Palos Verdes Kelp Forest Restoration Project

Project Year 5: July 2017 – June 2018

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Table of Contents

Introduction

Kelp forest ecosystems are iconic and productive features along the coast of California with services that span a wide array of consumptive (e.g., commercial and recreational fishing) and non-consumptive (e.g., tourism, scuba diving and coastal protection) uses. *Macrocystis pyrifera* (giant kelp) forms a 3-dimensional habitat supporting over 700 species of fish, algae, and invertebrates (Graham, 2004). The importance of kelp as a habitat for fish species is enormous; this habitat functions as nursery habitat for newly settled juvenile fishes and has a demonstrated value as a refuge from predation (Dayton, 1985; Steneck et al., 2002). Drift kelp and associated dissolved organic matter provide an energetic resource to populations of species both within and around kelp forests (Harrold and Reed 1985; Duggins et al., 1989; Graham et al., 2007; Tegner and Dayton, 2000). These habitats support fisheries for a number of invertebrates [e.g., *Strongylocentrotus spp.* (sea urchins), *Panulirus interruptus* (California spiny lobster), *Parastichopus spp.* (sea cucumbers)] and finfish [e.g., *Paralabrax clathratus* (kelp bass), *Semicossyphus pulcher* (California sheephead)], in addition to giant kelp being harvested itself for a variety of human uses (Tegner and Dayton, 2000). Through both fishing activities and non-consumptive uses, California's ocean-related activities support the state economy by bringing in 40+ billion dollars a year in revenue (Kildow and Colgan, 2005) and giant kelp is a critical and iconic feature of this system.

California kelp forests have been severely depleted by human activity, mainly overfishing, which has caused several ecological shifts within the habitat, primarily attributed to the loss of key predator species (Dayton et al., 1998; Tegner and Dayton, 2000). In a balanced ecosystem, sea urchin consumption of kelp is limited primarily by predation on urchins (Dayton, 1985; Edwards, 2004). Three species historically controlled sea urchin populations in the Southern California Bight (SCB): *Enhydra lutris nereis* (southern sea otter), California spiny lobster and California sheephead. The Southern Sea Otter was locally extirpated in the 1850's (Jackson, 2001). Spiny lobster *and* sheephead are under significant fishing pressure, which simultaneously reduces the size and number of individuals able to successfully prey on sea urchins (Cowen, 1983; Lafferty, 2004). Additionally, thriving populations of abalone once served as competitors to urchins (Tegner and Dayton, 2000). Currently two species are now Federally Endangered (Black Abalone, *Haliotis cracherodii*; and White Abalone, *H. sorenseni*) and two more are Federal Species of Concern (Pink Abalone, *H. corrugata*; and Green Abalone, *H. fulgens*) (CDFW, 2005). Thus, both urchin predators and competitors have been chronically depleted throughout the SCB.

Predation is one of the most significant and persistent causes of kelp forest loss in southern California (Steneck et al., 2002). Sea urchins, typically *Strongylocentrotus purpuratus* (purple sea urchins) and *Strongylocentrotus franciscanus* (red sea urchins), will aggregate in fronts and clear expanses of kelp forest if left unchecked, leaving the reef devoid of standing macroalgae (Harrold and Reed 1985; Graham 2004). These urchin barrens are observed to support far fewer species and a corresponding decrease in biomass (Bradley and Bradley, 1993; Graham, 2004). This reduction in ecosystem structure and function leads to spatially and temporally unstable kelp forests and reduces production. Though Graham (2004) described urchin barrens in the Channel Islands National Park (CINP) as short-lived and localized, they have persisted for more than 30 years in the northeastern and northwestern Atlantic along the border of Norway and Russia (Norderhaug and Christie, 2009). Similar observations have been made in the northeastern Pacific from Alaska to California (Jackson, 2001; Smith et al., 2004; Steneck et al., 2002). A survey spanning the SCB in 2008 determined that approximately 30% of the reefs contain urchin barrens (Pondella et al., 2011), suggesting that they are a widespread phenomenon in our region.

Project Background

This project developed from an interest in the protection and preservation of giant kelp communities in the Southern California Bight. Roughly one hundred years of data exists on the extent of giant kelp canopy off of the Palos Verdes Peninsula. These data describe a loss over this timeframe of approximately 80% (Figure 1).

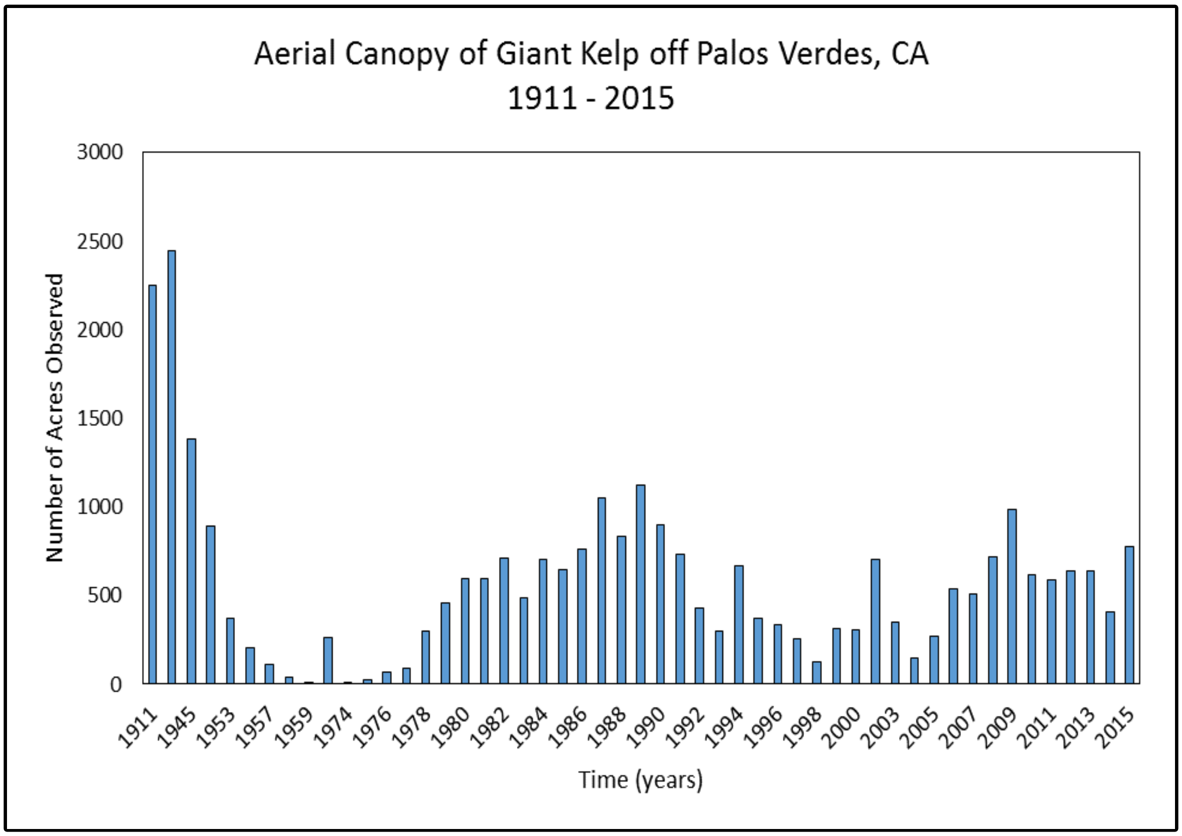


Figure 1. Status of the Kelp Beds 2015, Ventura Los Angeles, Orange, and San Diego Counties. Central Region Kelp Survey Consortium and Region Nine Kelp Survey Consortium, July 2016. Prepared by: MBC Applied Environmental Sciences. Costa Mesa, CA 92626

Subtidal observations based upon mapping efforts conducted by the Santa Monica Baykeeper in 2010 identified large expanses of nearshore rocky reef that were dominated by high densities of purple and red sea urchins. In total, 61.5 hectares were described to exist in an urchin barren state. Subsequent SCUBA based community monitoring has further qualified these barrens as areas featuring low diversity and productivity relative to areas of the Palos Verdes Peninsula supporting temporally and spatially stable giant kelp forests. Additional study has defined the status of the urchins themselves in these barrens of being in poor physical condition with low gonadosomatic indices relative to urchins in neighboring kelp forests (Claisse et al. 2013).

The persistence of these urchin barrens, especially in the context of favorable conditions for giant kelp recruitment and development in southern California, argues for the active restoration of these barren reefs.

Kelp forests in Santa Monica Bay, adjacent to the largest urban area on the west coast of the United States, are directly affected by anthropogenic impacts associated with urban development and population increase. These include an extensive and diverse set of stressors (e.g., commercial and recreational fishing, sedimentation, urban runoff, and pollution) (Stull et al. 1987; Dojiri et al. 2003; Schiff 2003; Love 2006; Pondella 2009; Foster and Schiel 2010; Sikich and James 2010; Erisman et al. 2011) that combine to further contribute to the decline of productive, stable kelp habitat along this important stretch of coastline. Given the complexity of factors impacting these urban rocky reefs, conservation and resource management efforts demand an equally diverse and proactive suite of strategies. One such endeavor is kelp restoration as conducted by The Bay Foundation, and the partners of the project which include, commercial sea urchin harvesters, academic researchers, federal and state biologists, resource managers, and public aquaria.

