Biological and Physical Characteristics of the Nearshore Environment of the Bunker Point Restoration Area and the Palos Verdes Peninsula II

A report to the:

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Introduction to Study Site

For a variety of reasons, the nearshore environment of the Palos Verdes Peninsula (Figure 1) has been intensively studied for decades. In particular the nearshore reefs of this headland have garnered attention due to a variety of anthropogenic activities (e.g.,commercial and recreational fishing, establishment of marine protected areas, giant kelp beds lost to pollution, landslides). Historically the greatest deleterious impact to the reefs at Palos Verdes was the loss of its kelp beds due to pollution from the Joint Water Pollution Control Plant's Whites Point outfall. By 1960 due to untreated sewage, the only kelp left on the peninsula was at Abalone Cove and in Portuguese Bend (North 1964). To exacerbate the situation, road construction on Palos Verdes Drive triggered the Portuguese Bend Landslide in 1956. From 1956 to 1999, approximately 5.7 to 9.4 million metric tons of sediment slid onto the inner shelf (Kayen 2002). By 1999, the landslide was dewatered, slowed appreciably and now only releases sediment due to wave action. Nonetheless the biological damage has been extreme, highlighted by the loss of the Portuguese Bend Kelp Bed leaving only the Abalone Cove Kelp Bed by 1974. Due to the infrastructure improvements of the Whites Point Outfall (i.e. expansion offshore and switch to secondary treatment) and the Wheeler North kelp restoration efforts of the early 1970's, giant kelp returned to the peninsula (Figure 2) and remains present today (Figure 3).

Figure 1. Satellite image of the Palos Verdes Peninsula (image adapted from NASA/JPL).

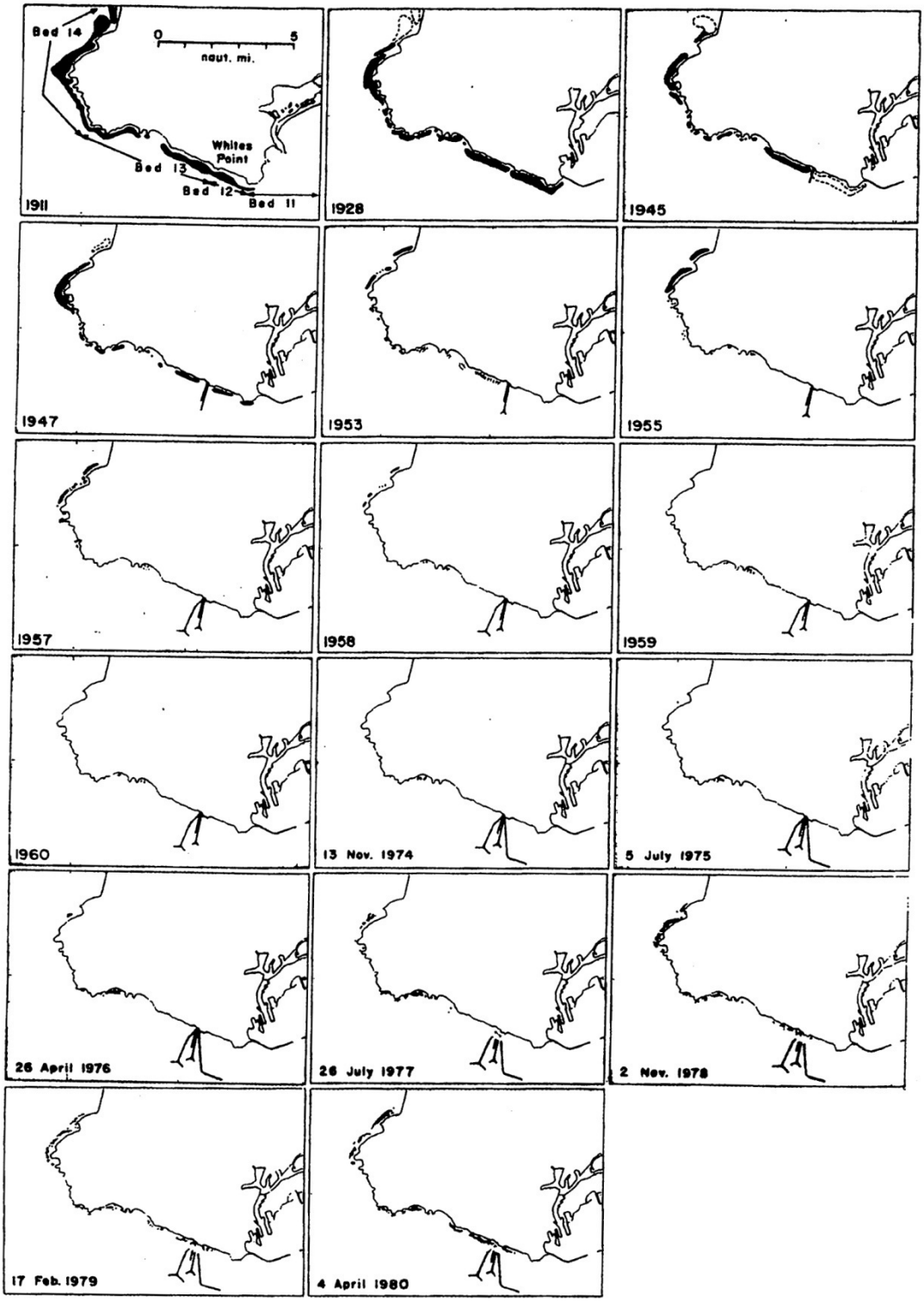

Figure 2. Palos Verdes kelp canopy from 1911-1980 (North 1964; MBC 2009).

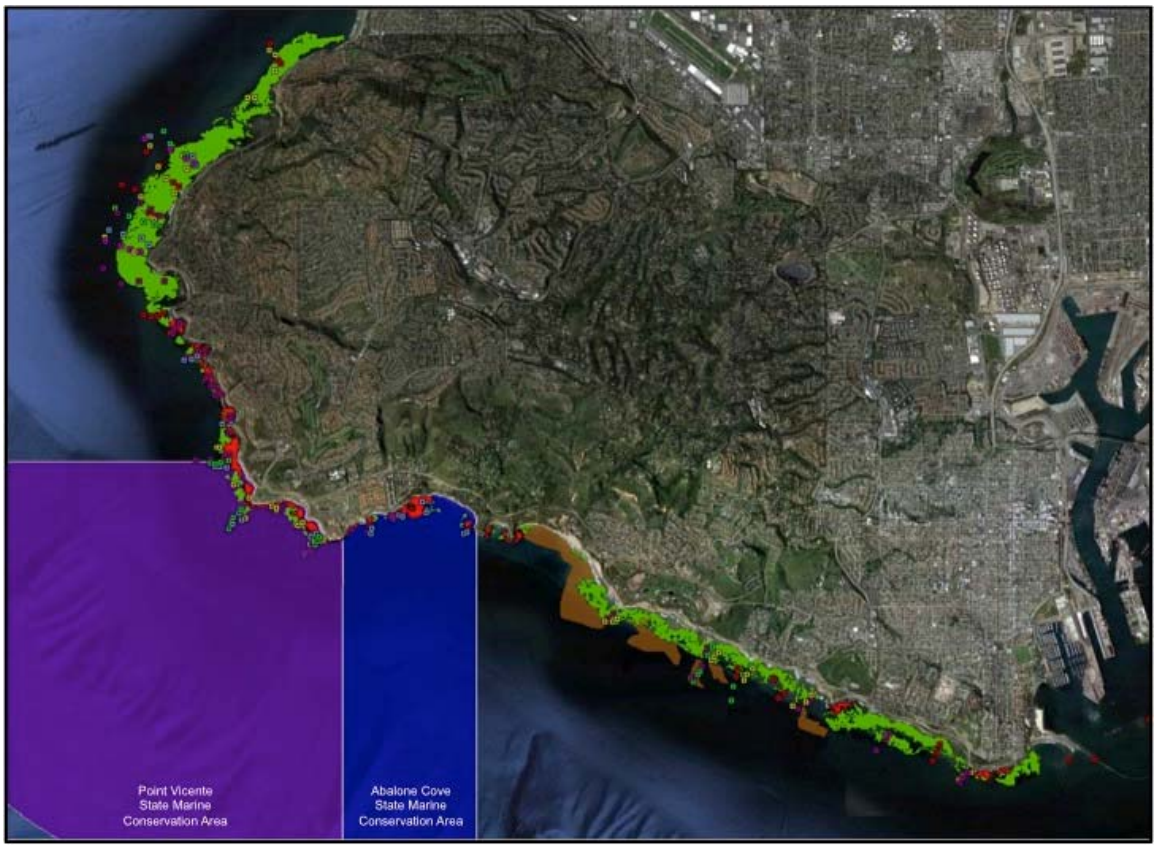

Figure 3. Palos Verdes Peninsula. Kelp canopy (green) in 2008 (Source: MBC Applied Environmental Sciences), urchin barrens (red), buried reef (brown), and sites of dive transects conducted by the VRG.

While these restoration and enhancement efforts ameliorated the historical consequences of the Whites Point Outfall throughout the peninsula, sedimentation and associated turbidity continue to have chronic impacts. First there is continued turbidity, sediment transport and scour associated with the sediment deposited in Portuguese Bend from the landslide (Figure 4). Further exacerbating this influx of sediment was the 16 acre landslide on June 2, 1999 from the 18th hole of the Trump National Golf Club, which sits above Bunker Point (Figures 5 and 6). A third point source of turbidity and sedimentation comes from the large storm drains that empty into this nearshore environment (Figure 7). With these various chronic stressors there is continued deleterious impacts to the nearshore rocky environment, especially from Portuguese Bend (buried reef) to Point Fermin (Stephens 1996).

To assess the biological condition of the reefs at Palos Verdes, a three parameter fish guild model (Bond, Stephens et al. 1999) was used to evaluate these reefs with respect to 29 mainland reefs in the Southern California Bight (Pondella 2009). For the Palos Verdes Peninsula, the relative reef quality was poorest east of Bunker Point to Point Fermin. With this general background in mind, the goals of this report are to summarize and synthesize the biological and physical sediment data for the Bunker Point to Whites Point study region. This study was designed to determine the status of the buried regions in this region and to examine this study sites potential for restoration and production of reefs.

Figure 4. Turbidity plume from the Portuguese Bend landslide.

Figure 5. Portuguese Bend and Bunker Point prior to the construction of the Trump National Golf Course, December 17, 1986. Turbidity plumes originating in Portuguese Bend can be observed.

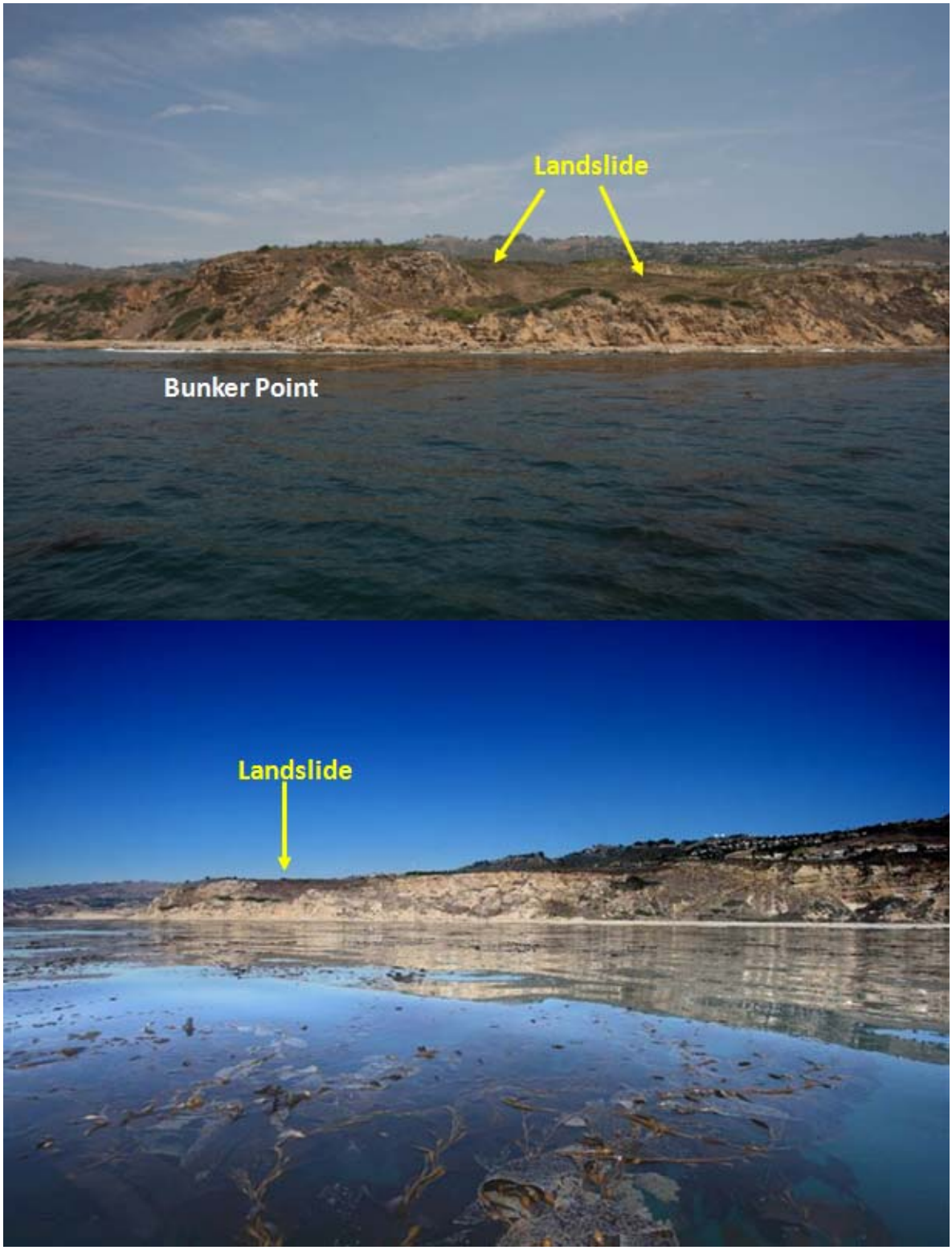

Figure 6. Bunker Point and location of Trump National Golf Course landslide (photo credits: upper picture D. Pondella, Lower picture D. Witting, NOAA).

Figure 7. Examples of large storm drains on the Palos Verdes Peninsula. Clockwise from top left: Abalone Cove, 3 Palms (between Bunker Point and Whites Point), and Rocky Point (photo credits, J. Williams).

Buried Reefs

The nearshore reefs (<30 m) of the peninsula have been intensively surveyed in the past for the Santa Monica Bay Restoration Commission (Pondella 2009), and finer-scale sampling has continued recently for this project. During these rocky reef surveys, buried reefs at Bunker Point with *Pterygophora* growing out of the sediment were observed on November 15, 2007, October 22, 2008, and April 20, 2010 (Figure 8). Considering that reef burial was not observed during the extensive surveys of this region in the 1990s (Stephens 1996), this burial likely occurred in the last decade. The reef's proximity to the Trump National Golf Course landslide suggests it has likely been buried since 1999. This reef at Bunker Point remained buried through the spring of 2010. In addition, we observed buried *Pteryogophora* on reefs near Whites Point throughout this study (Figure 9).

