

Discussion

A series of objectives were set out for Hard Benthos in the Santa Monica Bay Restoration Commission's Comprehensive Monitoring Program (SMBRC 2007) and the data available from the Bight'08 program were applied to addresses these objectives in the multiple ways. First, it provided a description of the status of reef habitat structure, benthic macro-algae and macro-invertebrates, and the biomass and density of reef fishes at 18 shallow water sites (<90 ft) within SMB in 2008. Second, additional analyses were performed to provide a spatial comparison of biomass and density of commercially and recreationally important rocky subtidal fishes and red urchins, including comparisons of size structures across groups of sites within the SCB. Finally, this data provides baseline information for sites that were sampled within the recently designated MPA's in SMB.

Substrate composition in rocky reefs within Santa Monica Bay is generally similar to that of the rest of the mainland SCB, though substrate at sites in the northern half of SMB was composed more of sand and cobble than the southern half, which is composed more of bedrock and boulders. Macroinvertebrate densities at SMB sites were typically much lower than the SCB average overall, with some exceptions mostly in the northern half of SMB. High runoff from land is common in SMB and elevated amounts of abiotic cover can be associated with this. Abiotic cover at rocky reefs was generally higher in SMB relative to the rest of the SCB, with the highest amount of abiotic cover on the west coast of Palos Verdes Peninsula, which is a vast area of continuous, somewhat protected rocky reef with several point sources of urban runoff. Invertebrate and algal coverage, and fish density and biomass are highly variable throughout SMB, yet typical for the entirety of the SCB. Big Rock, a site in the Malibu region, is noteworthy for having the highest total fish biomass of any site in the SCB. Big Rock is a small, relatively isolated high relief reef. Reefs such as these can tend to concentrate fishes and in this instance the high biomass was due to a high abundance of a large bodied species (opaleye) and high numbers of sargo, both species that are not heavily targeted in commercial or recreational fisheries.

Some recreationally and commercially targeted fishes on rocky reefs in SMB appeared to be doing poorly relative to other mainland sites, while commercially exploited urchins appear to be doing relatively well by some metrics compared to other mainland sites. Mean sizes of kelp bass and California sheephead in SMB were smaller than those from mainland sites outside the Bay, with low proportions of individuals above the minimum legal size limit. This difference was primarily due to larger fishes at four sites south of SMB (Little Corona, Crystal Cove, Laguna and La Jolla). Nicholas Canyon however, did have a very high biomass of large barred sand bass and the highest biomass and density of kelp bass in the entire SCB, made up though of mostly moderately sized individuals. In the southern part of Santa Monica Bay (i.e. Flat Rock North to Point Fermin), kelp bass exhibited a clear decrease in biomass and density with proximity King Harbor, consistent with what appears to be localized effects of fishing. For the commercially exploited red sea urchin, test sizes within SMB sites were larger than at other mainland sites, though test sizes at sites in the Malibu region were smaller than those in the Palos Verdes region. This contrasts though with the density pattern as densities in the northern half of Santa Monica Bay (from Deep Hole to Point Dume) were among the highest along mainland, while areas on the west side of Palos Verdes Peninsula were among the lowest. Finally, only a single abalone was recorded on transects in SMB. It was, however, a federally endangered white abalone, typically assumed to be at depths greater than the scope of this work.

The 3 sites in the Bight ’08 program that will fall into the recently designated MPAs in SMB, tend to stand out as exceptions relative to other SMB sites with respect to some metrics. The physical structure of reefs at two of these sites, Point Vicente and Point Dume, are more typical of island reefs than mainland reefs, with a high proportion of bedrock and moderate to high relief. Point Vicente also had almost no abiotic cover, likely due to this high relief nature. Point Dume had the highest macroinvertebrate density of all mainland SCB sites, while Point Vicente also stood out at a higher level than other sites in the Palos Verdes region. These high densities are dominated by sea urchins, sea stars, and solitary green anemones. Point Vicente had the third highest density of purple urchins in SMB, making it potentially susceptible to urchin barrens and a candidate for kelp restoration efforts as part of an adaptive management effort. Point Dume, Little Dume and Point Vicente also had well above average Fish Guild Values relative to the rest of the SCB. At Point Dume and Point Vicente this was likely due to their high relief nature providing a variety of micro-habitats for various fish guilds. For most commercial or recreationally targeted fishes however, their density and biomass was relatively low at the three sites, with the exception of California sheephead at Little Dume, which had the 8^{th} highest biomass of all sites across the SCB.

Conclusions

The Bight'08 program used a standardized survey protocol to assess the range in biological conditions of the nearshore rocky reefs in the Southern California Bight (SCB). These data were applied to addresses the SMBRC's monitoring program objectives in the following ways:

1) We were able to provide a description of the status of reef habitat structure, benthic macro-algae and macro-invertebrates, and the biomass and density of reef fishes at 18 shallow water sites (<90 ft) within the Santa Monica Bay in 2008 (Objectives 1 and 2).

2) A spatial comparison of biomass and density of commercially and recreationally important rocky subtidal fishes and red urchins is provided, including comparisons of size structures across groups of sites within the SCB. (Objective 5).

   Kelp bass and California sheephead had significantly smaller size class structure compared to other mainland and island reefs, this is a clear indication of fishing pressure on these kelp bed species. Barred Sand Bass, which is not a primarily kelp bed species, was not significantly different from other mainland sites. Red Urchins, on the other hand, were significantly larger in Santa Monica Bay.