To enable the recovery of historical kelp forests in Santa Monica Bay, the "Kelp Project" has engaged in sea urchin suppression to reduce the density of urchins on shallow rocky reefs since 1997, these early efforts (1997-2009) were supported by the Santa Monica Baykeeper. The Kelp Project has demonstrated that reducing urchin density from as high as 100 sea urchins per square meter to < 2 sea urchins per square meter enabled the natural development of giant kelp and other macroalgae at restoration areas in Malibu and Palos Verdes (Figures 2, 3). Restoration areas off of Escondido Beach, Malibu have proven resilient to disturbances for over 10 years. After reaching restoration targets of < 2 sea urchins per square meter and > 1 giant kelp holdfast per 10 square meters the restoration measures were stopped in 2004 (Ford and Meux 2010). The kelp in this area has matured and recovered from many disturbances of note, namely large-scale red tide events in 2005 and 2006 and a 200-year storm event in the same period. This resilience to disturbance was a key test for the permanence of the restoration effort. Surveys performed in the restoration areas off Escondido Beach in 2008 have quantified large kelp plants in high densities (Pondella et al. 2011). Kelp restoration efforts are now focused on 61.5 hectares of existing urchin barrens which have been identified along the Palos Verdes Peninsula (Figure 4).

Kelp Restoration Goals

The purpose of the project is to reduce the density of purple sea urchins to two per square meter within the boundaries of sea urchin barrens off the Palos Verdes Peninsula. This will allow for the recruitment and development of giant kelp and other species of macroalgae. This project will reduce sea urchin grazing pressure to restore biogenic habitat to rocky reefs that historically supported kelp forests. This will increase the spatial and temporal stability, biomass and production associated with the kelp forest/rocky reefs on the Palos Verdes Peninsula.

In addition, an initial focus of the kelp project has been to generate a more inclusive community engaged in the management of this highly productive and highly valued ecosystem. The red sea urchin fishery is one of the most important commercial fisheries in the State of California. In 2015, red urchin landings ranked 4th by weight (8.1 million lbs.) and 7th in value (6.8 million US Dollars) (CDFW 2016). The gonads of both male and female red sea urchins, known as "uni" in Japanese, are the object of the fishery. The majority of effort for this fishery is concentrated in southern California with Santa Barbara, Oxnard-Ventura, and Los Angeles ports having the most landings in the region (CDFW 2016). Commercial sea urchin harvesters have been a central part of this project since its inception. Several commercial sea urchin harvesters have retained contracts with The Bay Foundation to cull the excess purple sea urchins from the restoration sites. This collaboration between scientists, project management, and the fishermen has been very productive and efficient. The direct results of the restoration work impact the rocky reef-kelp forest ecosystem and have the ability to increase the value of the reefs for the commercial red sea urchin fishery. The disparate and complimentary expertise of the project partners in this effort has been central to its success. Thus, the project directly increases the ecological structure and function of the rocky reefs off of Palos Verdes while creating a more comprehensive Santa Monica Bay community in restoring the kelp forests off our coast.

Figure 2. Long Point pre-restoration in 2005.

Figure 3. Long Point post-restoration in 2008.

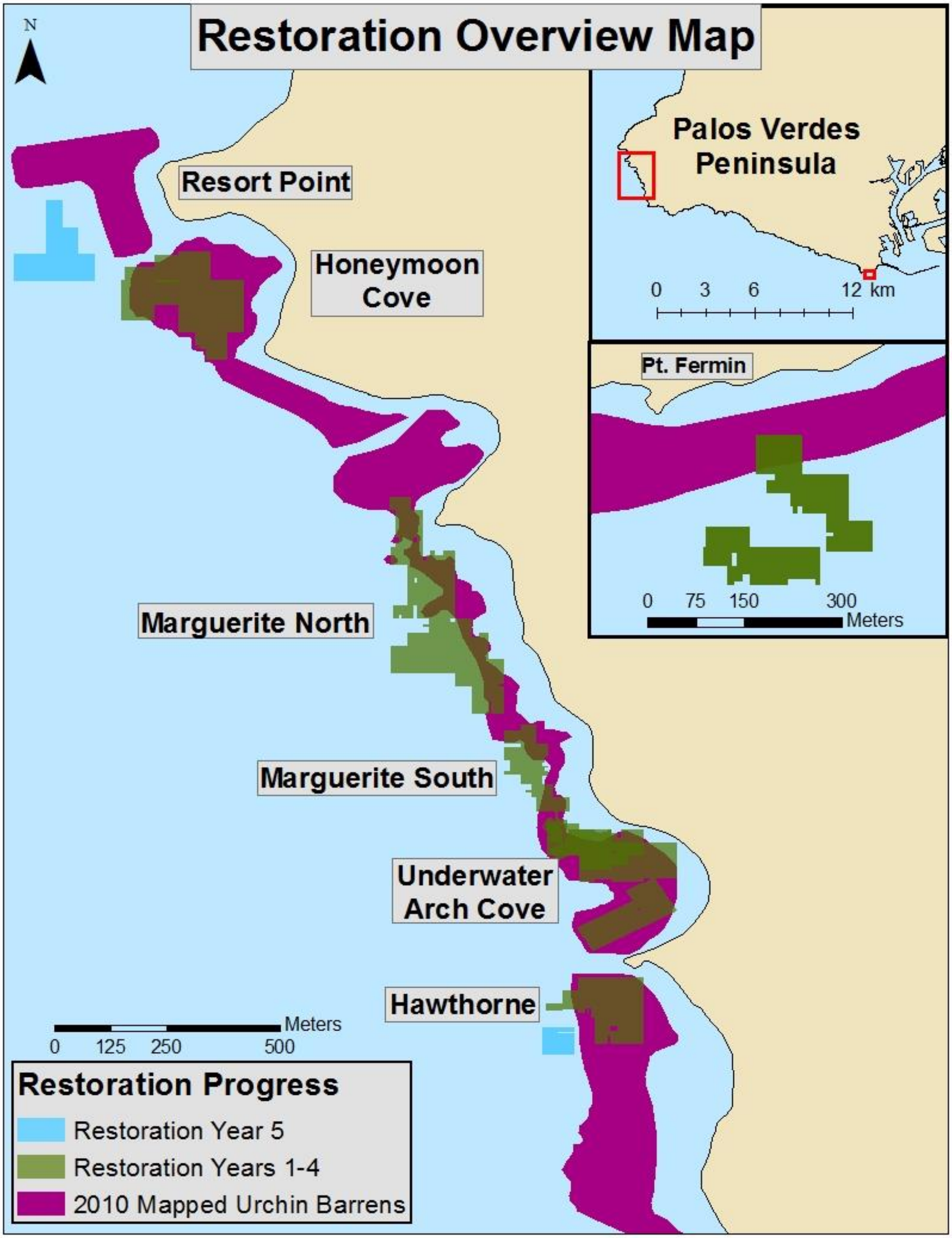


Figure 4. Urchin barrens as mapped in 2010 and areas restored, representing a possible expansion and/or shift of urchin barrens. The locations of restoration areas completed in years 1 through 4 are in green, areas restored in year 5 are blue.

Methods

Description of Restoration, Control, and Reference Sites
All of the project restoration, reference, and control sites are located off the Palos Verdes Peninsula, Los Angeles County, California. Table 1 below shows all potential restoration sites along with the area in hectares, initially described in 2010 surveys, and representative central GPS coordinate for each.

Table 1. Area and GPS coordinates for restoration, reference and control sites.

Restoration Site Name	Area (Hectares)	Perimeter (Meters)	Centroid (Decimal Degrees)
Honeymoon Cove	4.07	1,509	33.764, -118.423
Christmas Tree Cove	4.09	2,264	33.761, -118.419
Marguerite	5.19	2,522	33.757, -118.418
Underwater Arch	5.36	2,183	33.752, -118.415
Hawthorne	8.96	1,789	33.747, -118.414
Portuguese Point	1.73	1,604	33.737, -118.376
Inspiration Point	2.57	1,965	33.736, -118.368
Whites Point	3.38	2,395	33.713, -118.315
Point Fermin	4.37	3,367	33.704, -118.291

The following sites were identified as urchin barrens in 2010 and are located within the Marine Protected Areas surrounding Point Vicente. Thus far these sites have only been monitored and will continue to be monitored as part of the experimental design of the overall project. Three of these sites received restoration work in the past, pre-MPA, (2005-2011) i.e., Kaplan Cove, Long Point and Old Marineland. Restoration work was conducted on a limited basis inside the MPA in the early part of 2012. Furtherance of restoration efforts within the MPAs might yield benefits to the goals of the MPAs generally and specifically to the MPA cluster on the Palos Verdes Peninsula.

Site Name	Area (Hectares)	Perimeter (Meters)	Centroid (Decimal Degrees)
Point Vicente East	4.8	2,812	33.740, -118.406
Kaplan Cove	2.3	1,115	33.737, -118.401
Long Point	0.82	1,240	33.736, -118.398
Old Marineland	1.2	744	33.737, -118.395
120 Reef	1.74	1,226	33.738, -118.392
Abalone Cove Kelp	9.1	3,397	33.740, -118.385
Reference Site Name	**Area (Hectares)**	**Perimeter (Meters)**	**Centroid (Decimal Degrees)**
Point Vicente West	-	-	33.740, -118.412
Rocky Point North	-	-	33.779. -118.426
Control Site Name			
Abalone Cove West	9.10	3,397	33.740, -118.385
Marguerite Central	5.19	2,522	33.757, -118.418

Pre-Restoration Monitoring

Restoration sites have been established in 5 sites off Palos Verdes: Honeymoon Cove, Marguerite, Underwater Arch Cove, Hawthorne and Point Fermin. Pre-restoration monitoring is conducted on all sites according to CDFW standards stipulated in the terms of the scientific collecting permit (SCP). Sites are divided into 30 m by 30 m blocks each comprised of 5 transects (2 m by 30 m swath) monitored by divers. Each transect is divided into 10 m long segments to estimate the density of purple urchins, red urchins, giant kelp and a characterization of the substrate. In certain instances these blocks, or the individual transects comprising them are truncated to fit the natural topography. This fine scale and spatially comprehensive methodology allows for greater resolution of inter-block variability and has been beneficial to the adaptive management of restoration teams.