Figure 8. Buried *Pterygophora* reefs at Bunker Point, October 22, 2008 (Photos credits: D. Witting, NOAA).

Figure 9. Buried *Pterygophora* reef at Whites Point, June 3, 2009 (Photo credit J. Williams).

Physical Effects of Turbidity on the Palos Verdes Peninsula

LIGHT AVAILABILITY

To analyze the effect of turbidity along the peninsula and its potential to limit algal growth at depth, we examined a survey of the water column profile of light energy [measured as photosynthetically active radiation (PAR)] that was conducted monthly from 1982-2009 at seven nearshore sites along the Palos Verdes Peninsula (Figure 10). This survey is part of the Joint Water Pollution Control Plant (JWPCP) NPDES monitoring program. Readings are taken at 0.5m, 1 m and then at 2 m intervals below the surface until contact with the bottom or 20 m depth, whichever comes first. The light energy value measured at each depth (quanta/sec/cm^2) is divided by the surface light energy measurement (also quanta/sec/cm^2) to obtain a percentage of the surface light energy that passes through the water column to each depth. That percentage was then averaged over every sampling period from April 1982 to December 2009 to obtain a mean percentage of surface light energy captured at each depth (Figure 11). By plotting the difference between the percentage at each site/depth and the average percentage of all sites at each depth, discernable patterns begin to appear (Figure 12). Patterns at the Lunada Bay (Palos Verdes Point) and Long Point stations show far below average light energy transmittance near the surface compared to other sites, but far greater transmittance further down in the water column, suggesting that the thick kelp canopy, rather than turbidity, impacts light penetration at those sites. Additionally, these data may suggest that turbidity at those sites is generally low when compared to thinner-canopied sites to the east, such as Abalone Cove and Cairns. Given the small differences in the percentages by site, it appears that there is sufficient light penetration at all stations to sustain macroalgae.

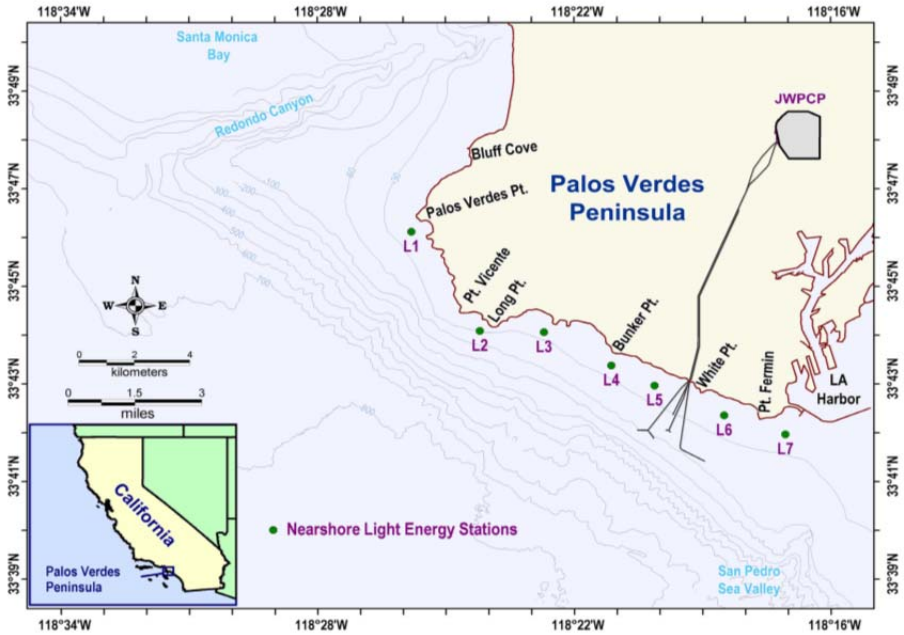

Figure 10. Locations of the JWPCP light energy stations.

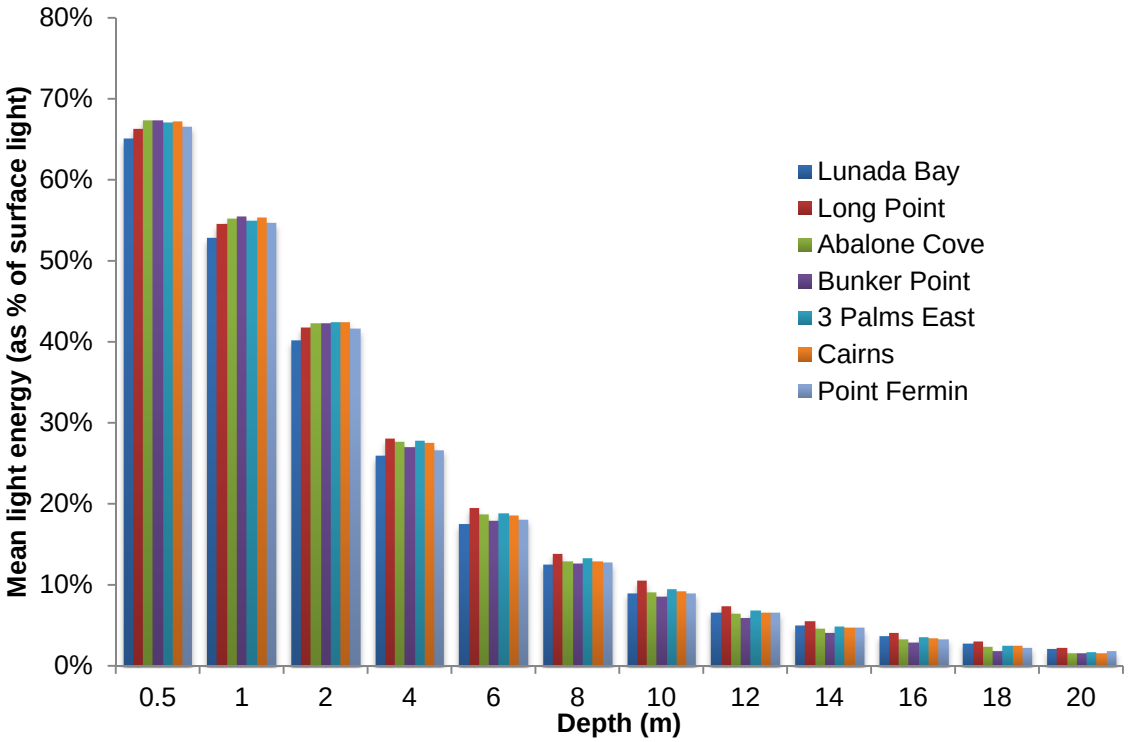

Figure 11. Mean light attenuation at seven sites along the Palos Verdes Peninsula.

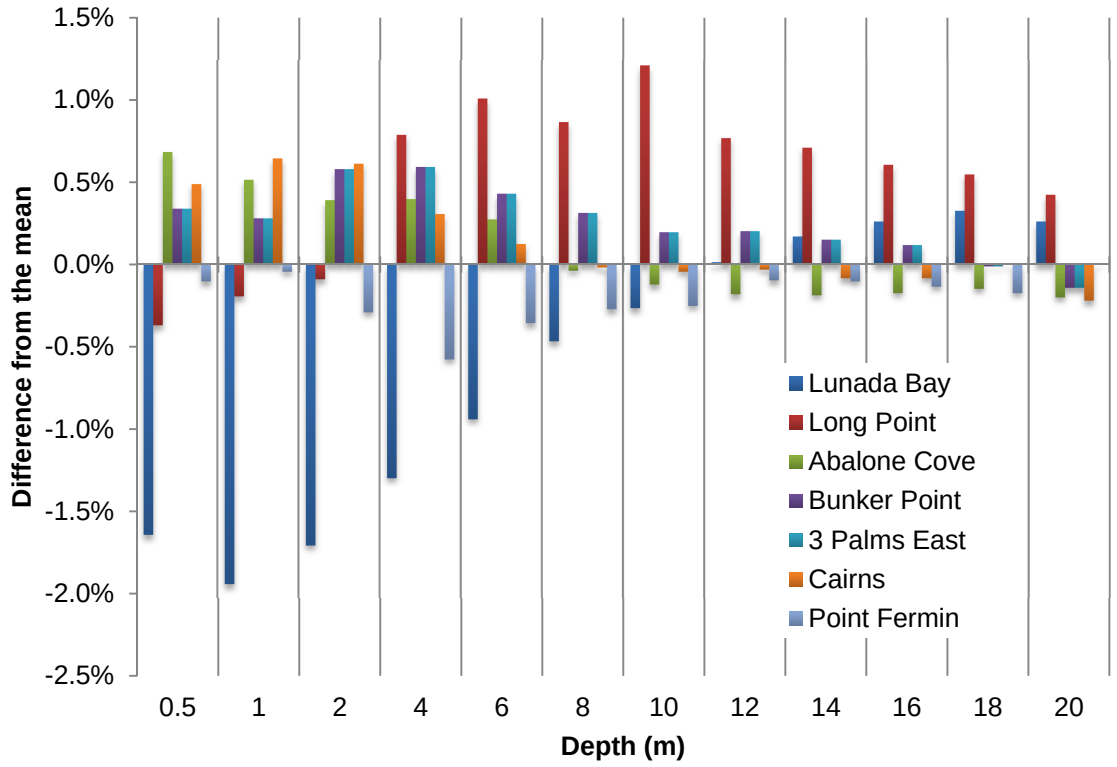

Figure 12. Light attenuation % difference from the mean at seven Palos Verdes Peninsula locations by depth.

GIS Analyses and Habitat Characterization

The restoration study site was defined in GIS as the area from just east of Bunker Point to just west of the Whites Point Outfall (Figure 13). The western border was defined as the transition from the high relief reef at Bunker Point and the transition to sediment covered reefs at Portuguese Bend. The eastern border was delineated to not include the Whites Point Outfall. The southern border is approximately the 30 m isobath and the northern border is the shoreline (http://coastalmap.marine.usgs.gov/regional/contusa/westcoast/pacificcoast/data.html). The geographic extent and character of marine hard bottom/reef was mapped by combining several different spatial datasets into a preliminary habitat data layer. This layer was then verified and corrected using underwater field observations and analyses of aerial and satellite photography. All mapping and spatial analysis was done using ArcGIS software. Spatial data layers were created and maintained in the shapefile format, using the UTM Zone 11 North, WGS84 projection to minimize distortion in both area and length measurements. These data layers are included with this report as ESRI format shapefiles and Google Earth compatible .kml files. Kelp canopy was a highly precise polygon spatial layer created by using a 2-meter rectangular grid to classify georeferenced aerial photography (Kelner 2005). Kelp canopy varies significantly over seasons and years. In this layer three years (1989, 1999 and 2002) of data was used. The 2008 canopy has also been obtained (Figure 3, data courtesy of E. Miller, MBC Applied Environmental Sciences). Triple beam and sidescan data were obtained from the Sea Floor Mapping Lab at Cal State University, Monterey Bay (http://seafloor.csumb.edu/SFMLwebDATA.htm). This area consists of approximately 2.9 km^2 (2,899,280 m^2) of nearshore environment (Figure 9). All data layers can be found at http://departments.oxy.edu/vrg/research.

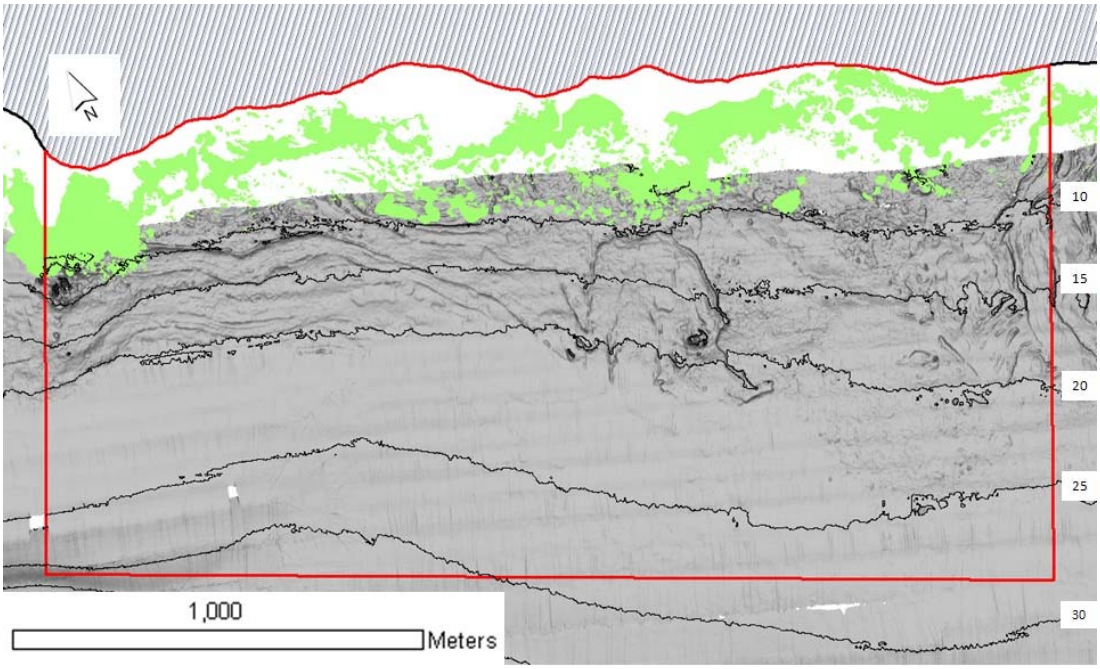

Figure 13. Bunker Point Restoration site study area, kelp canopy is in green, side scan imagery is in gray with the 10, 15, 20, 25 and 30 m isobaths.

To determine the sediment depth over the rock throughout this area, we conducted scuba surveys at twelve locations (Figure 14). These surveys were conducted perpendicular to the coastline starting at the 20 m isobath, and divers would measure the sediment depth at 10 m intervals until completely uncovered and unbroken reef habitat was found. The initial sediment characterization was conducted in Spring 2009 and a second survey was conducted in Spring 2010. A third survey was conducted in Spring 2011 to fill in spatial gaps, determine fidelity of buried reefs, and concentrate surveys on possible restoration sites. Sites that were primarily rock were excluded from the second and third surveys. With the exception of stations 11 and 12, all surveys were conducted over mapped rocky reef habitat. Between each of these study periods we had long winters of cold El Niño storms associated with heavy rains. This set up a natural experiment of the effects of heavy swell and rain on the study site.

All transects in the defined study site (lines 1-8 and 13) were completed over mapped reef habitat. The sediment depth and the percent of rock covered by sand remained varied from 2009 to 2011 (Table 1, Figure 15), though no buried reefs were cleared of sand over time. Consistent with the visual observations of the *Pterygophora* beds, these findings indicated that reef habitat continued to be buried, especially at areas near lines 2, 13, 3, 7, 8, 11 and 12.