3) While in this context we cannot directly address the objectives related to changes over time (Objectives 2, 4, or 5), however these data will provide another point of reference for comparison with past and future data, including providing baseline information for evaluating the effectiveness of ASBS's and future MPA's (Objective 6).

Recommendations

1) Develop recreational and commercial fishing pressure metrics to overlay with these reef metrics elucidate how fishing pressure varies on small spatial scales.

2) Develop stock models for commercial and recreational fishes and invertebrates.

3) Continue to evaluate the Malibu ASBS and the Marine Protected Areas due to be established in the bay. Integrate ongoing monitoring efforts with these groups.

4) Survey reefs that have not been surveyed in the bay including artificial reefs and shipwrecks.

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APPENDIX A - B08 PARTICIPANTS

Organization	Coastal Ecology	Microbiology	Water Quality	Rocky Reefs	Areas of Special Biological Significance	Coastal Wetlands and Estuaries	Bioaccumulation
AMEC Incorporated					X		
Aquatic Bioassay and Consulting Laboratories	X		X		X		
Associated Laboratories		X					
California Polytechnic University			X				
California State Parks					X	X	
California State University Channel Islands						X	
California State University Long Beach	X						
California Dept. of Fish and Game	X					X	X
California Department of Public Health			X				
Camp Pendleton Marine Corps Base						X	
Channel Islands National Marine Sanctuary	X						
Chevron USA Products Company	X						
City of Carlsbad						X	
City of Coronado						X	
City of Del Mar						X	
City of El Cajon						X	
City of Encinitas		X				X	
City of Escondido						X	
City of Imperial Beach						X	
City of La Mesa						X	
City of Laguna Beach					X		
City of Lemon Grove						X	

Organization	Coastal Ecology	Microbiology	Water Quality	Rocky Reefs	Areas of Special Biological Significance	Coastal Wetlands and Estuaries	Bioaccumulation
City of Long Beach			X				
City of Los Angeles Environmental Monitoring Division	X	X	X			X	
City of Poway						X	
City of San Marcos						X	
City of Santee						X	
City of Solana Beach						X	
City of Vista						X	
City of Chula Vista						X	
City of Malibu					X		
City of Newport Beach					X	X	
City of Oceanside			X			X	
City of Oxnard	X		X				X
City of San Diego	X	X	X		X		X
City of Ventura			X			X	
Coastal Conservancy			X			X	
CRG Marine Laboratories	X		X		X		X
Encina Wastewater Authority	X	X	X				
Jet Propulsion Laboratory			X				
Los Angeles County Dept. of Beaches & Harbors	X						
Los Angeles County Dept. of Health Services		X					
Los Angeles County Dept. of Public Works		X			X		
Los Angeles County Sanitation Districts	X	X	X	X			X
Los Angeles Department of Water and Power	X						
Los Angeles Regional Water Quality Control Board					X	X	X
Loyola Marymount University		X					X
Marine Pollution Studies Laboratory - Granite	X						

Organization	Coastal Ecology	Microbiology	Water Quality	Rocky Reefs	Areas of Special Biological Significance	Coastal Wetlands and Estuaries	Bioaccumulation
Canyon							
Marine Pollution Studies Laboratory - Rancho Cordova	X						X
Marine Biological Consultants	X						
Monterey Bay Aquarium Research Institute			X				
Natural History Museum of Los Angeles County	X						
National City						X	
National Parks Service				X			
Nautilus Environmental	X				X		
NES Energy, Inc.	X						
National Oceanic and Atmospheric Administration	X	X	X			X	
NRG Energy, Inc.	X						
Orange County Environmental Health Division		X					
Orange County Public Facilities and Resources					X	X	
Orange County Sanitation District	X	X	X				X
Port of Long Beach	X						
Port of Los Angeles	X		X	X			
Port of San Diego	X					X	X
Reliant Corporation	X						
Resource Conservation District						X	
Riverside County Flood Control District			X				
San Bernardino Flood Control District			X				
San Diego County						X	
San Diego County Dept. of Environmental Health						X	

Organization	Coastal Ecology	Microbiology	Water Quality	Rocky Reefs	Areas of Special Biological Significance	Coastal Wetlands and Estuaries	Bioaccumulation
San Diego Regional Water Quality Control Board					X	X	
San Diego State University				X			
San Elijo Joint Powers Authority	X						
San Elijo Lagoon Conservancy						X	
San Francisco Estuary Institute							X
Santa Ana Regional Water Quality Control Board			X			X	
Santa Ana River Watershed Management Authority						X	
Santa Monica Bay Restoration Commission						X	
Scripps Institution of Oceanography			X				
Sea Ventures							
South Orange County Water Authority							
Southern California Coastal Water Research Project	X	X	X	X	X	X	X
Stanford University		X					
State Water Resources Control Board	X	X	X	X	X	X	X
Tijuana Estuary National Estuarine Research Reserve						X	
University of California, Los Angeles		X	X				
University of California, San Diego				X	X		
University of California, Santa Barbara		X	X	X		X	
University of California, Santa Cruz					X		
University of South Carolina						X	
University of Southern California			X		X		
US EPA Region IX						X	X

Organization	Coastal Ecology	Microbiology	Water Quality	Rocky Reefs	Areas of Special Biological Significance	Coastal Wetlands and Estuaries	Bioaccumulation
US EPA Office of Research and Development	X						
US Fish and Wildlife Service						X	
US Geological Survey	X						
US Navy					X		
Vantuna Research Group, Occidental College	X			X	X		
Ventura County Public Health Laboratory		X					
Ventura County Watershed Protection Division			X			X	
Weston Solutions	X	X	X		X	X	