Post-Restoration Monitoring

Post-restoration monitoring is conducted within 1-2 weeks after urchin suppression by the restoration teams. This work is performed by The Bay Foundation staff to ensure that restoration work is achieving performance standards. The standards are 1) the initial reduction of purple sea urchins to a density of 2 per square meter and 2) that this is being applied in a comprehensive manner sweeping through an area and not leaving pockets of high urchin densities. All restoration areas are surveyed pre and post restoration actions to describe the status of the restoration areas and entered into a georeferenced database. Post-monitoring can be completed more quickly than pre-monitoring as only the density of urchins are counted. All 15 (30 m x 2 m) transects, covering 100% area of the 30 m x 30 m block are surveyed during post-monitoring to ensure that no pockets of high density urchins are left in the site. All restoration sites are re-surveyed, by roaming over the area, on a monthly to quarterly basis to ensure that purple urchin densities remain at two sea urchins per square meter and to observe the response of the biota to the restoration actions.

Response Monitoring (September 2017 through August 2018)

This monitoring focuses on responses of the natural community to restoration activities. The focus of this effort is subtidal utilizing an adapted Cooperative Research and Assessment of Nearshore Ecosystems (CRANE) methodology led by the Vantuna Research Group. These data provide values relating to production, species richness, and biomass. In addition, an adaptation of the Core and Biodiversity protocols used throughout the west coast of North America as part of the MARINe network will be applied to the intertidal and shallow subtidal areas addressed in the scope of work (led by the Vantuna Research Group). This method identifies trends in sessile and motile organisms and coverage in the intertidal zone. Lastly, the application of a gonadosomatic index generated in 2011 for red and purple sea urchins specific to the Palos Verdes Peninsula is applied to gather data on secondary production values for these species that play a pivotal role in the ecology of the kelp forests and support one of California’s largest nearshore fisheries (Claisse et al. 2013). Urchins were collected and dissected for this report in fall 2015.

Community Analyses

As part of the quantitative characterization of the community structure of the reefs, we examined patterns in the overall kelp forest community using UPC (percent cover) data as well as the fish and swath (benthic macroinvertebrates and kelps) data combined. Density metrics were square root transformed (fish and swath data), while percent-cover metrics (UPC benthic cover data) were arcsine square root transformed. Two-dimensional, non-metric multidimensional scaling (nMDS) was used to examine patterns among kelp forest communities.

Table 2. Response monitoring (CRANE) metadata. See Appendix B for all CRANE data tables.

	Survey Dates						Spring	Summer		
Designation	**Site**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2016**	**2017**	**2018**
Control	Abalone Cove Kelp West	8/31/2011	6/22/2012	6/21/2013	7/25/2014	9/2/2015	2/10/2016	6/29/2016	7/21/2017	7/18/2018
	Christmas Tree Cove	2/7/2011	2/29/2012	5/10/2013	1/15/2015	11/13/2015	–	7/26/2016	7/25/2017	7/18/2018
	Hawthorne Control	5/13/2011	7/6/2012	6/18/2013	6/19/2014	9/23/2015	–	9/16/2016	9/15/2017	6/22/2018
Restoration	Underwater Arch Cove	2/7/2011	6/12/2012	6/13/2013	7/11/2014	9/23/2015	2/10/2016	6/22/2016	7/18/2017	6/22/2018
	Honeymoon Cove	1/28/2011	3/13/2012	5/31/2013	7/2/2014	8/19/2015	2/10/2016	6/22/2016	7/18/2017	6/22/2018
	Hawthorne Restoration	5/3/2011	6/12/2012	6/11/2013	6/19/2014	10/7/2015	–	9/30/2016	8/25/2017	7/11/2018
Reference	Ridges North	8/12/2011	7/17/2012	4/26/2013	10/29/2014	9/11/2015	–	6/3/2016	6/30/2017	7/11/2018
	Rocky Point North	6/24/2011	6/29/2012	7/2/2013	7/11/2014	9/25/2015	2/10/2016	6/10/2016	6/29/2017	7/6/2018
	Point Vicente West	10/12/2011	8/10/2012	4/24/2013	4/18/2014	9/23/2015	2/10/2016	6/22/2016	7/25/2017	7/18/2018
	Bottom Temperature (ºC)						Spring	Summer		
Designation	**Site**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2016**	**2017**	**2018**
Control	Abalone Cove Kelp West	18.0	13.0	18.0	16.9	18.8	13.9	17.5	18.0	18.7
	Christmas Tree Cove	15.0	11.1	17.0	15.5	17.0	–	18.0	17.5	19.3
	Hawthorne Control	15.0	18.0	16.5	17.0	21.5	–	19.0	18.0	18.0
Restoration	Underwater Arch Cove	15.0	19.0	15.0	15.8	21.5	13.9	15.0	18.5	18.0
	Honeymoon Cove	15.0	11.5	18.0	16.5	18.8	13.9	16.2	20.3	18.3
	Hawthorne Restoration	14.4	19.0	17.0	17.0	21.0	–	18.0	16.8	20.6
Reference	Ridges North	18.0	16.6	13.7	19.8	21.0	–	15.0	17.9	22.0
	Rocky Point North	18.0	15.0	18.0	21.0	21.0	13.9	14.3	16.8	19.5
	Point Vicente West	11.0	19.0	13.2	13.5	21.0	13.9	15.2	19.7	19.5
	Coordinates									
Designation	**Site**	**Latitude**	**Longitude**							
Control	Abalone Cove Kelp West	33.73940	-118.38809							
	Christmas Tree Cove	33.76150	-118.42014							
	Hawthorne Control	33.74737	-118.41526							
Restoration	Underwater Arch Cove	33.75291	-118.41499							
	Honeymoon Cove	30.76459	-118.42406							
	Hawthorne Restoration	33.75068	-118.41558							
Reference	Ridges North	33.78697	-118.42065							
	Rocky Point North	33.77966	-118.42739							
	Point Vicente West	33.74073	-118.41283							

Timeline and Effort of Restoration

Restoration and monitoring activities have been conducted in restoration, control and reference sites since July 2013. Urchin suppression efforts have expanded each year to encompass two coves (Underwater Arch and Honeymoon), and two open shore areas (Marguerite, Resort Point, and Hawthorne). These areas are located somewhat centrally on the Palos Verdes Peninsula. The sites are nearly contiguous and share similarities in ocean exposure. An additional site, Point Fermin, was started to the south and east of these other locales. Point Fermin is roughly the south east terminus of the Palos Verdes Peninsula. Further south and east of Point Fermin is Cabrillo outer beach and the break wall for the Ports of Los Angeles and Long Beach. The progression of restoration activities by expanse restored by area and by year is contained in Table 3. Table 4 provides values for the hours of effort spent SCUBA diving by the project to achieve these results.

All of the field work involved in this project is subject to sea state, oceanic climate and weather. Remaining work in all of the sites listed in Table 4 is projected for this coming operational year, July 1, 2018 through June 30, 2019. Much of the area yet to be monitored and restored can be very challenging i.e., comprised of high relief and/or shallow subtidal habitat. The windows for safe and effective operations in these areas are few in a typical year in southern California. The atypical El Nino conditions that persisted throughout 2015-2016 provided few opportunities for restoration or monitoring activities to be conducted safely and with appropriate accuracy. During the winter of 2016-2017 El Niño conditions relaxed, a resurgence of juvenile purple urchins emerged in new areas off the peninsula, and the pace of our work increased.

Table 3. Total effort diving towards project goals July 1, 2013 through June 30, 2018.

Effort (dive hours)	Monitoring	Restoration
The Bay Foundation	1572.82	71.93
Commercial Sea Urchin Harvesters	-	5553.13
LA Waterkeeper	133.37	1030.86
Total Dive Hours	1706.19	6655.92

Table 4. Restoration areas targeted for July 1, 2018 through June 30, 2019. During this reporting period (Year 5) White Point has been partially pre-monitored. However, restoration effort has not started at White Point. During Year 6 of the project Resort Point and White Point will be targeted for restoration.

Site Name	**Total Area Acres**	**Start Date**	**Area Cleared (Acres)**	**Status**	**Centroid**
Resort Point/Honeymoon	9.40	Sept 2017	4.00	In progress	33.764, -118.315
White Point	8.35	May 2018	0.00	In progress	33.713, -118.315

Results

Urchin Densities Pre and Post Restoration

During 2018, monitoring and restoration activities occurred in 3 sites; Hawthorne, Resort Point and White Point (Figures 5, 6, and 7 respectively). The following maps display the estimated purple urchin densities before restoration activities [within each 10 m segment]. Density data from previous years are transparent and gray areas represent blocks currently in progress and will be cleared in project year 6. Figures 8 and 9 display the estimated purple urchin densities after urchin suppression and restoration within each 10m segment for Marguerite, Hawthorne and Point Fermin. Urchin density maps for all sites are included in Appendix A.

Table 5. Restoration progress by site years 1 through 5.