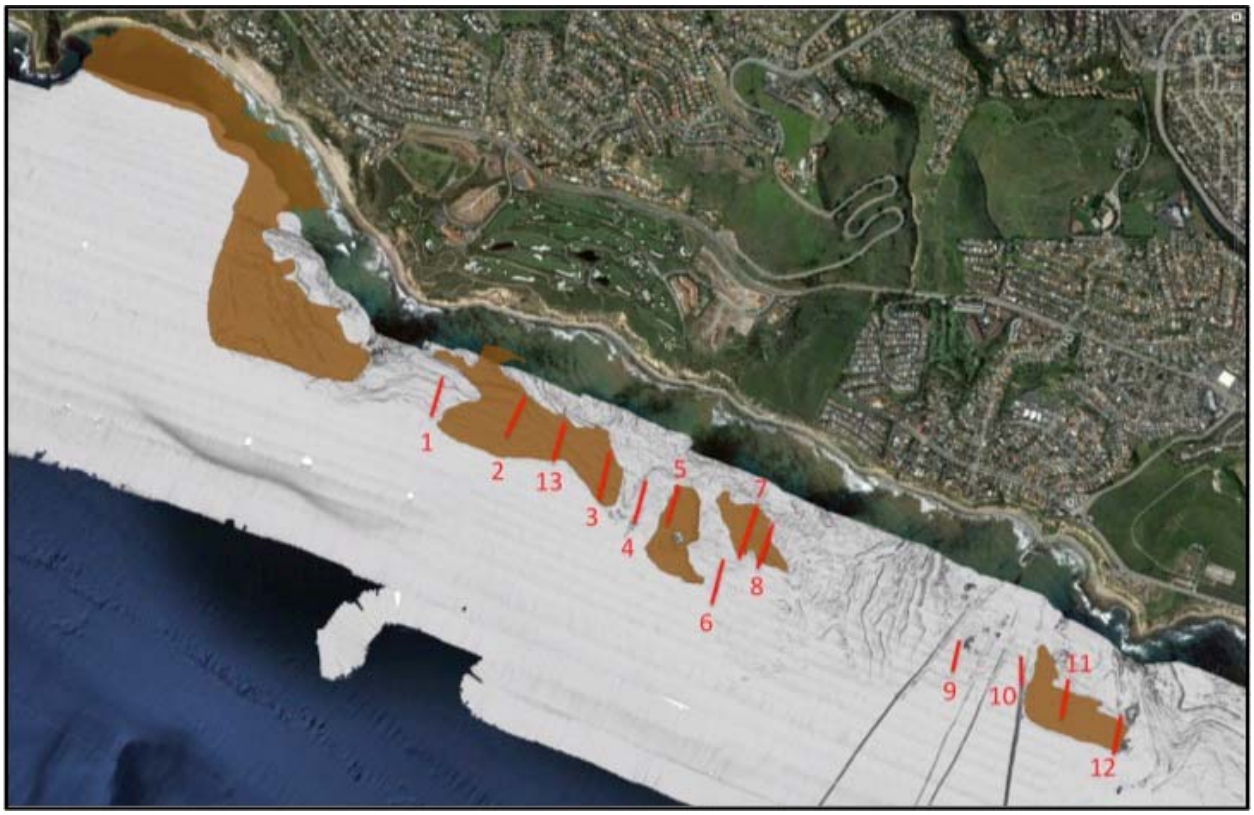

Figure 14. Mapped reef habitat, sediment survey transects (red numbered lines), and areas with buried rocky reef (brown polygons).

Table 1. Mean sediment depth (cm) and percent of rock versus sand at thirteen stations from Bunker Point to Whites Point.

	2009	*2010*	*2011*	*2009*		*2010*		*2011*	
Line	**Sediment Depth (cm)**			**Rock**	**Sand**	**Rock**	**Sand**	**Rock**	**Sand**
1	5.6			71%	29%				
2	3.5	3.8	19.2	60%	30%	15%	85%	12%	88%
13			9.0					15%	85%
3	3.2	10.7	3.6	0%	100%	0%	100%	10%	90%
4	2.1	3.5		22%	78%	42%	58%		
5		21.3				0%	100%		
6	1.8			39%	62%				
7	3.0	5.0	7.5	0%	100%	8%	92%	27%	73%
8	1.2	4.6	4.0	40%	60%	0%	100%	26%	74%
9	2.6	2.5		22%	78%	10%	90%		
10	19.9			0%	100%				
11	36.6	25.4	43.1	0%	100%	18%	82%	27%	73%
12	19.0	1.3	17.7	0%	100%	0%	100%	9%	91%

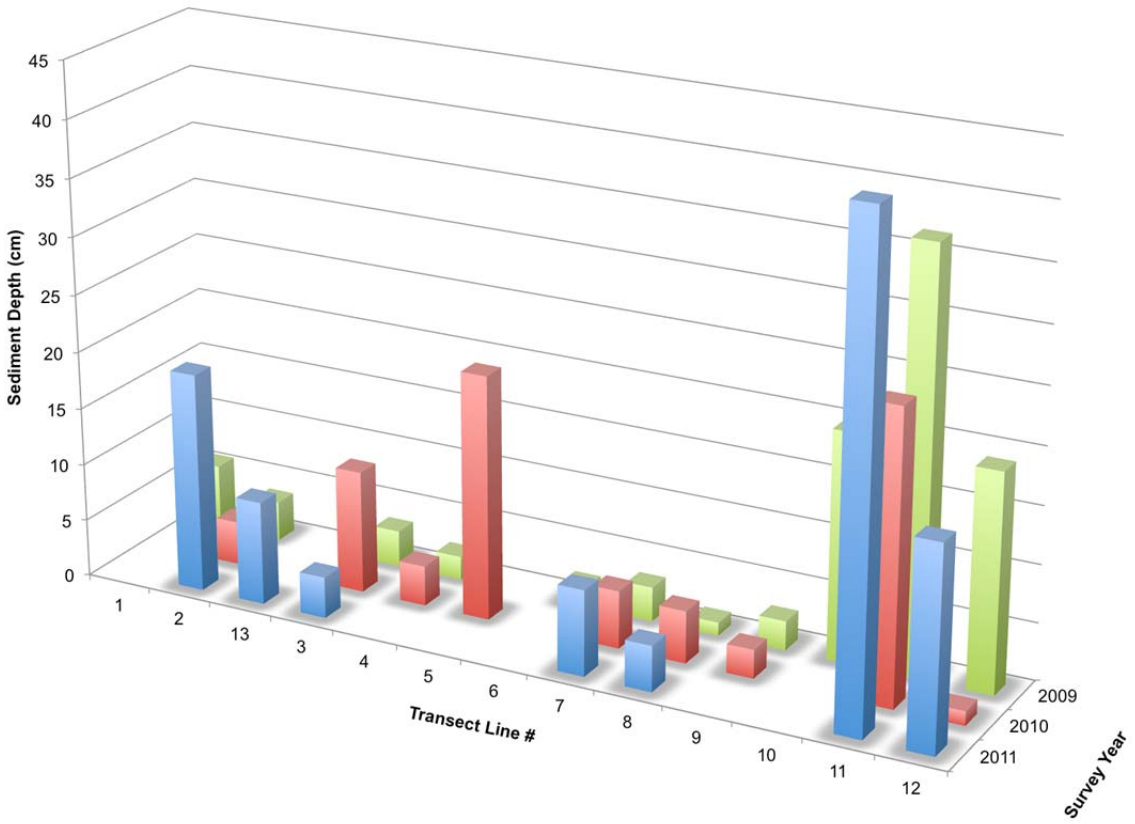

Figure 15. Mean sediment depth at 13 stations (see Figure 15) during Spring 2009, 2010 and 2011.

Biological and Physical Characteristics of Rocky Reefs on the Palos Verdes Peninsula

To examine the potential efficacy of fishery production enhancement reefs in this region, we conducted an intensive biological and physical sampling program throughout the Palos Verdes Peninsula. Using the CRANE protocols, 186 surveys at 33 sites were conducted from 2007-2011 (Figure 3). In order to determine the effects of the sedimentation and turbidity on the study area, we conducted a habitat characterization utilizing metrics generated from the uniform point contact (UPC) data set. The physical substrate (Figure 16) and relief (Figures 17 and 18) of reefs varied throughout the peninsula. Most of the variation in substrate was associated with the fraction of sand versus bedrock with the exception of Old Marineland, a shallow (< 7 m) reef with a large proportion of cobble that is currently being restored through Santa Monica Baykeeper's (SMBK) Kelp Restoration and Monitoring Program. Most of the variation in physical relief was associated with the proportion of flat (0 – 0.1 m) reef versus moderate (1-2 m) and high relief (> 2m) reef, particularly when comparing at typical long-shelf Palos Verdes Peninsula reef such as Rocky Point to short-shelf reefs on the southwest side of the peninsula, like Point Vicente East/West and Long Point East/West (inside newly-created the Point Vicente State Marine Conservation Area). The notable exception to this trend was again at Old Marineland where the shelf is very short, but rocky reef is only present in the shallow subtidal creating a zone that was almost entirely of low relief cobble.

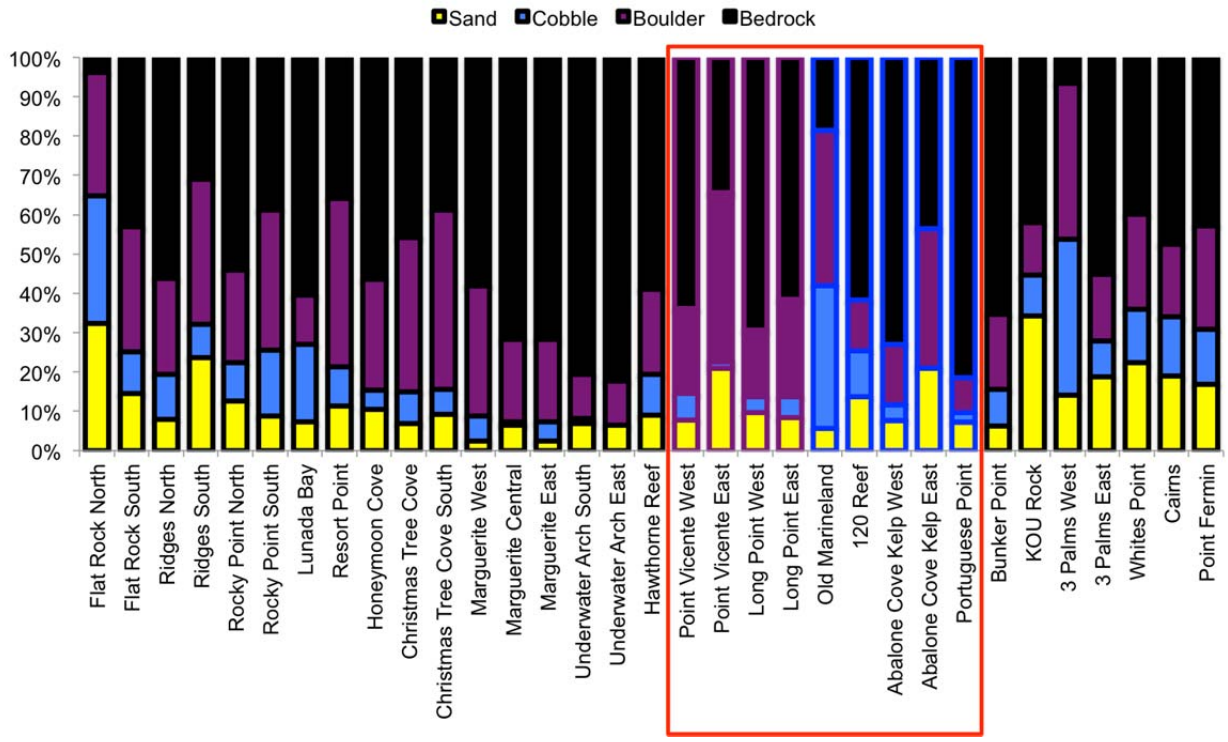

Figure 16. Substrate composition of reefs on the Palos Verdes Peninsula. Reefs within Marine Protected Areas are outlined in red.

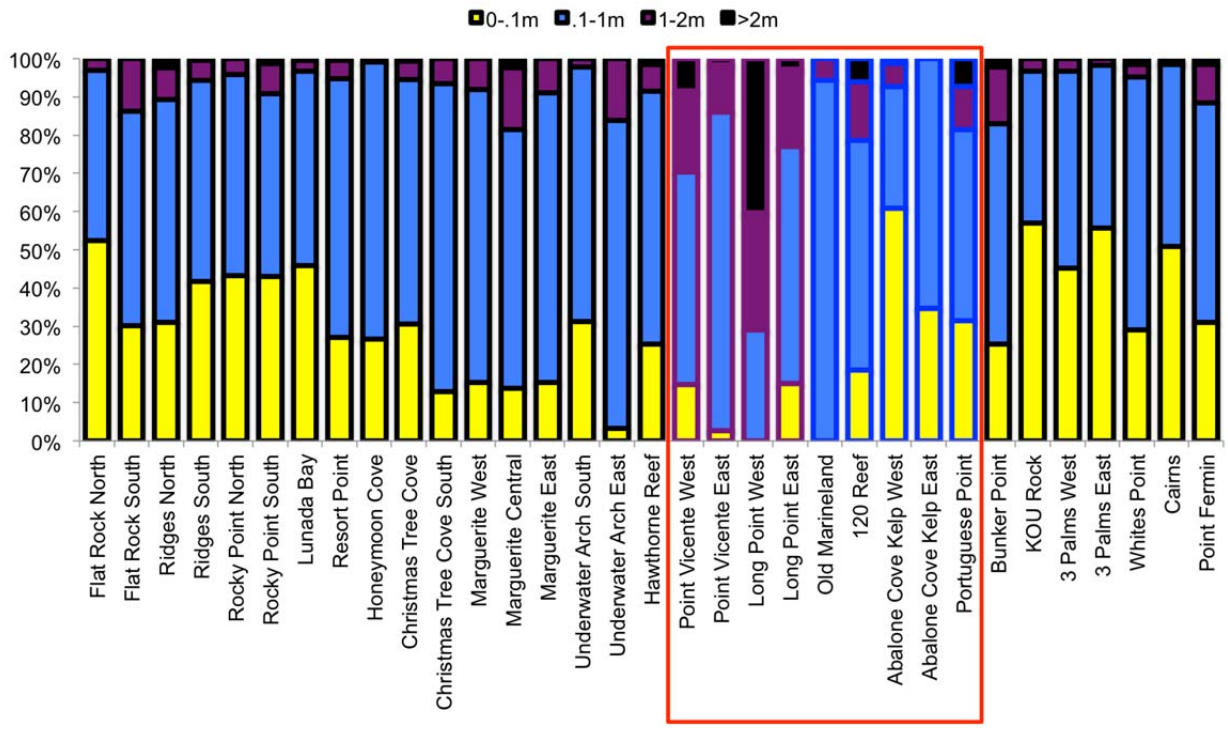

Figure 17. Percentages of physical relief categories of reefs on the Palos Verdes Peninsula. Reefs within Marine Protected Areas are outlined in red.

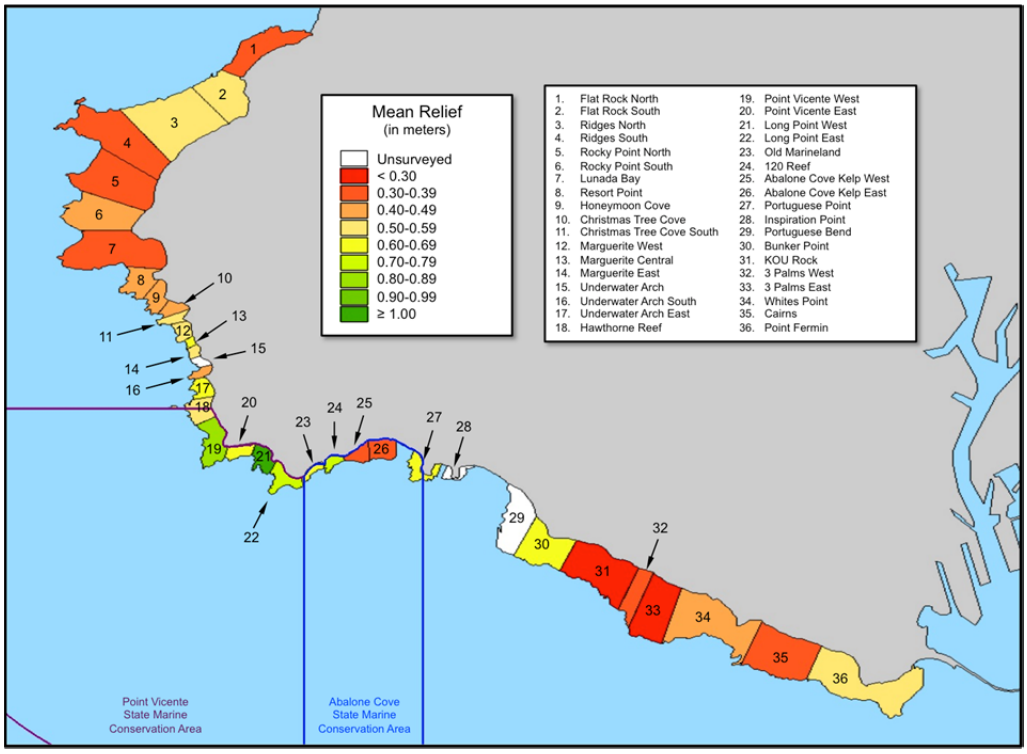

Figure 18. Mean relief scaled from low (red) to high (green) at each of the 36 currently delineated reefs on the Palos Verdes Peninsula.

SEDIMENTATION INDICATORS

The most striking aspect of the benthos was the evidence of sedimentation effects on the eastern stretch of the peninsula (Long Point to Point Fermin). Bare rock cover on rocky reefs (Figure 19) can be an indicator of scouring by either abiotic sources (e.g, sand, shell hash, wave action) and is typical of areas that are under stresses of high flow and/or high sedimentation. The proportion of abiotic cover (including bare rock, bare sand, shell hash, sediment, and detritus) on rocky reefs (Figure 20) was far higher in sedimentation affected areas, such as those near storm drains (Lunada Bay, Marguerite East, Underwater Arch East, and Old Marineland), landscaping runoff zones (Bunker Point, KOU Rock, and 3 Palms East/West), and landslide areas (Abalone Cove Kelp East/West, Bunker Point to Whites Point). It should be noted that surveys at Cairns were performed prior to the November 2011 landslide above the reef, and that sedimentation effects will likely be noticeable in future surveys. Biological indicators of sedimentation effects include the benthic cover proportion of sediment resistant tubeworms (Figure 21), including *Phragmatopoma californica*, *Salmacina tribranchiata*, and *Diopatra ornata*. Tubeworm cover at landslide impacted reefs (Abalone Cove Kelp East/West, Bunker Point, and KOU Rock) and the reef adjacent to the Ports of Los Angeles and Long Beach (Point Fermin) was far above average. These three metrics in conjunction (Figure 22) provide insight into which reefs are most affected by various forms of sedimentation along Palos Verdes Peninsula. While sedimentation effects in the Abalone Cove Kelp area appeared to be localized due to the largely slowed Abalone Cove landslide, effects of the continuous Portuguese Bend and recent Trump National Golf Course landslide were prominent as far as Whites Point.

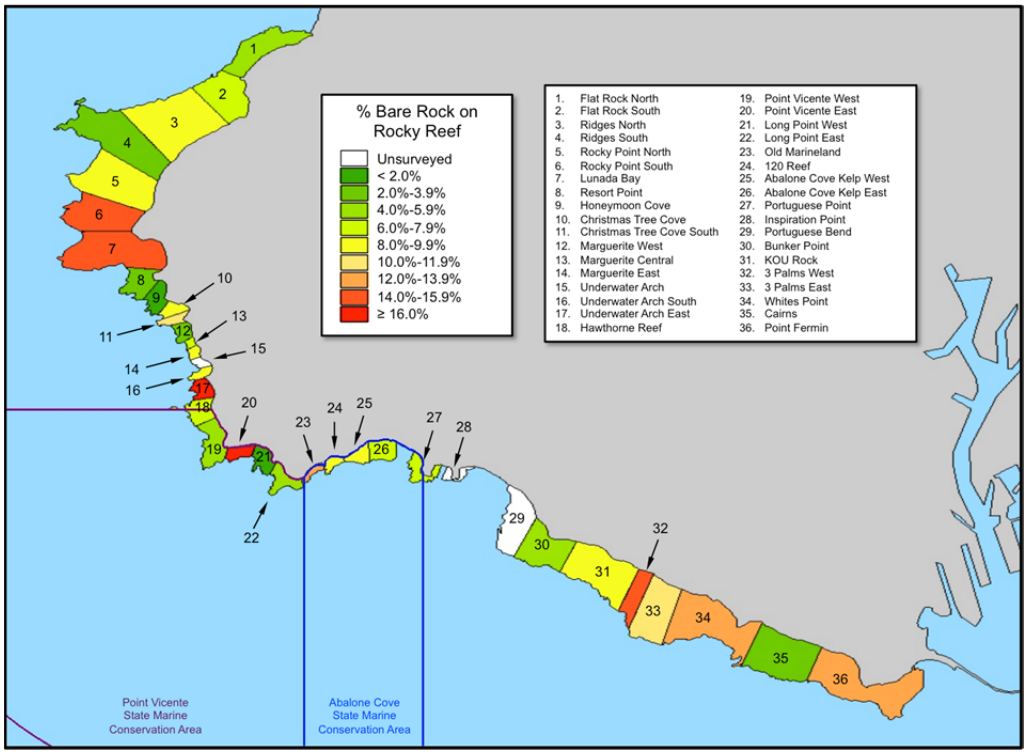

Figure 19. Percentage of bare rock cover on rocky reef scaled from low (green) to high (red) at each of the 36 currently delineated reefs on the Palos Verdes Peninsula.

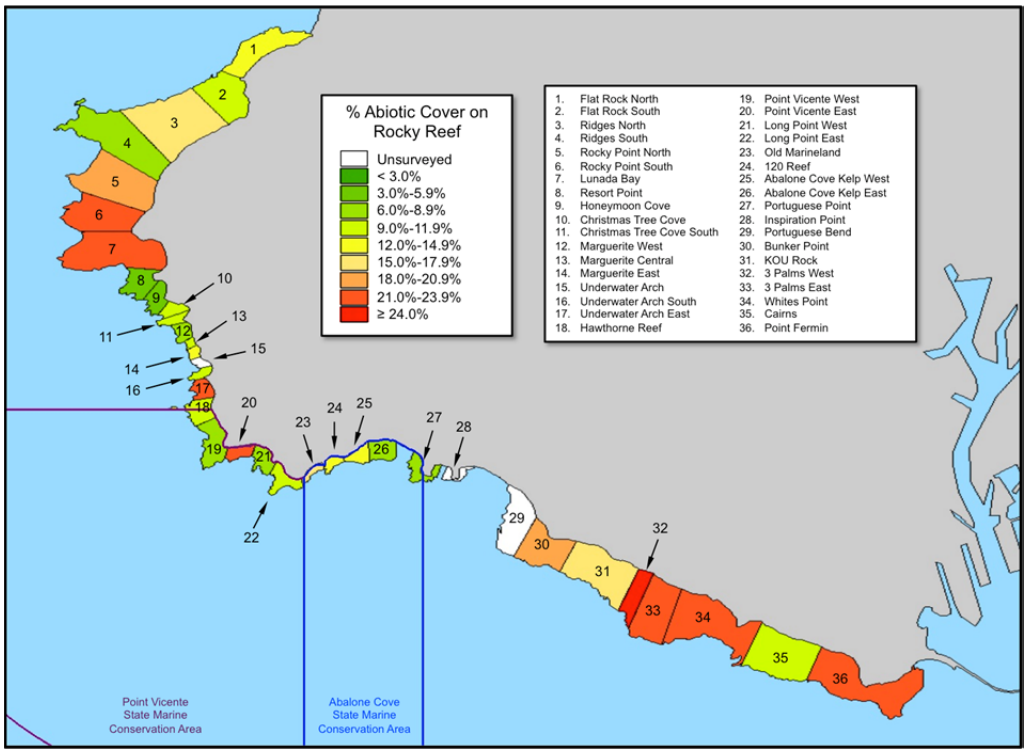

Figure 20. Percentage of abiotic cover on rocky reef scaled from low (green) to high (red) at each of the 36 currently delineated reefs on the Palos Verdes Peninsula.

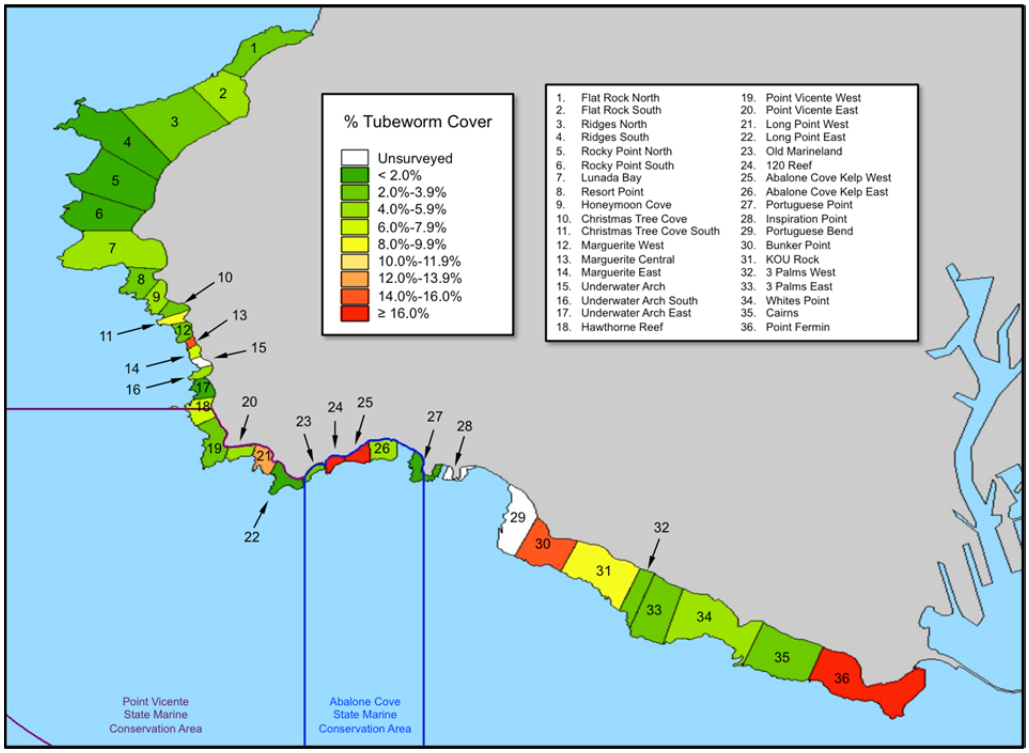

Figure 21. Percentage of tubeworm cover scaled from low (green) to high (red) at each of the 36 currently delineated reefs on the Palos Verdes Peninsula.

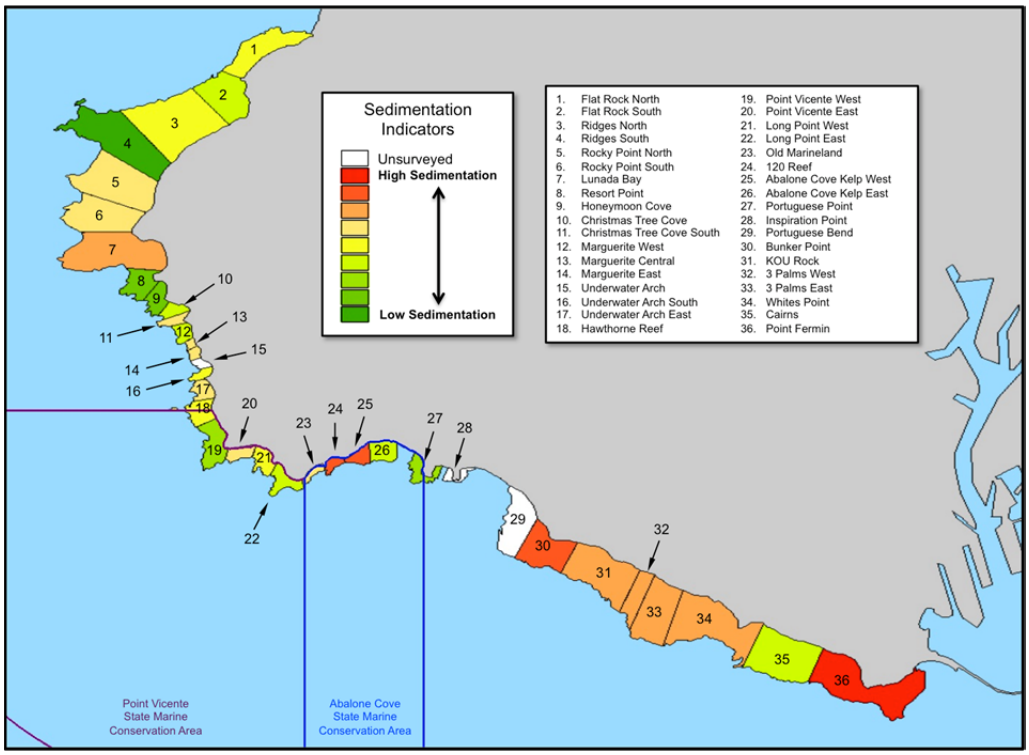

Figure 22. Relative scale of sedimentation indicators scaled from low (green) to high (red) at each of the 36 currently delineated reefs on the Palos Verdes Peninsula.

URCHIN BARREN INDICATORS

Percent coverage on reefs was also used to help determine the location and fidelity of urchin barrens on the Palos Verdes Peninsula. In addition to bare rock cover on rocky reefs (Figure 19) being an indicator of scour by sedimentation, it can also be an indicator of scouring by biotic sources (sea urchin/mollusc grazing, macroalgal abrasion, etc.), and is typical of areas that are under stresses of high flow and/or overpopulation of grazers. Reefs that have been grazed excessively can no longer support the growth of algae, with the notable exception of crustose coralline algae (CCA) (Watanabe and Harrold 1991). These multilayered algae are somewhat resistant to grazing, can facilitate urchin recruitment, and can inhibit recruitment of other invertebrate and algal species (Baskett and Salomon 2010), thereby potentially helping to sustain urchin barrens (see red polygons in Figure 3). High bare rock and CCA cover (Figure 23) was found at every reef along Palos Verdes Peninsula from Honeymoon Cove to Abalone Cove Kelp West. These reefs are all known to have patchy to persistent urchin barrens and are targets for both past and upcoming SMBK Kelp Restoration and Monitoring Program.