Site Name	Area Cleared (Acres) Year 1 July 2013 - June 2014	Area Cleared (Acres) Year 2 July 2014 - June 2015	Area Cleared (Acres) Year 3 July 2015 - June 2016	Area Cleared (Acres) Year 4 July 2016 - June 2017	Area Cleared (Acres) Year 5 July 2017- June 2018	Total Area (acres)
Honeymoon Cove	6.77	1.56	0	0	0	**8.33**
Underwater Arch Cove	5.91	2.46	0	0	0	**8.37**
Marguerite	0	6.75	2.04	5.1	0	**13.89**
Hawthorne	0	4.29	0	0	0.89	**5.18**
Point Fermin	0	0	3.93	1.35	0	**5.28**
Resort Point	0	0	0	0	4.00	**4.00**
Total Area	**12.68**	**15.06**	**5.97**	**6.45**	**4.89**	**45.05**

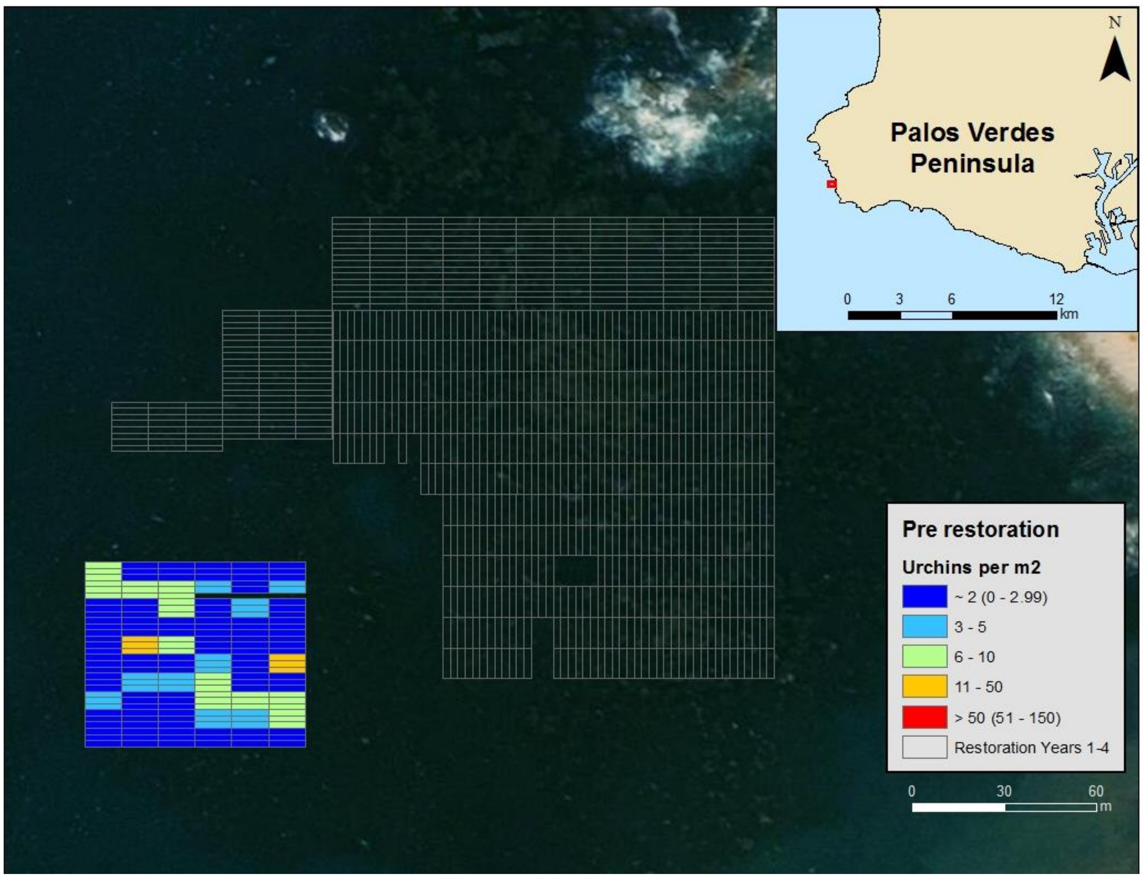


Figure 5. Density of *S. purpuratus* (individuals per square meter) pre-restoration in Hawthorne, Palos Verdes, California. Red square in the inset map indicates the where the restoration area is off Palos Verdes. See Appendix A for larger map images.

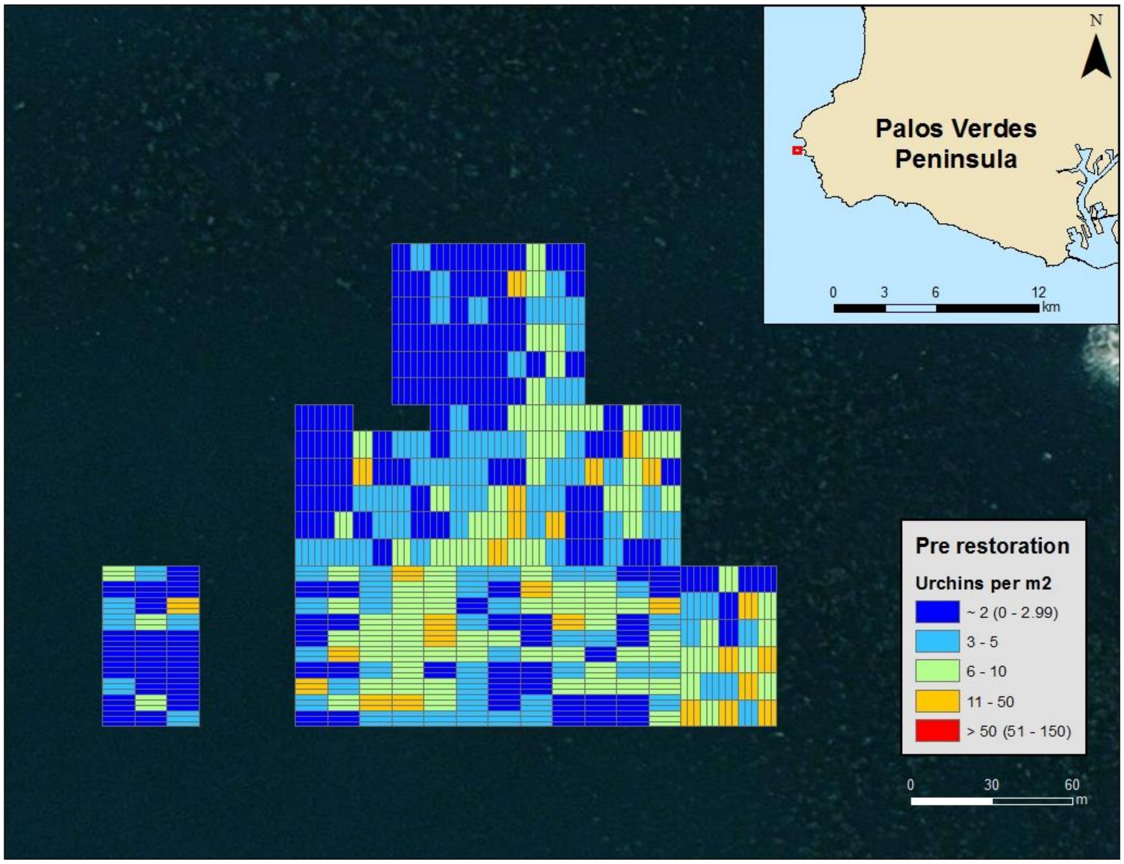


Figure 6. Density of *S. purpuratus* (individuals per square meter) pre-restoration in Resort Point, Palos Verdes, California. Red square in the inset map indicates the where the restoration area is off Palos Verdes.

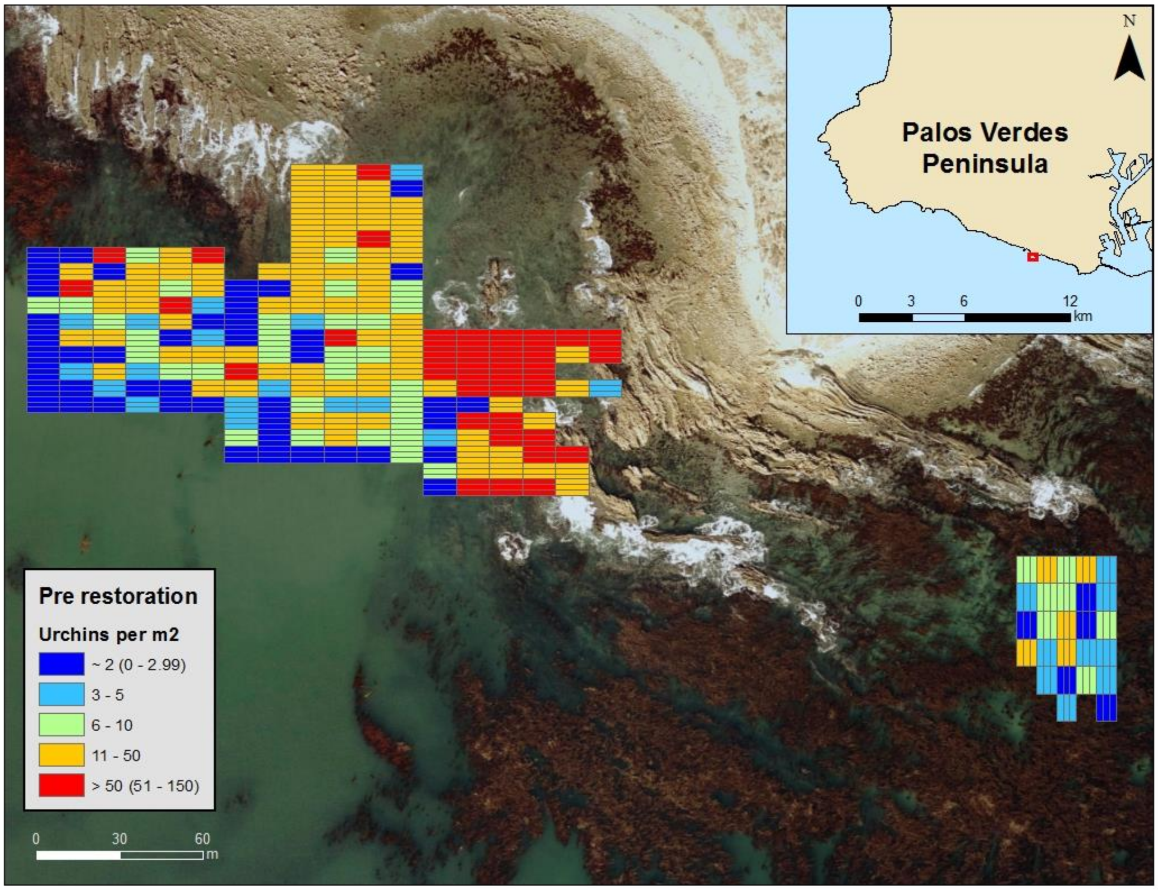


Figure 7. Density of *S. purpuratus* (individuals per square meter) pre-restoration in White Point, Palos Verdes, California. Red square in the inset map indicates the where the restoration area is off Palos Verdes. Average purple urchin density for this site is 67.8 urchins per m^2.