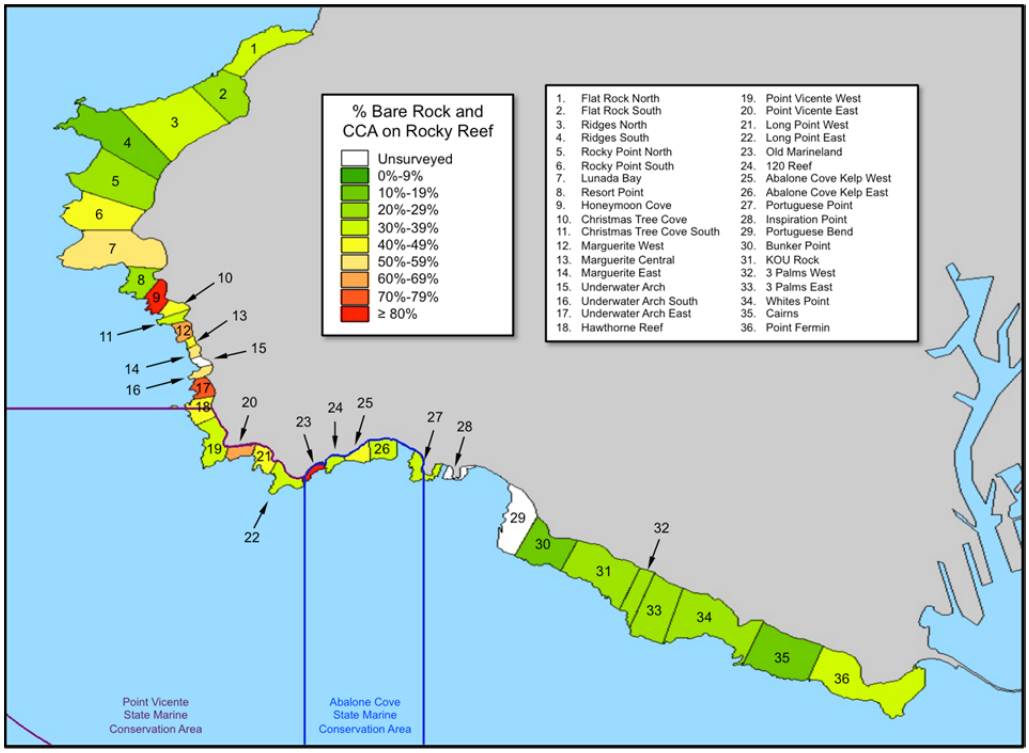

Figure 23. Percentage of bare rock and crustose coralline algae cover scaled from low (green) to high (red) at each of the 36 currently delineated reefs on the Palos Verdes Peninsula.

A second part of CRANE protocols (swath) was used to determine macroalgal and macroinvertebrate densities in conjunction with the UPC surveys at each reef. Macroalgal densities provided insight into not only the community structure of each reef, but also the presence or absence of appropriate habitat for kelp forest obligates. One of the more obvious signs of the presence of an urchin barren was the lack of macroalgae (Figure 24), an effect most clearly seen in reefs from extending from Resort Point to Portuguese Point – including the area where bare rock and CCA cover was the highest. The species most closely associated with kelp forests is giant kelp (*Macrocystis pyrifera*). While macroalgae along the Palos Verdes Peninsula consisted of several species, including giant kelp, *Pterygophora californica*, and other smaller kelps (Figure 25), giant kelp was the lone canopy creating species. Reefs with dense giant kelp forests (Figure 26) require relatively clear, nutrient rich water, and are considered to be among the most productive areas in southern California. Dense giant kelp forests were found along the western side of Palos Verdes Peninsula from Flat Rock North to Resort Point, in areas with less turbidity and sedimentation issues and nearer to the nutrient rich waters of Redondo Submarine Canyon. *Pterygophora californica* creates understory canopies on flatter reefs, and can withstand more turbidity than giant kelp. During these surveys, *Pterygophora californica* was found in moderate densities along the same stretch as giant kelp (Figure 27), creating an understory in addition to a giant kelp canopy, and in high densities in the sediment-affected reefs from Bunker Point to Point Fermin.

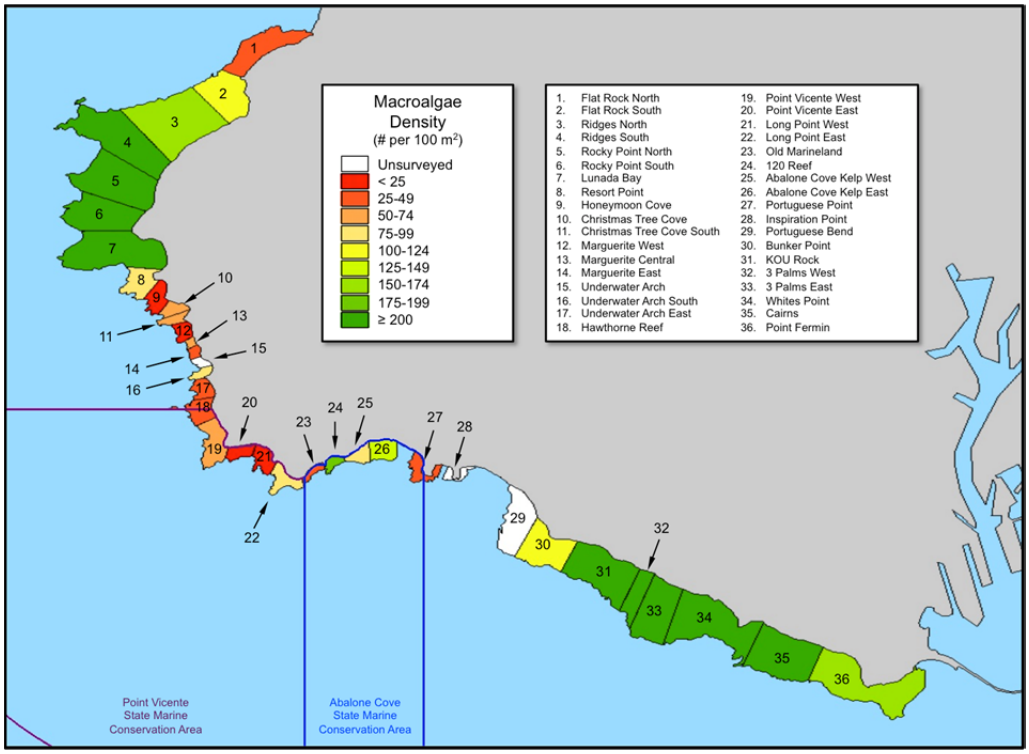

Figure 24. Density of macroalgae (individuals per 100 m^2) scaled from low (red) to high (green) at each of the 36 currently delineated reefs on the Palos Verdes Peninsula.

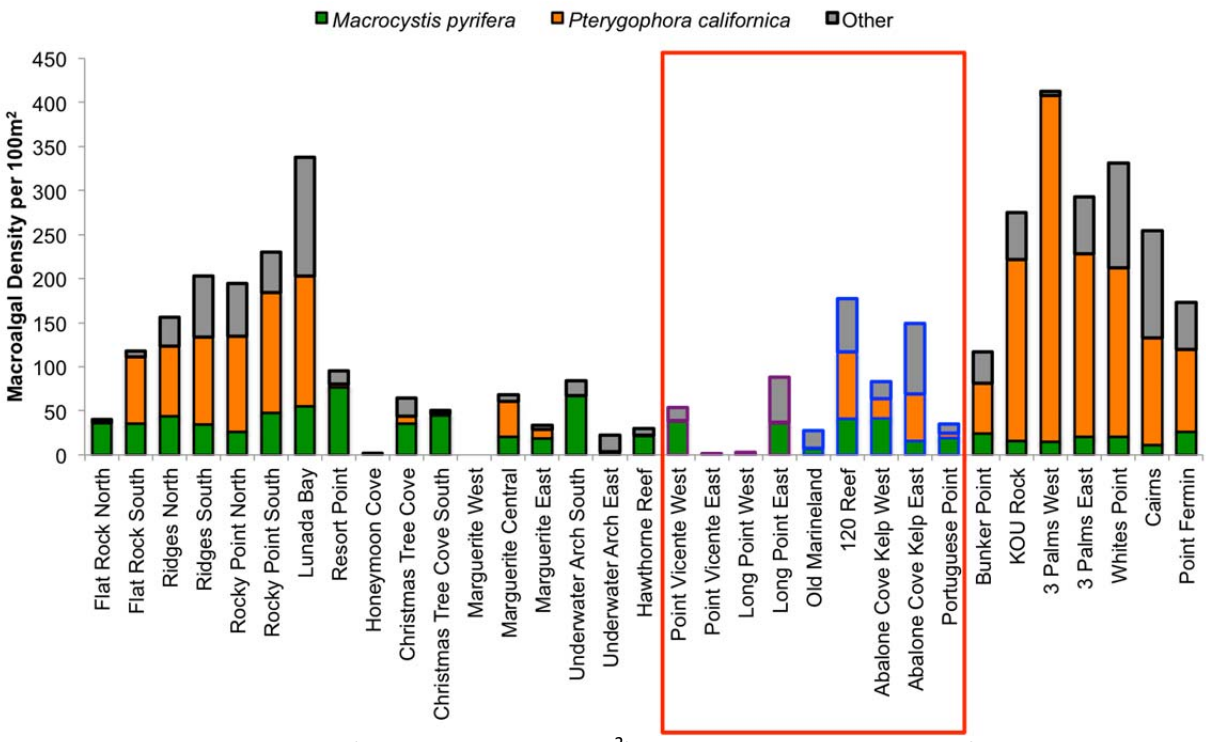

Figure 25. Macroalgae density (individuals per 100 m^2) separated by species at reefs on the Palos Verdes Peninsula. Reefs within Marine Protected Areas are outlined in red.

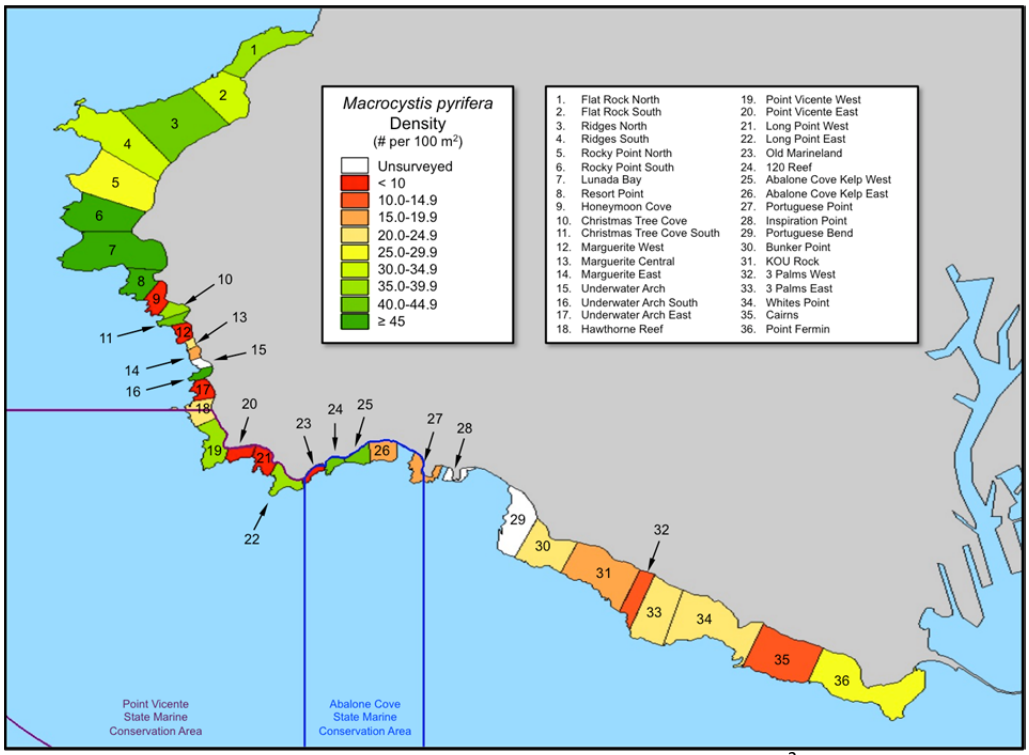

Figure 26. Density of giant kelp (*Macrocystis pyrifera;* individuals per 100 m^2) scaled from low (red) to high (green) at each of the 36 currently delineated reefs on the Palos Verdes Peninsula.

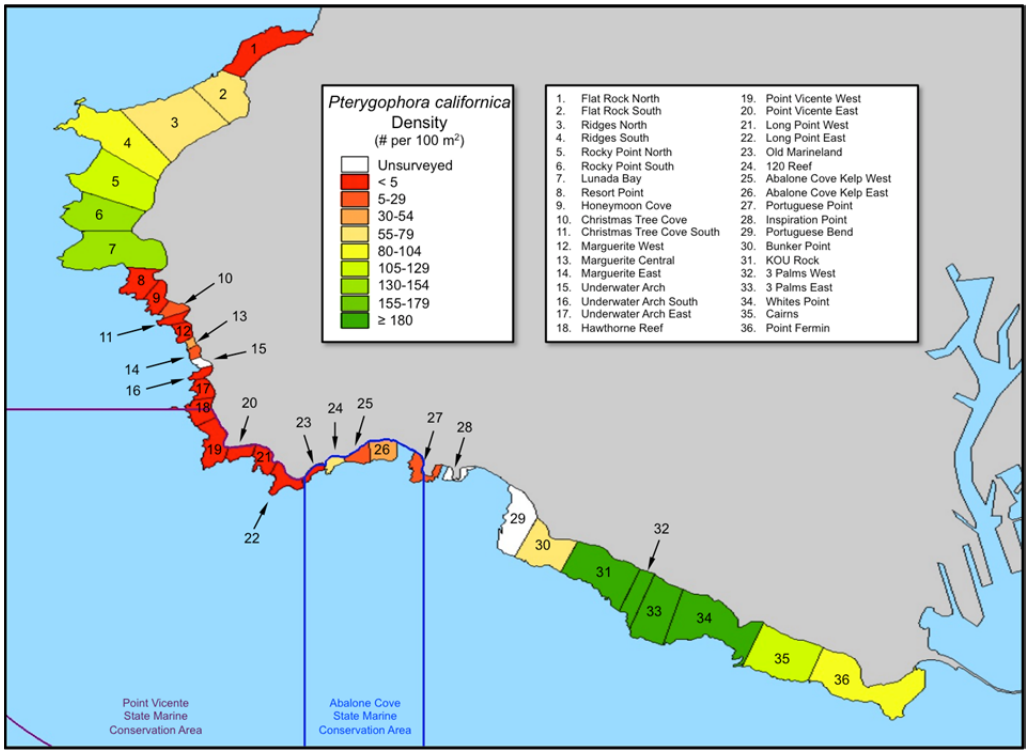

Figure 27. Density of *Pterygophora californica* (individuals per 100 m^2) scaled from low (red) to high (green) at each of the 36 currently delineated reefs on the Palos Verdes Peninsula.

Macroinvertebrate densities vary widely along the Palos Verdes Peninsula (Figure 28), and are highly influenced by the massive quantities of urchins (*Strongylocentrotus spp.*) and sea stars (*Patiria miniata*, *Pisaster spp.*) at sites along the southwestern portion of the peninsula (Figure 29). Sites with exceptionally high densities of purple sea urchins (*Strongylocentrotus purpuratus*) are limited to reefs between Honeymoon Cove and Portuguese Point (Figure 30) – the same reefs with benthic cover and macroalgal densities indicating persistent urchin barrens. In addition to having a high density of purple sea urchins, previous research (Claisse et al 2012) shows that urchins inside barren areas have significantly smaller test sizes than in non-barren areas. The same stretch of reefs from Honeymoon Cove to Portuguese Point (Figure 31) has many of the smallest purple sea urchin mean test sizes at Palos Verdes Peninsula. Similarly, reefs from Marguerite West to Portuguese Point have the highest density of red sea urchins (*Strongylocentrotus franciscanus*; Figure 32) and reefs from Lunada Bay to Abalone Cove Kelp East have red sea urchins with the smallest mean test sizes (Figure 33).

As a direct competitor for resources, density comparisons of abalone species (*Haliotis spp.*) and urchins would provide good information regarding the nature of urchin overpopulation, but this once-thriving commercial fishery in southern California was so severely overfished and devastated by disease that all recreational and commercial fisheries were closed in 1996 (CDFG 2005), and few abalone were found on transect at any of the Palos Verdes Peninsula reefs (Table 2) making analysis difficult. Interestingly, endangered white abalone (*Haliotis sorenseni*) were found on transect at 16 m depth at both Ridges North and Ridges South, and has been several more have been noted off transect in the same area. While not

necessarily an indication of urchin barrens, low densities of urchin predators like California spiny lobster (*Panulirus interruptus*; Figure 34) are also found from Resort Point to Portuguese Point and at reefs closest to the Port of Los Angeles (Cairns and Point Fermin) – perhaps also indicative of heavy fishing pressure. Of note, California spiny lobster densities are highest inside CDFG Fishing District 19a, where commercial fishing for non-baitfish species is prohibited. In conjunction, red and purple sea urchin densities and test sizes, bare rock and CCA benthic coverage, macroalgal density, and California spiny lobster density at each reef provides insight into the size and severity of urchin barrens along the Palos Verdes Peninsula (Figure 35), with the strongest indication of moderate to severe barrens being located between Resort Point and Portuguese Point.

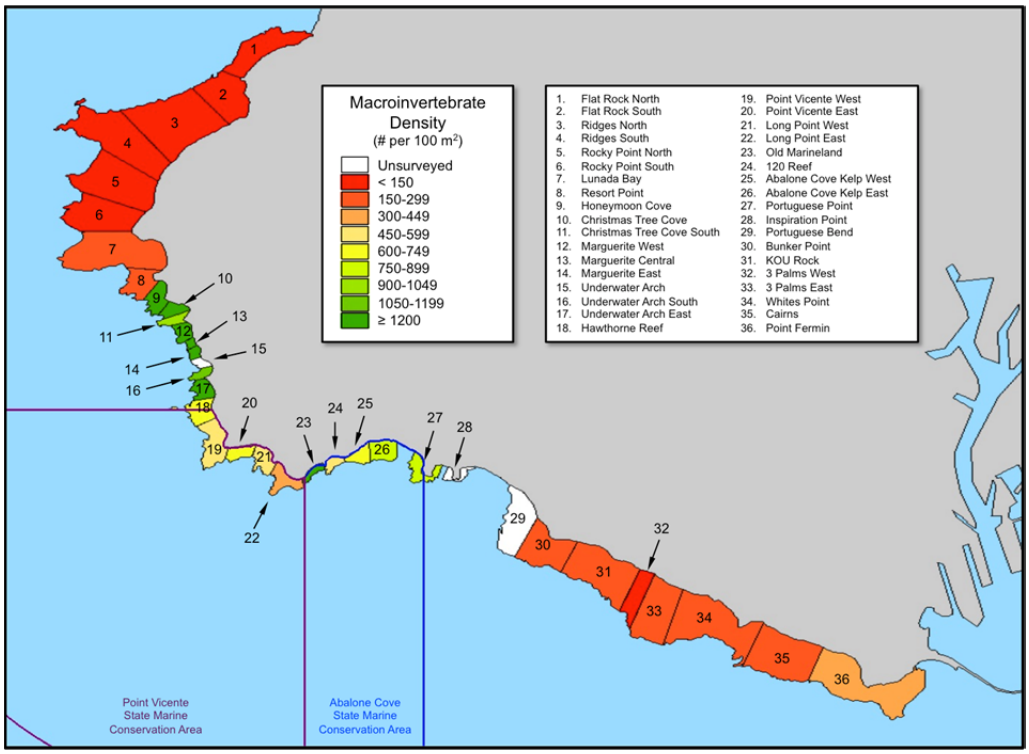

Figure 28. Density of macroinvertebrates (individuals per 100 m^2) scaled from low (red) to high (green) at each of the 36 currently delineated reefs on the Palos Verdes Peninsula.

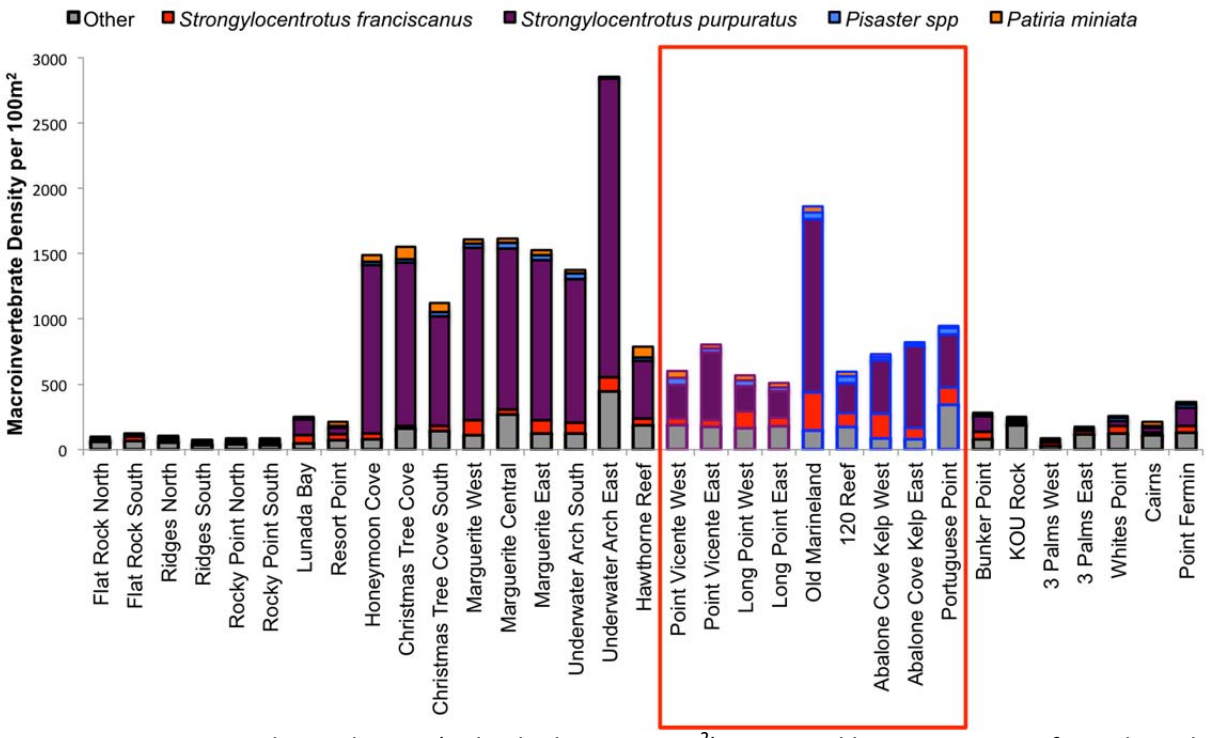

Figure 29. Macroinvertebrate density (individuals per 100 m^2) separated by species at reefs on the Palos Verdes Peninsula. Reefs within Marine Protected Areas are outlined in red.

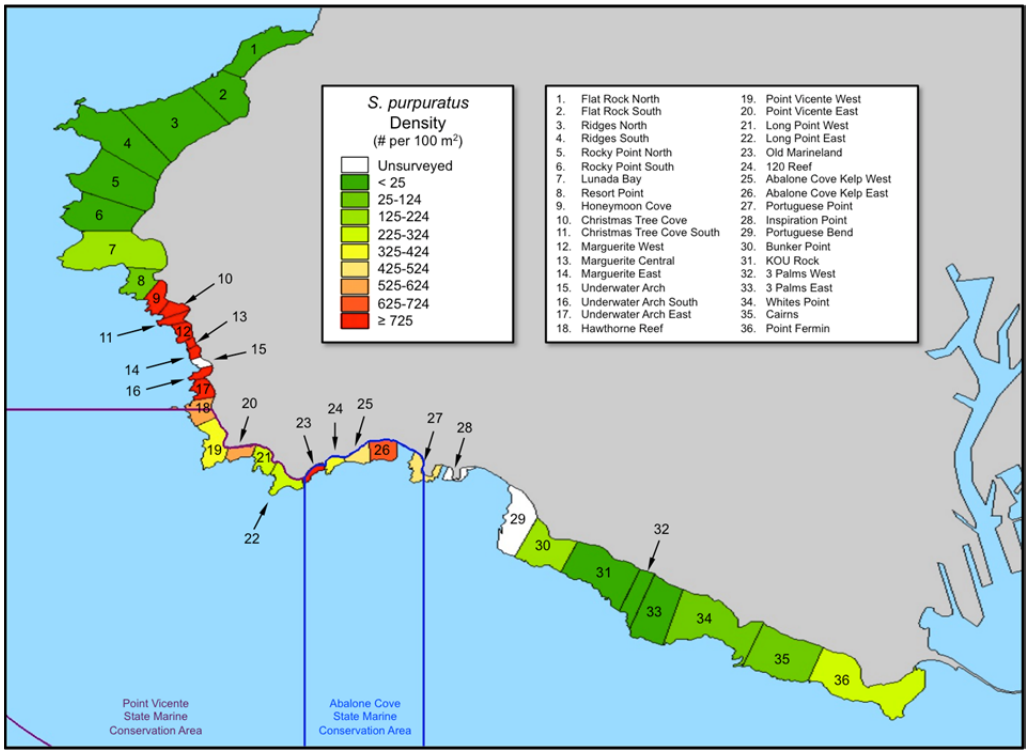

Figure 30. Density of purple urchins (*Strongylocentrotus purpuratus*; individuals per 100 m^2) scaled from low (green) to high (red) at each of the 36 currently delineated reefs on the Palos Verdes Peninsula.

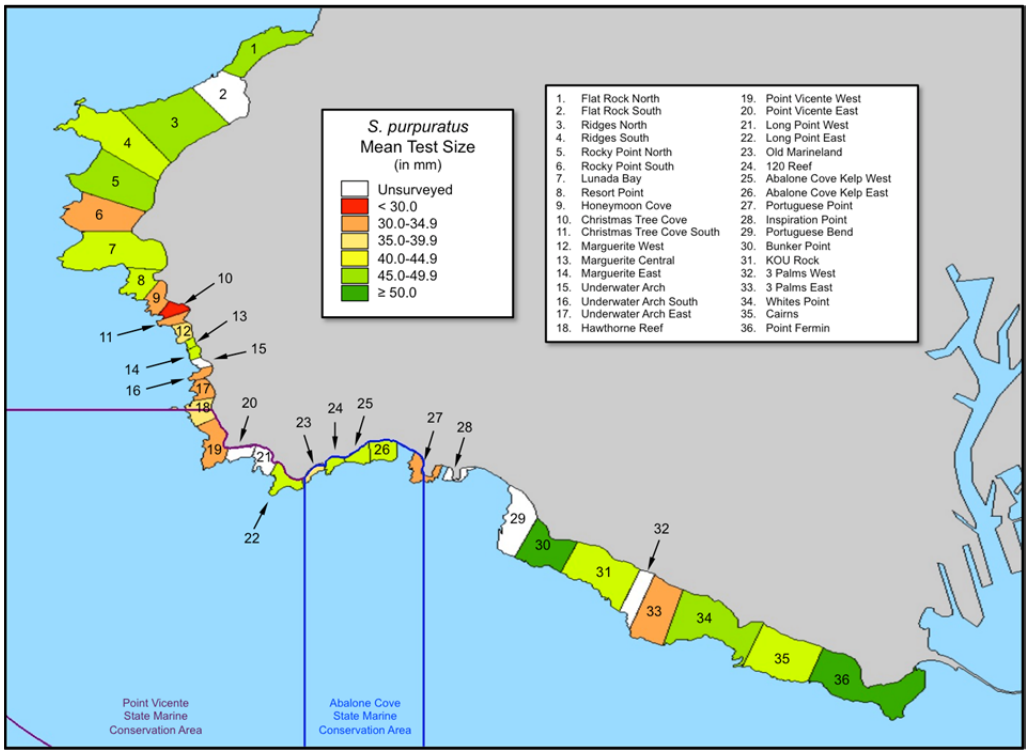

Figure 31. Mean test size of purple urchins (*Strongylocentrotus purpuratus*; in mm) scaled from low (red) to high (green) at each of the 36 currently delineated reefs on the Palos Verdes Peninsula.

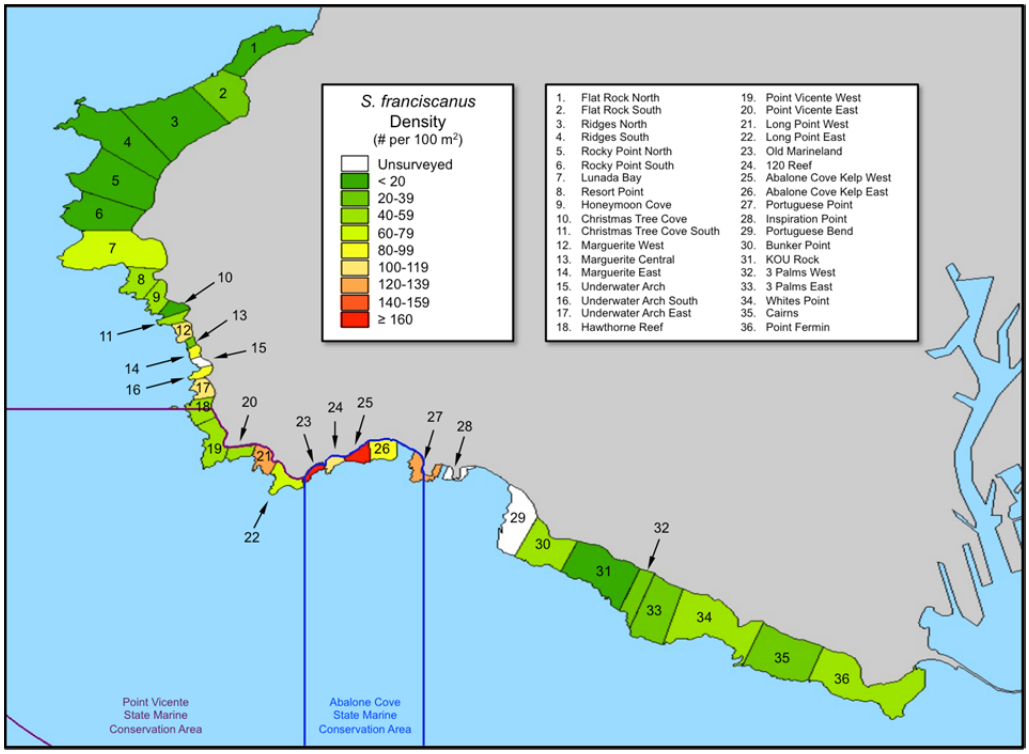

Figure 32. Density of red urchins (*Strongylocentrotus franciscanus*; individuals per 100 m^2) scaled from low (green) to high (red) at each of the 36 currently delineated reefs on the Palos Verdes Peninsula.