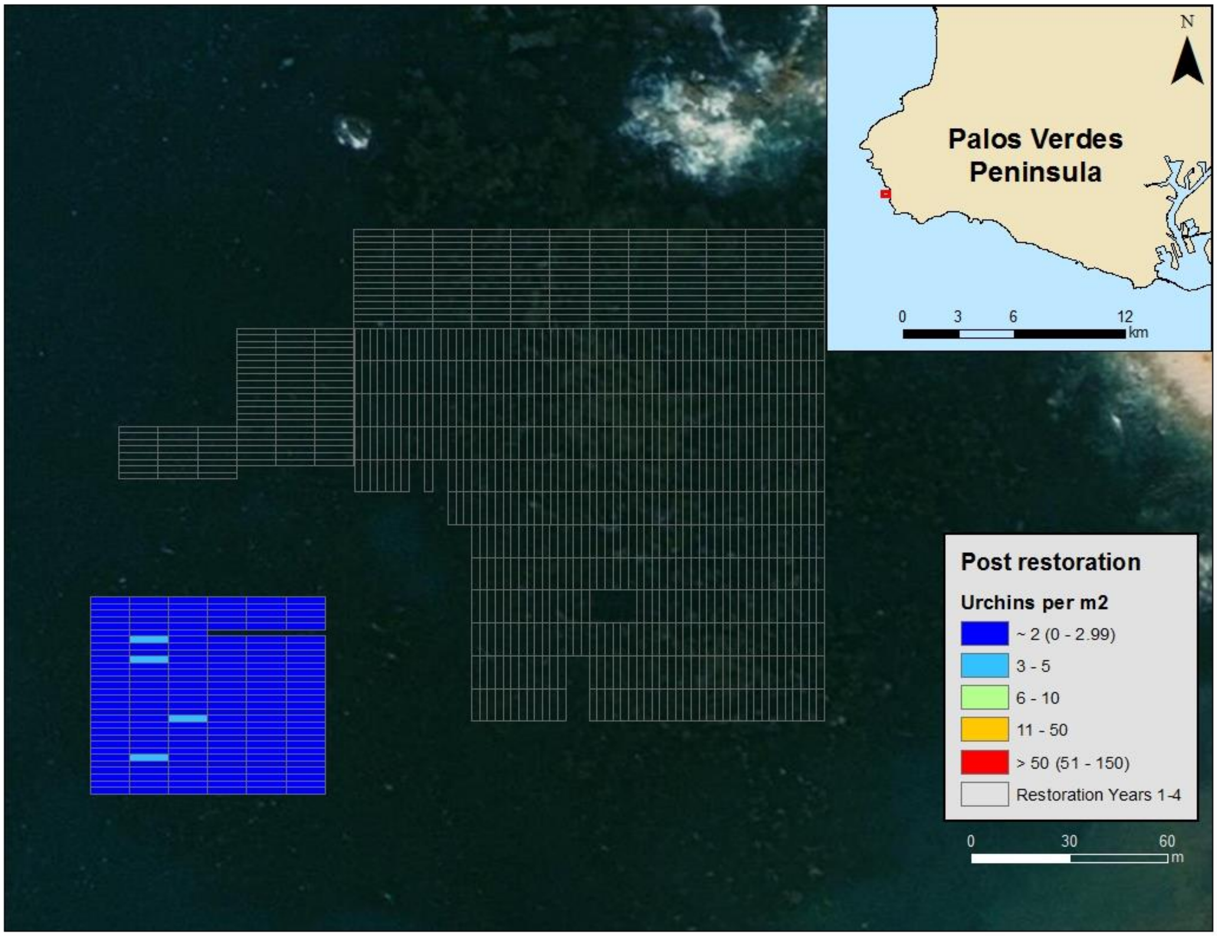


Figure 8. Density of *S. purpuratus* (individuals per square meter) post-restoration in Hawthorne, Palos Verdes, California. The transparent blocks represent areas restored in previous years. Red square in the inset map indicates the where the restoration area is off Palos Verdes. See Appendix A for larger map images.

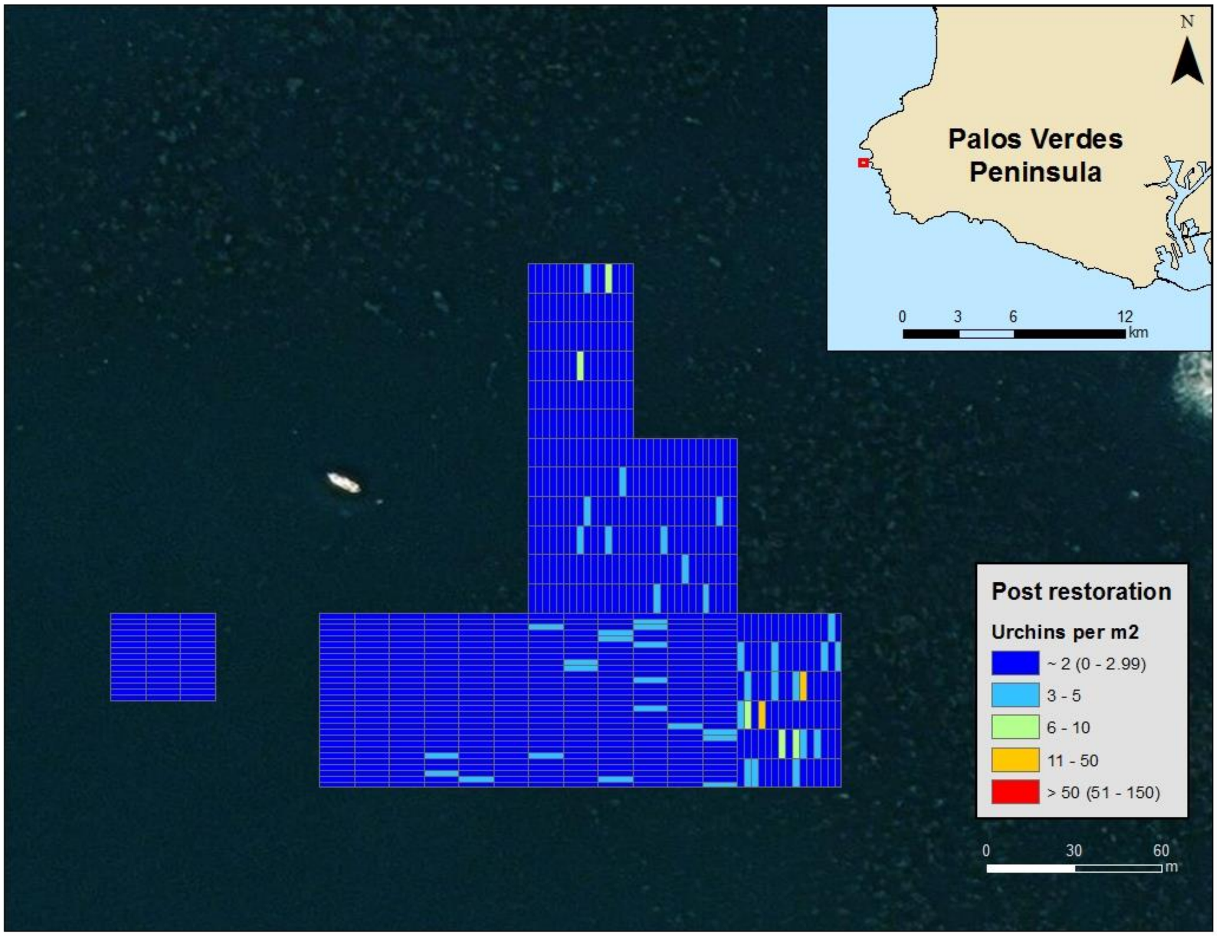


Figure 9. Density of *S. purpuratus* (individuals per square meter) post-restoration in Resort Point, Palos Verdes, California. Red square in the inset map indicates the where the restoration area is off Palos Verdes.

The estimated total number of purple urchins culled within restoration sites is 3,602,051 reducing the overall average density from 17.74/m^2 to 1.35/m^2 (Table 6). Purple urchin density in some sites are less than the target density of 2/m^2. These low values may in part be attributed to habitat patchiness, physical differences among sites, and sediment. In Addition, visibility and surge affect the accuracy of these counts, transects monitored during better conditions were found to be closer to the targeted 2/m^2. Table 6 below shows the estimated number of urchins removed from each site by year.