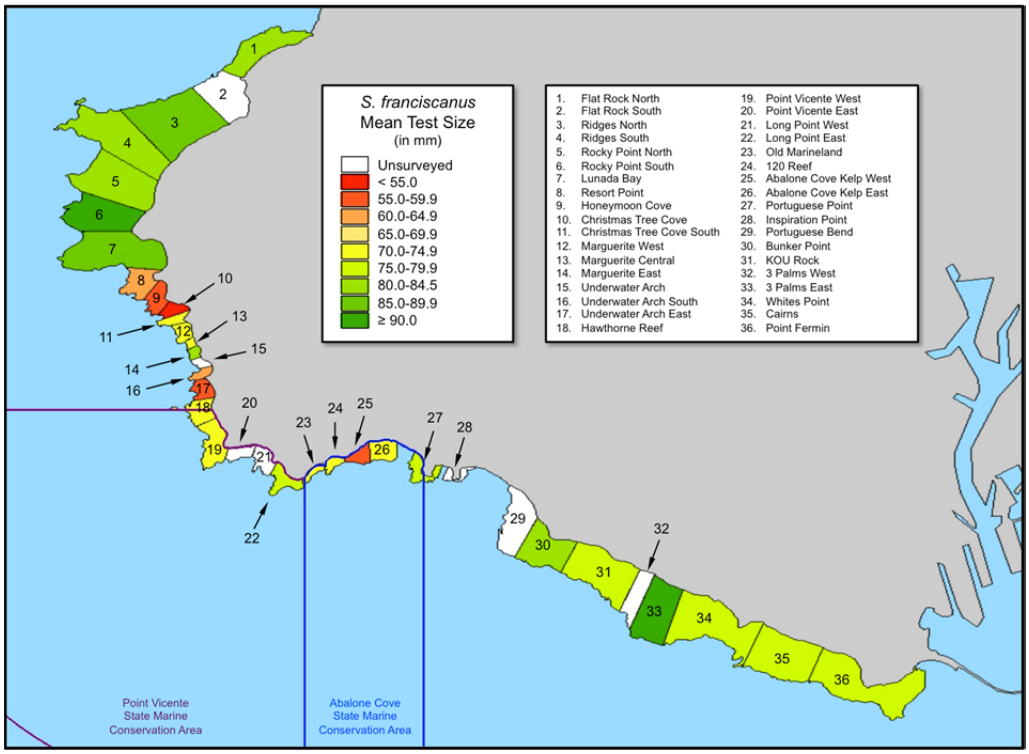

Figure 33. Mean test size of red urchins (*Strongylocentrotus franciscanus*; in mm) scaled from low (red) to high (green) at each of the 36 currently delineated reefs on the Palos Verdes Peninsula.

Table 2. Densities (individuals per 100 m^2) of pink abalone (*Haliotis corrugata*), green abalone (*Haliotis fulgens*), threaded abalone (*Haliotis kamtschatkana assimilis*), and white abalone (*Haliotis sorenseni*) at Palos Verdes Peninsula.

Reef	*H. corrugata*	*H. fulgens*	*H. kamtschatkana assimilis*	*H. sorenseni*
Long Point East			0.083	
Lunada Bay	0.208			
Point Fermin		0.069		
Ridges North	0.139			0.069
Ridges South				0.104
Rocky Point North		0.0005		
Underwater Arch South		0.278		

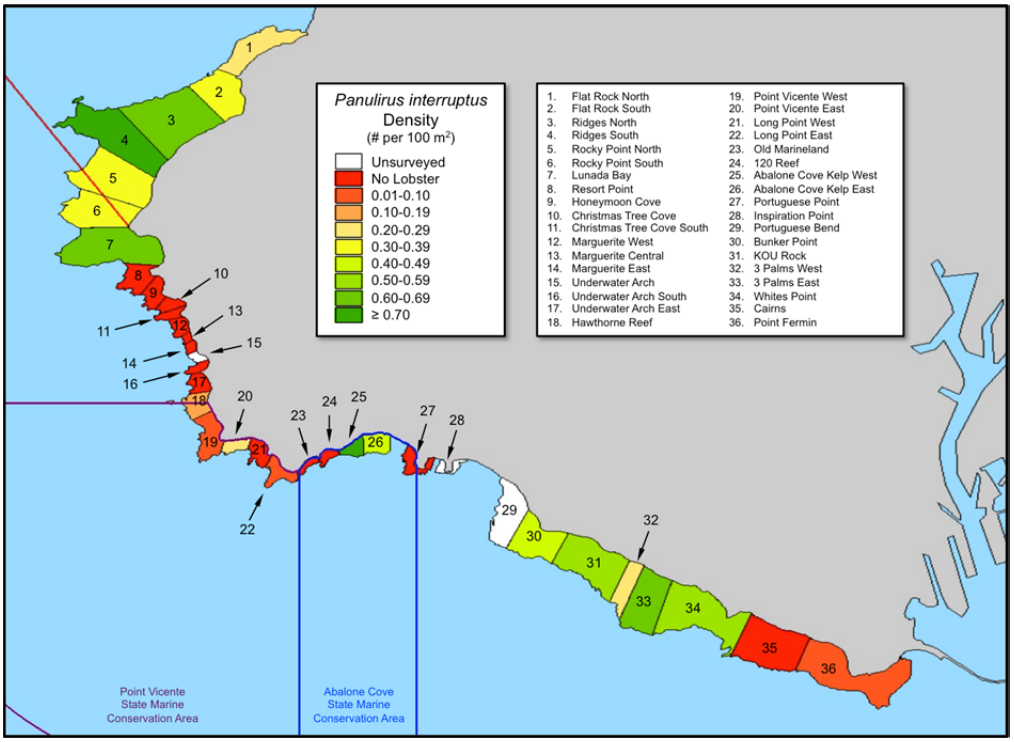

Figure 34. Density of California spiny lobster (*Panulirus interruptus*; individuals per 100 m^2) scaled from low (red) to high (green) at each of the 36 currently delineated reefs on the Palos Verdes Peninsula. Red line indicates the limit for CDFG Fishing District 19a, where commercial fishing is prohibited.

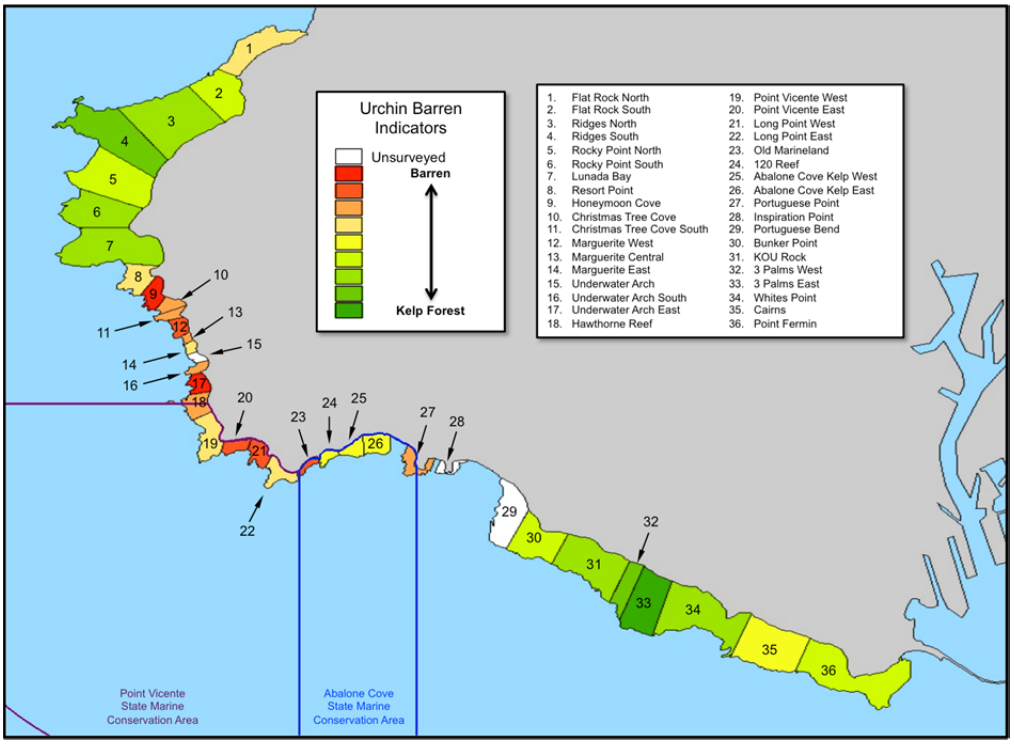

Figure 35. Relative scale of urchin barren indicators scaled from low (green) to high (red) at each of the 36 currently delineated reefs on the Palos Verdes Peninsula.

EMERGING FISHERIES

In addition to the long-established, high-value commercial fisheries of California spiny lobster and red sea urchin (CDFG 2006), there are several emerging commercial fisheries in southern California. Along the Palos Verdes Peninsula, three such species are found with relative frequency: Kellet's whelk (*Kelletia kelletii*), wavy turban snails (*Megastraea undosa*), and giant keyhole limpets (*Megathura crenulata*). There is no apparent discernible pattern for Kellet's whelk distribution at the Palos Verdes Peninsula (Figure 36). This rapidly expanding fishery species (CDFG 2010) has some of the highest relative densities on reefs (Ridges South, Whites Point) that are directly adjacent to some of the lowest relative densities (Ridges North, Cairns). One possible concern with surveying this species is their propensity to bury themselves in sediment, thus making them uncountable. Further, this emerging fishery is difficult to assess through fisheries-dependent means as most landings are a product of bycatch from crab and lobster fishing rather than targeted trapping (CDFG 2010).

Another small but emerging fishery species, the wavy turban snail (Figure 37; CDFG 2001), exhibits a similarly unstructured pattern with regards to density at Palos Verdes Peninsula. Ongoing studies aim to address questions about size-structure with regards to this mainly recreational species prior to expected fisheries growth. A third species of mollusc, the giant keyhole limpet, is of interest due to the potential for biomedical applications using the species hemolymphatic proteins. Though giant keyhole limpet densities are relatively low at most Palos Verdes Peninsula reefs (Figure 38), higher densities are found at several areas within both urchin barren (Marguerite West, Old Marineland) and non-urchin barren areas (Whites Point). Recently, concern has been raised that demand for this species will increase rapidly should the use of keyhole limpet hemocyanin (KLH) continue to show promise as part of cancer vaccines. As with wavy turban snails, ongoing studies aim to address size-structure patterns throughout the Southern California Bight.

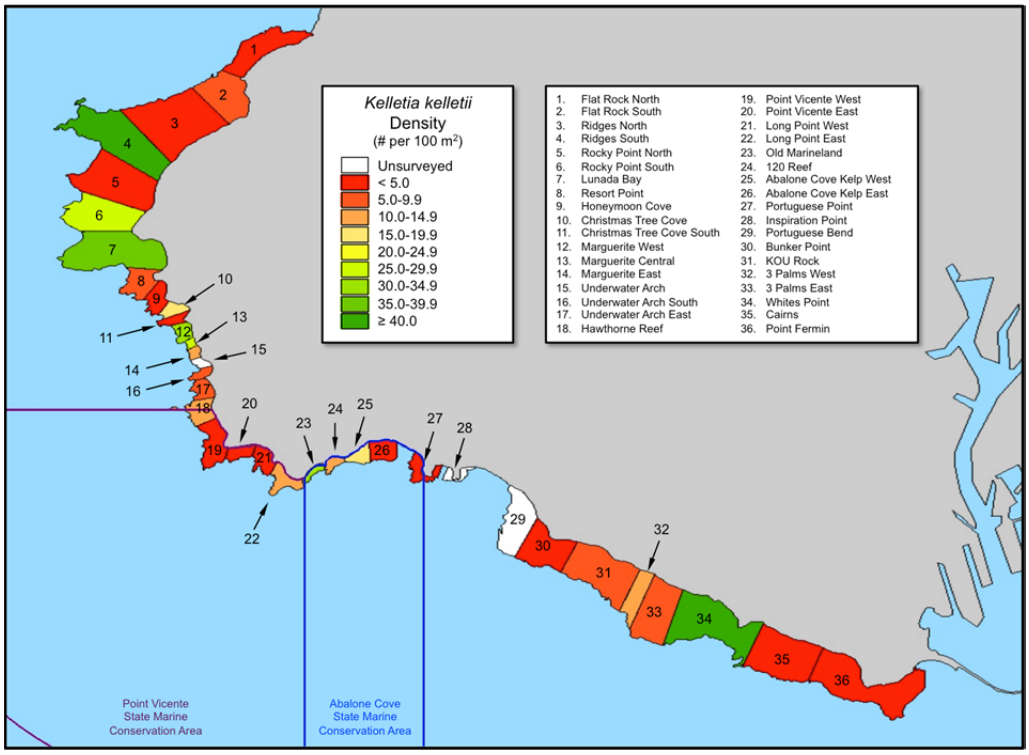

Figure 36. Density of Kellet's whelk (*Kelletia kelletii*; individuals per 100 m^2) scaled from low (red) to high (green) at each of the 36 currently delineated reefs on the Palos Verdes Peninsula.