Table 6. Estimated quantity of purple urchins *(S. purpuratus)* culled per restoration site (July 1, 2013 – June 30, 2018).

Site	Year 1	Year 2	Year 3	Year 4	Year 5	Total by Site
Underwater Arch Cove	855,804	347,346		44,305		1,247,455
Honeymoon Cove	1,133,975	201,774				1,335,749
Hawthorne Cove		196,857			9,006	205,863
Marguerite Cove		443,018	75,258	39,095		557,371
Point Fermin			159,605	35,166		194,771
Resort Point					60,842	60,842
	1,989,779	1,188,995	234,863	118,566	69,848	3,602,051

Gonadosomatic indices of red and purple urchins

A total of 33 red and 318 purple urchins were collected for the gonadosomatic study from 2017 (Table 7). All urchins test diameter was measured to the nearest mm (Figures 10 and 12) and weighed to the nearest .01 gram. In addition, gonads were carefully removed from all individuals and weighed to the nearest .01 gram. Urchins were collected from two existing kelp/reference site and three restoration sites on October 24, 2017 to compare gonad indices between site types. Additional attempts to collect more urchins in November and December were made, but unfavorable weather conditions prevented collections on those planned days. Only ten red sea urchins were collected at our kelp/reference sites, preventing the comparison of the gonad weight to test diameter relationship between kelp/reference sites and restoration. All urchins collected at White Point were within a kelp forest, thus the designation of kelp/reference site for these urchins.

Table 7. Urchin collections for 2017 dissections. Collection occurred on October 24, 2017.

Site Type	Location	Reds	Purples
Kelp/Reference	Lunada Bay	2	110
Kelp/Reference	White Point	8	71
Restoration	Honeymoon Cove - R4	6	44
Restoration	Underwater Arch Cove - W1	9	25
Restoration	Marguerite - T8	8	68

For red sea urchins both the diameter of the test (t = 1.85, p = 0.074) and the gonadosomatic index (t = 1.88, p = 0.074) was not significantly different between the kelp reference and restoration sites (Figures 10 and 11). Gonadosomatic index is the ratio of the weight of the gonad to the overall weight of the animal. Only ten red sea urchins were collected at our kelp/reference sites, preventing the comparison of the gonad weight to test diameter relationship between kelp/reference sites and restoration. Also due to low numbers of red sea urchins found at all sites, there were no comparisons made among sites.

For purple sea urchins both the diameter of the test ($F_{4,313}$=16.17, p <0.001) and the gonadosomatic index ($F_{4,313}$=6.41, p <0.001) were significantly different among the kelp reference and restoration sites (Figures 12, 13, & 14). A posthoc Tukey's test revealed that the kelp reference site and most of the restoration sites were relatively similar to each other. The restoration site Underwater Arch Cove – W1 had the lowest gonadosomatic index compared to the other sites. The lower gonadosomatic index for this site could be explained by a few local factors. Kelp canopy decreased in UWAC (Figures 18 & 19) for 2016, reducing forage opportunity within the cove. A corresponding recruitment of purple urchins occurred increasing intraspecific competition for food and space.

The measurement of gonad development in sea urchins is an important measure of secondary production in the giant kelp forest ecosystem and will be used to inform adaptive management of the restoration project and inform research related to giant kelp forests and associated fisheries.

Strongylocentrotus franciscanus

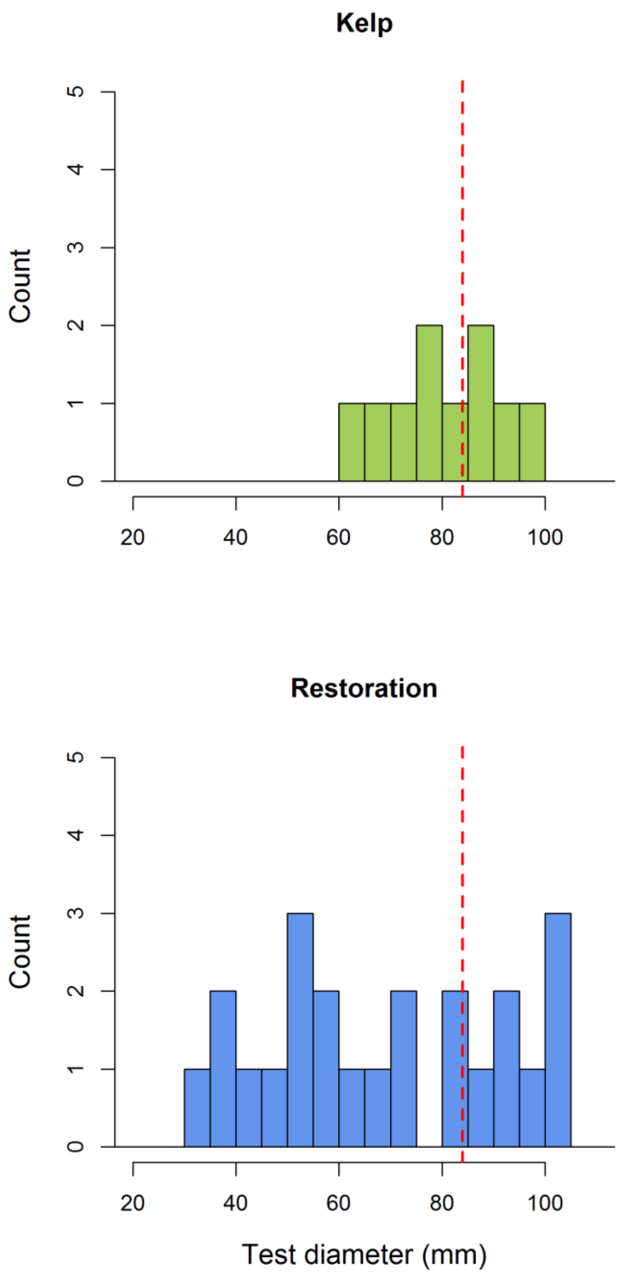


Figure 10. Histogram of Red Urchin (*Strongylocentrotus franciscanus*) test diameter for urchins collected in Kelp Forest Reference and Restoration Sites with data from collections during Fall 2017. The red line indicates the minimum size limit (84 mm) for the red urchin fishery.

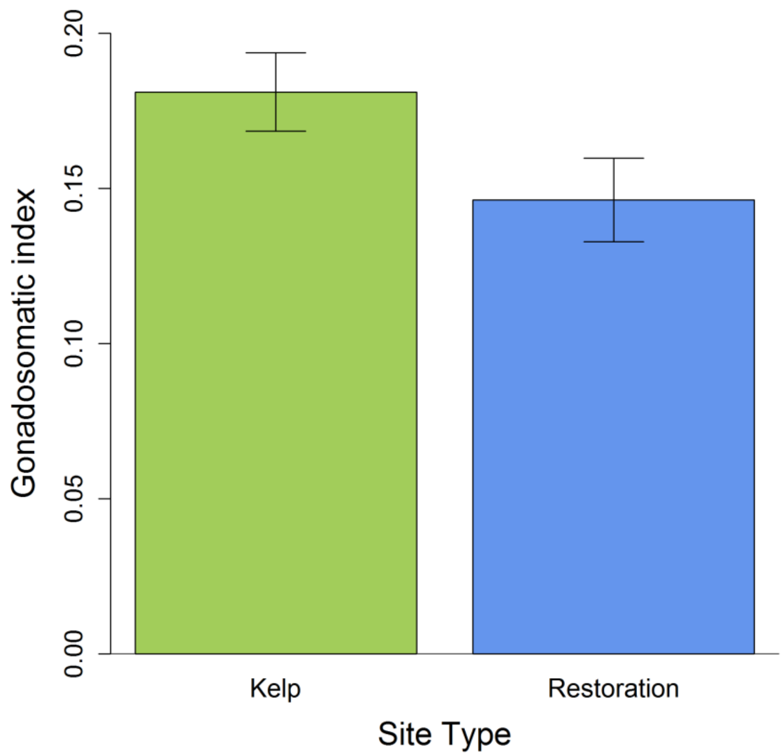


Figure 11. Gonadosomatic index of red sea urchins compared between kelp reference (green bar) and restoration sites (blue bar). Gonad weight was not significantly different between the kelp reference and restoration sites (t = 1.88, p = 0.07).