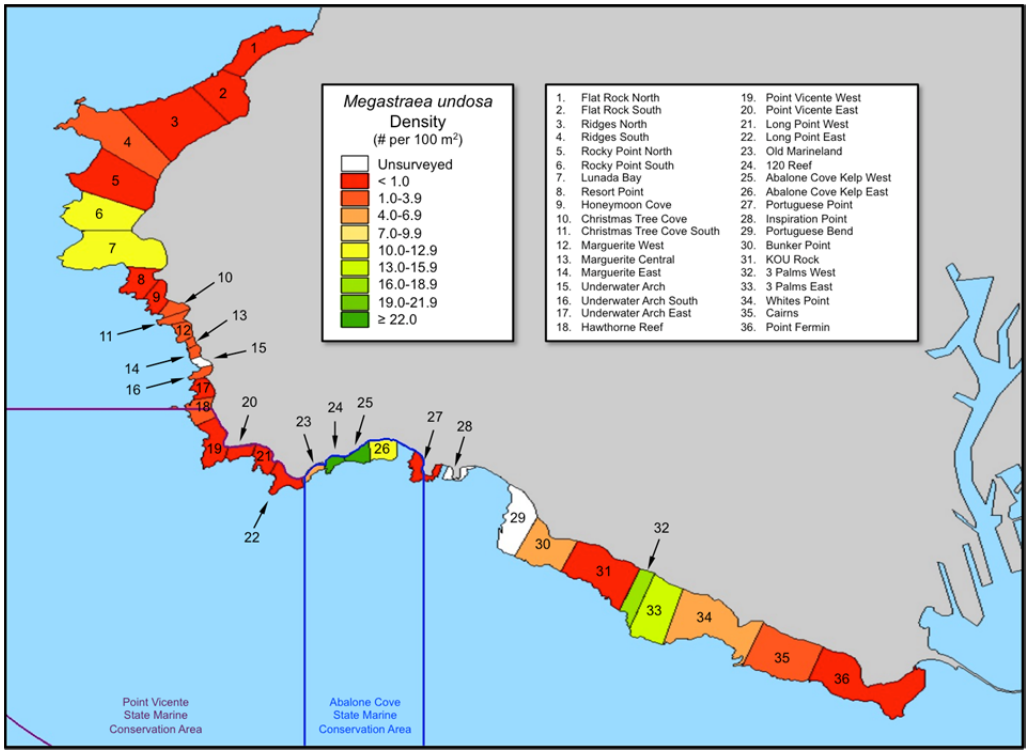

Figure 37. Density of wavy turban snails (*Megastraea undosa*; individuals per 100 m^2) scaled from low (red) to high (green) at each of the 36 currently delineated reefs on the Palos Verdes Peninsula.

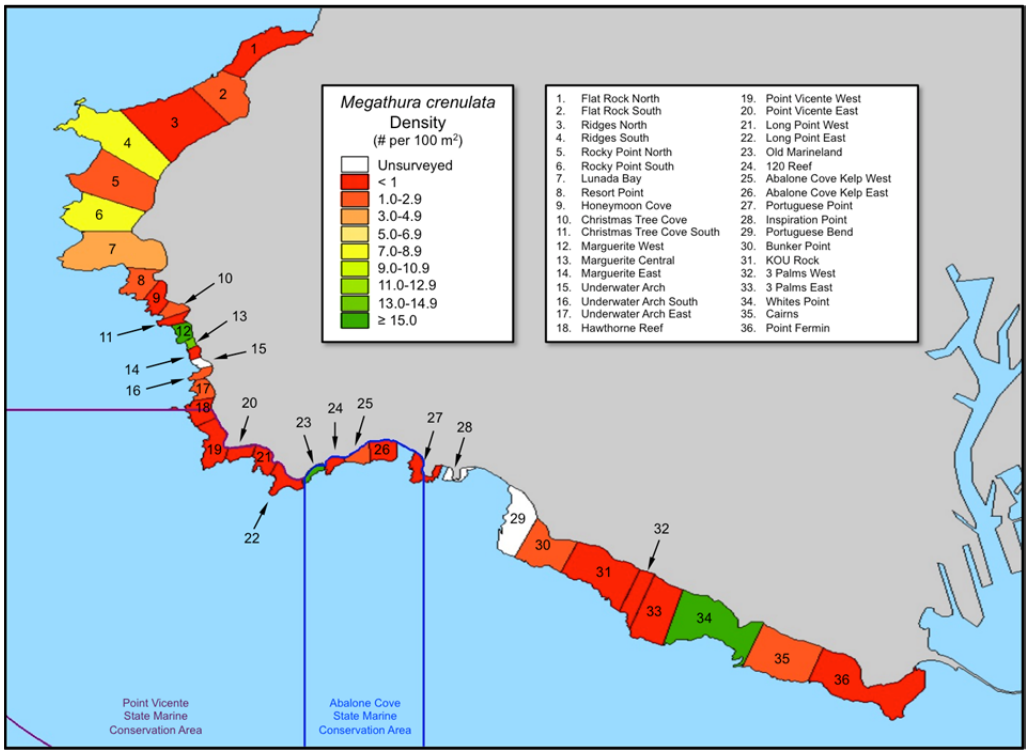

Figure 38. Density of giant keyhole limpets (*Megathura crenulata*; individuals per 100 m^2) scaled from low (red) to high (green) at each of the 36 currently delineated reefs on the Palos Verdes Peninsula.

IMPORTANT FINFISH FISHERIES

Illustrating the complexity of this system, in spite of the sedimentation and turbidity problems from Bunker Point to Whites Point, the biomass and production potential for commercial and recreational fish species of the reefs was remarkably high. The biomass of legal sized (> 30 cm TL) kelp bass (*Paralabrax clathratus*) was higher at nearly every reef from Bunker Point to Point Fermin compared to the rest of the peninsula (Figure 39). California sheephead, *Semicossyphus pulcher*, showed similar patterns, specifically from Bunker Point to 3 Palms West (Figure 40), Lunada Bay, and Point Vicente West. The reason for this increased biomass of fishery species in the area may reflect differential fishing pressure around the peninsula and/or elevated production along this stretch of coastline. Anecdotally, there are regularly observed bait schools and seasonal squid in these areas. Associated with these are commercial seiners and regular pods of dolphins.

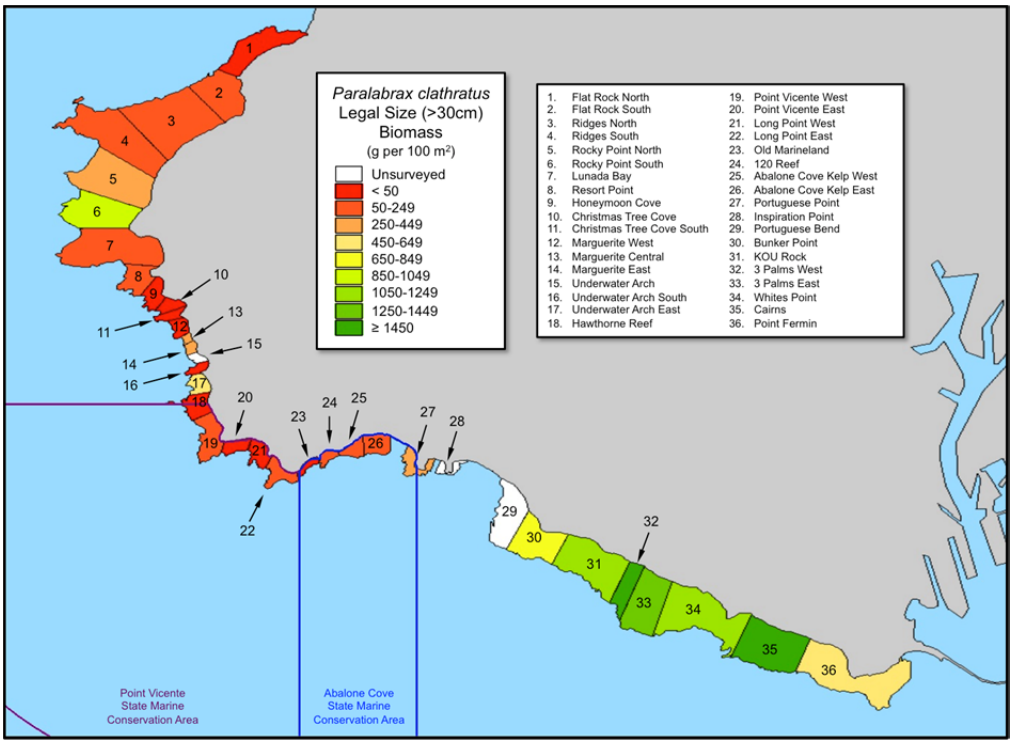

Figure 39. Kelp bass (*Paralabrax clathratus*; legal size only) biomass (grams per 100 m^2) scaled from low (red) to high (green) at each of the 36 currently delineated reefs on the Palos Verdes Peninsula.

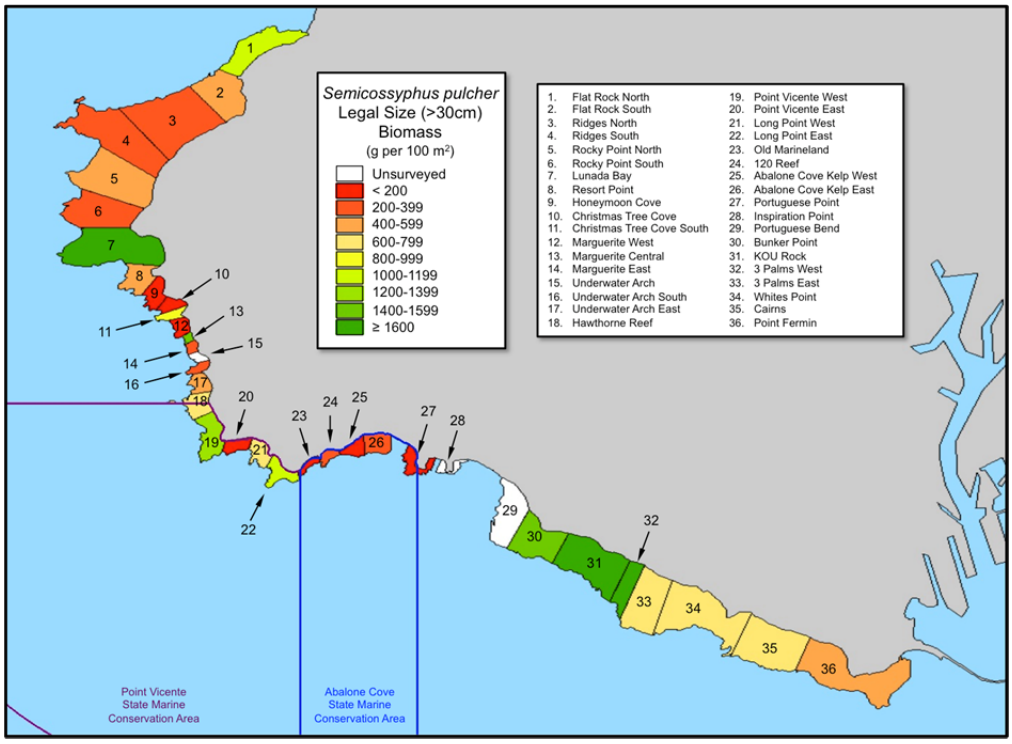

Figure 40. California sheephead (*Semicossyphus pulcher*; legal size only) biomass (grams per 100 m^2) scaled from low (red) to high (green) at each of the 36 currently delineated reefs on the Palos Verdes Peninsula.

POTENTIAL EFFECTS OF RESTORATION AT THE BUNKER POINT RESTORATION AREA

Areas of low-relief buried reef in the Bunker Point Restoration Area (see brown polygons in Figure 3) that can be restored through the addition of high relief quarry rock are located in depths of 13-20 m. Biomass densities of legal sized kelp bass and California sheephead (> 30 cm TL each) at nearby low-relief reefs (3 Palms East, Point Fermin, Whites Point, and Bunker Point) were compared to biomass densities at surrounding reefs with higher relief features at those same depths (Cairns and KOU Rock). Data were $\log_{10}(x+1)$ transformed to meet assumptions of normality and analyzed using a Welch Two-Sample t-test. Legal sized kelp bass (mean high relief = 2033 g/100 m^2, mean low relief = 457 g/100 m^2; t = 2.75, df = 7.18, p = 0.028) and California sheephead biomass (mean high relief = 4073 g/100 m^2, mean low relief = 406 g/100 m^2; t = 3.66, df = 3.97, p = 0.022) were both significantly higher at the reefs with high relief features (Figure 41), illustrating the potential for highly increased availability of targeted species and productivity at restored reefs.

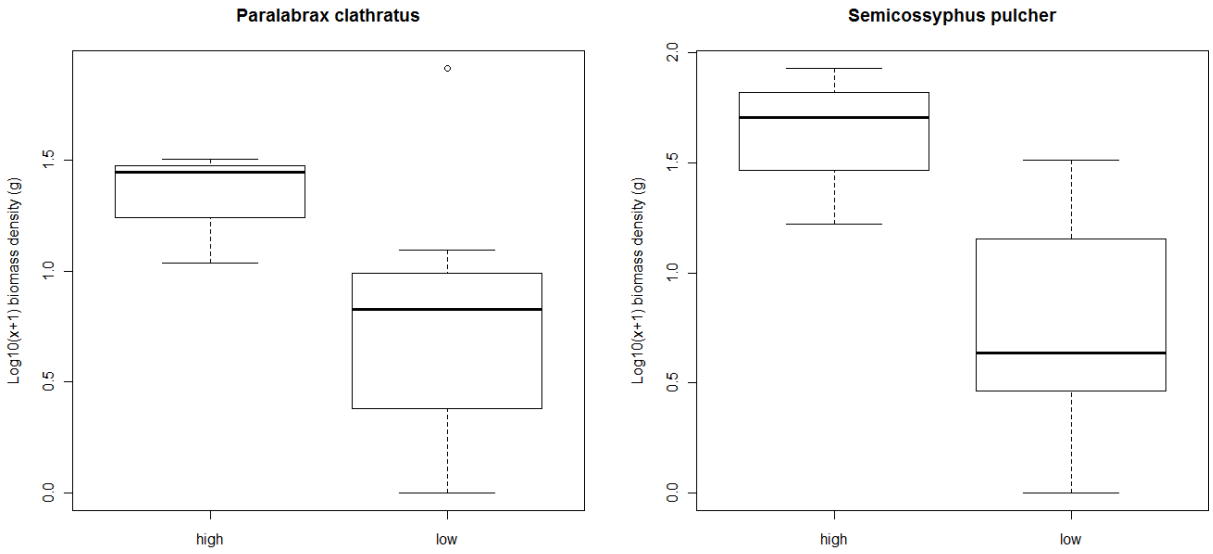

Figure 41. Biomass (grams per 100 m^2) of legal size (> 30 cm) kelp bass (*Paralabrax clathratus*; mean high relief = 2033 g/100 m^2, mean low relief = 457 g/100 m^2; t = 2.75, df = 7.18, p = 0.028) and California sheephead (*Semicossyphus pulcher*; mean high relief = 4073 g/100 m^2, mean low relief = 406 g/100 m^2; t = 3.66, df = 3.97, p = 0.022) at high relief and low relief sites in the 15-25 m depth zones on the Palos Verdes Peninsula.

RECOMMENDATIONS FOR RESTORATION AND FUTURE STUDIES

These analyses show that the reefs within the Bunker Point Restoration Area can potentially hold a tremendous amount of value. Unburied sections of the reefs (typically the shallower areas, < 10 m) have enough biomass of fisheries species to make the reefs among the most productive areas (with respect to those species) at Palos Verdes Peninsula, despite the lack of suitable habitat in the deeper, buried regions. Should high relief features that can act as pinnacle reefs (like KOU Rock) be placed on top of buried areas, biomass densities of catchable kelp bass and California sheephead can potentially increase by as much as 290% and 900%, respectively, at those depths (Figure 41).

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