Strongylocentrotus purpuratus

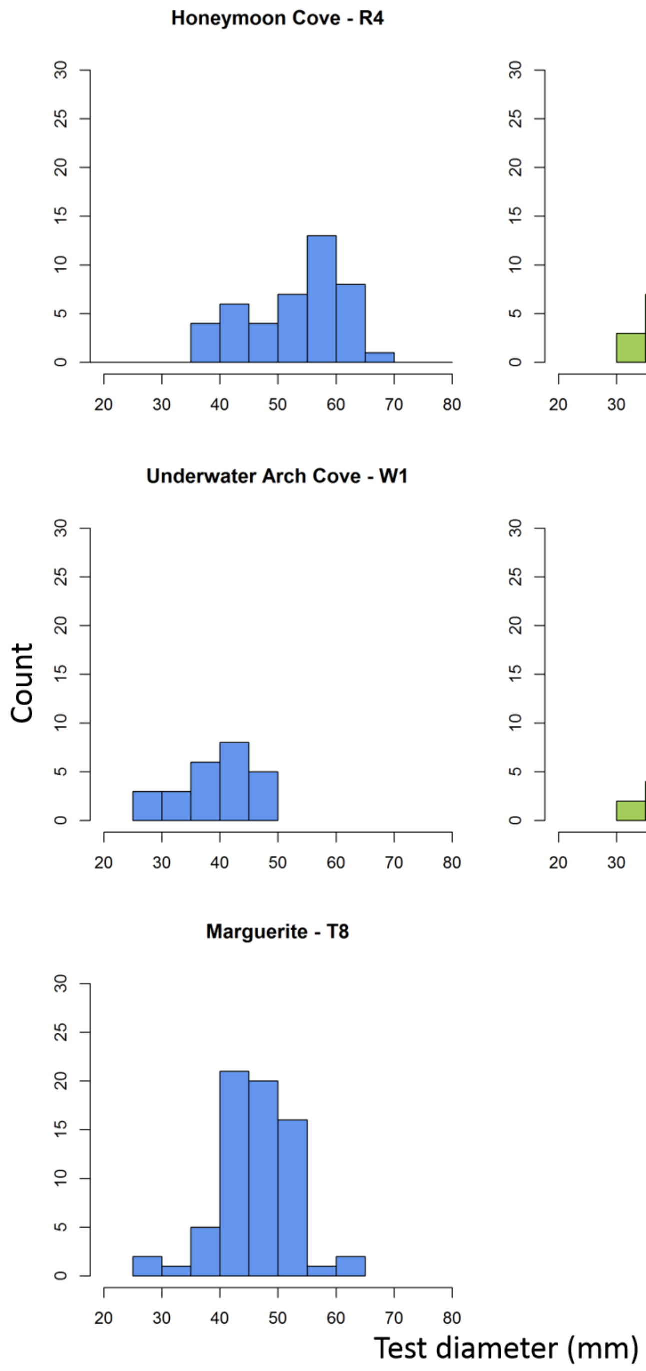


Figure 12. Histogram of Purple Urchin (*Strongylocentrotus purpuratus*) test diameter for urchins collected in Kelp Forest Reference and Restoration sites with data from collections during Fall 2017. Green bars indicate Kelp Reference sites and blue bars indicate Restoration sites.

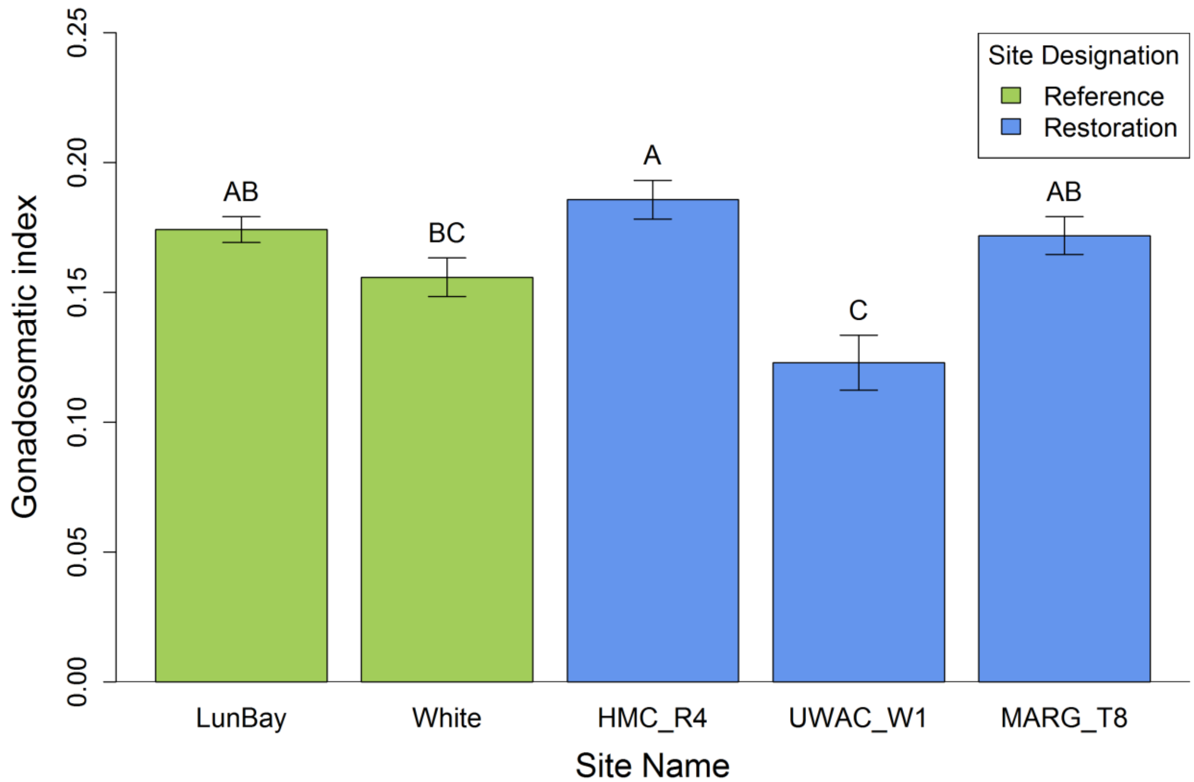


Figure 13. Gonadosomatic index of purple sea urchins compared among kelp reference (green bars) and restoration (blue bars) sites. Gonad weight significantly different among the Kelp reference and restoration sites ($F_{5,313}$=6.41, p <0.001). Letters above error bars show which sites are significantly different from each other from a Tukey's posthoc test. Site codes are as such: LunBay = Lunada Bay, White = White Point, HMC_R4 = Honeymoon Cove – R4, UWAC_W1 = Underwater Arch Cove – W1, MARG_T8 – Marguerite – T8.

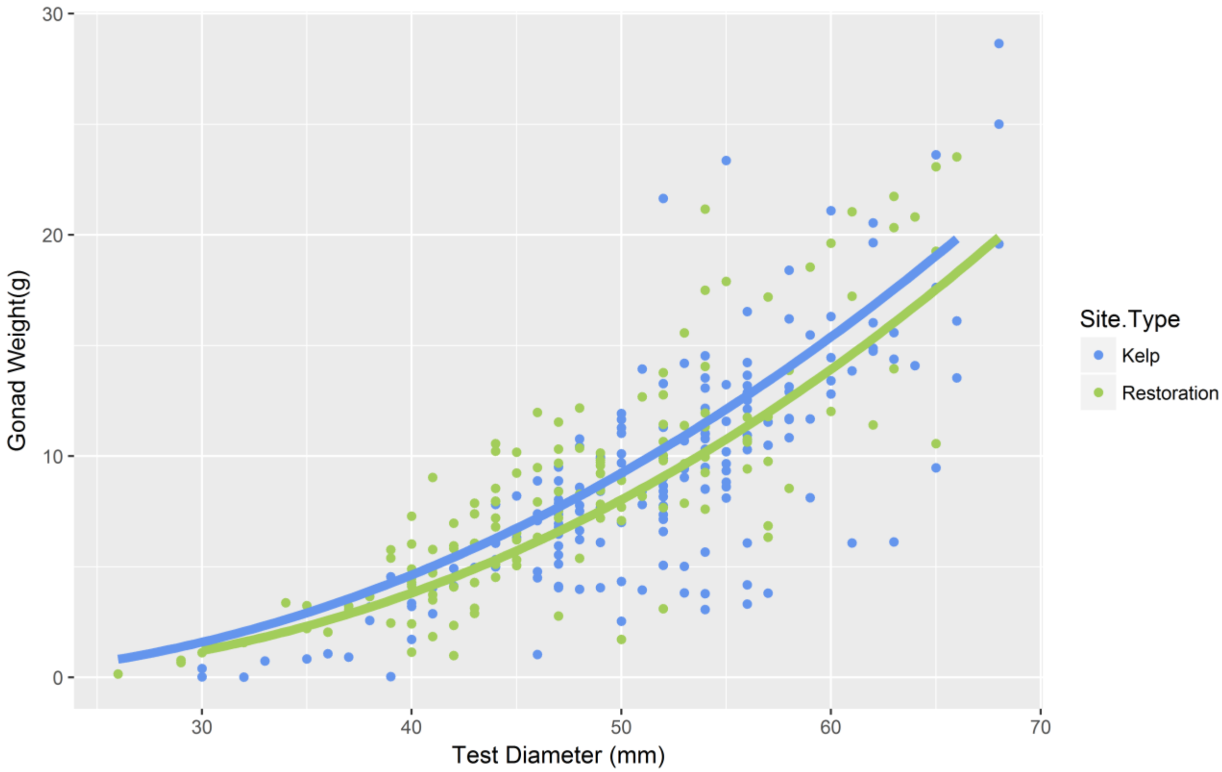
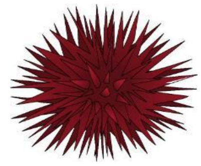


Figure 14. Relationship between Purple Urchin (*Strongylocentrotus purpuratus*) gonad weight (g) and urchin test diameter (mm) in site designations Kelp Forest Reference (green) and Restoration (blue) from 2017 collections.

Purple and Red Urchin Densities by Site

Both *Strongylocentrotus franciscanus* (red sea urchin) and *Strongylocentrotus purpuratus* (purple sea urchin) abundance declined in 2015 (Figures 15 & 16). Their numbers remained low until the end of Year 5 where pulses of urchins (majority purple urchins) were observed in several areas off the peninsula. The initial decline of purple sea urchins within restoration sites in 2014 is due to our restoration efforts; however, the decline in purple sea urchin in our reference sites is most likely due to the localized wasting event of purple sea urchins. TBF suspended sea urchin suppression from the fall of 2015 through the spring of 2016 to monitor the wasting event. Sea urchin suppression continued in the late spring of 2016 once lesions on sea urchins were no longer found and densities of greater than $2/m^2$ persisted within our restoration sites. Red sea urchin densities also dropped during this time period even though TBF does not suppress this species. The decline in abundance was most likely caused by two factors, 1) sea urchin wasting event, and 2) commercial sea urchin harvesters extracting the red sea urchins for the fishery. A small uptick in urchins was recorded during community analysis surveys for Year 5. However, we believe this trend will be dramatically higher in Year 6 due to current observations off the peninsula.



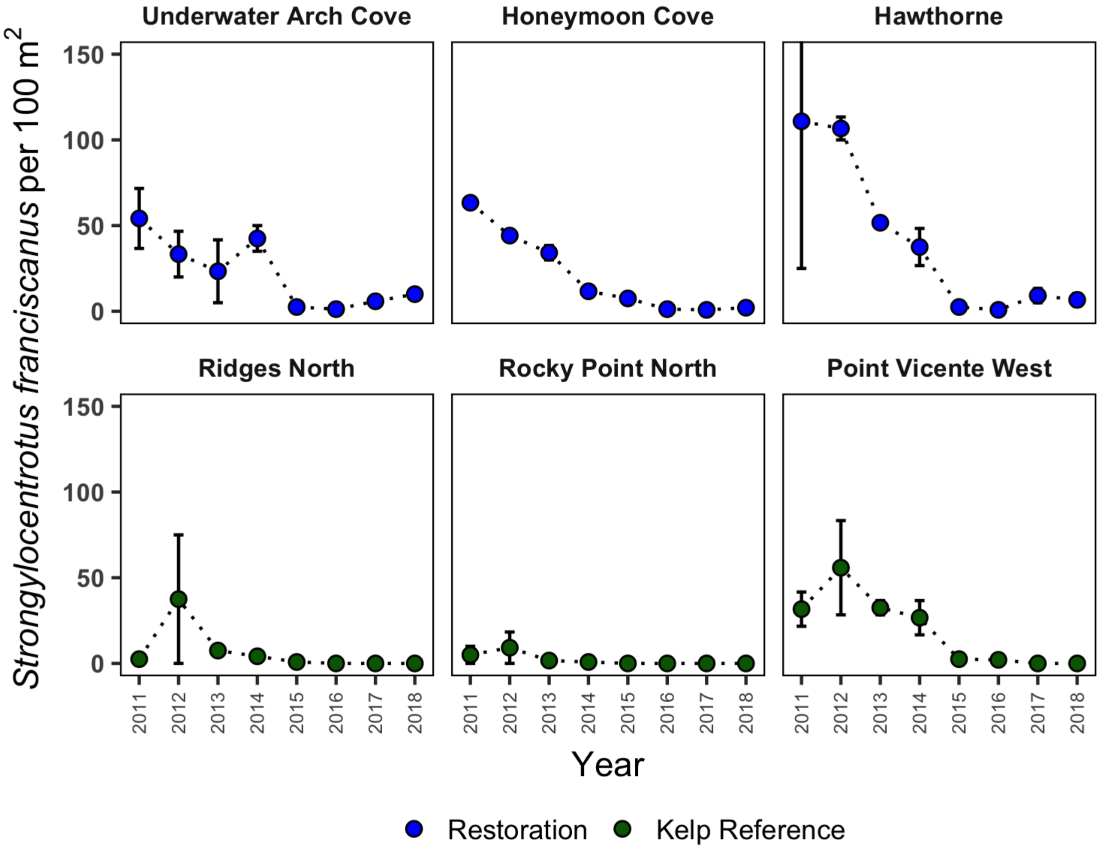
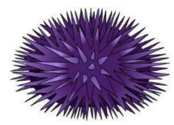


Figure 15. *Strongylocentrotus franciscanus* density (individuals/100 m^2). Sites Underwater Arch, Honeymoon Cove, and the majority of Hawthorne were restored as of 2014. *Strongylocentrotus franciscanus* density was not significantly different by site designation in 2018 (t= 2.72, p = 0.11).



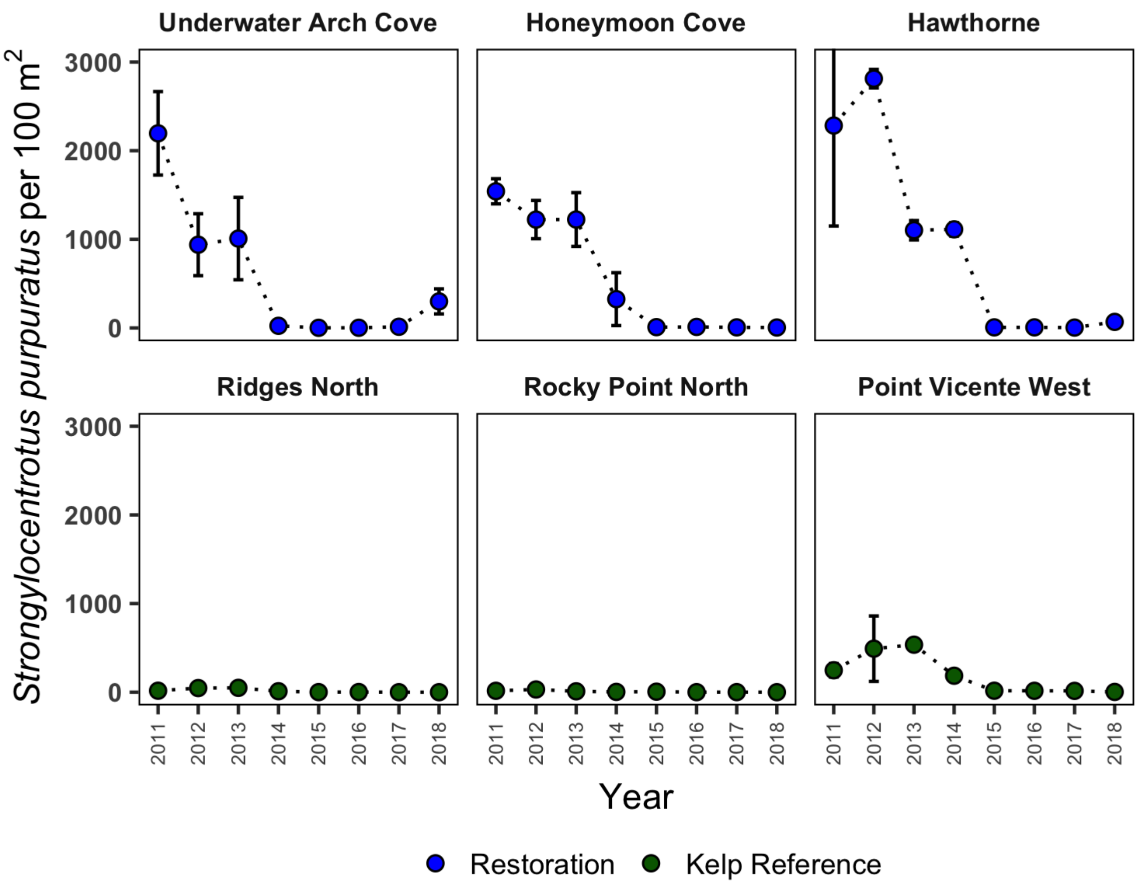


Figure 16. *Strongylocentrotus purpuratus* density (individuals/100 m^2). Sites Underwater Arch, Honeymoon Cove, and the majority of Hawthorne were restored as of 2014. *Strongylocentrotus purpuratus* density was not significantly different by site designation in 2018 (t= 1.38, p = 0.30).

Kelp Canopy Area and Percent Cover by Site

Since 2003, MBC Applied Environmental has been hired by the Central Region and Region Nine Kelp Survey Consortium to to take quarterly aerial surveys of the mainland Southern Californian kelp forests. These kelp surveys inform the consortiums about the status of the kelp forests and serve to determine possible impacts that dischargers and environmental variables are having on the kelp beds. These surveys consist of digital color and infrared color photos taken of the kelp beds that are then processed into base maps. These surveys cover approximately 355 km of the southern Californian coastline.

The consortiums provided TBF with the base maps of annual kelp bed maxiums of the Palos Verdes kelp beds, which can be used to show the progress of restoration off Palos Verdes. Surveys from 2011 through 2015 show an overall increase in kelp canopy acreage off the peninsula; however, kelp canopy dropped in 2016 due to the ENSO (Figure 17). In 2017, sea conditions returned to more normal state and kelp canopy started to recover in areas that the ENSO limited kelp canopy.

The presence of kelp into most restoration areas is found only to start in 2014 and further increases in 2015 (Figure 18 & 19). Focusing on kelp restoration areas where urchin suppression had occured, canopy percent cover (Figure 18) and area of the site (Figure 19) increased in the completed restoration sites of Honeymoon Cove, Underwater Arch Cove, and Hawthorne. In 2015, the two completed restoration sites saw an increase in kelp canopy cover to 45% of the restoraton site at Underwater Arch and 82% of the restoraton site at Honeymoon Cove (Figure 18). These drastic increases within both sites can only be accreditted to the removal of purple sea urchins from these sites. In 2016, three of the restoration sites (Marguerite, Hawthorne, and Underwater Arch Cover) saw kelp canopy disapear due to the ENSO. Unlike most kelp forests along the Californian coast, Honeymoon Cove did not follow this pattern, in 2016 the kelp canopy did decrease, and in 2017 almost the entire restoration site was covered in kelp canopy. The kelp canopy in 2017 occupied 98% of the restoration site, a 1.25 ha area. This increase in kelp was additionally quantified in the CRANE surveys (Figure 20). Point Fermin was the only site to increase its kelp canopy in 2016, and in 2017 nearly the entire site (99%) was covered with the kelp canopy (Figure 18). Lastly, the most recent restoration site, Resort Point, has had a persisitent kelp canopy since the start of this project. Urchin suppression at Resort Point has focused on protecting this existing kelp forest.

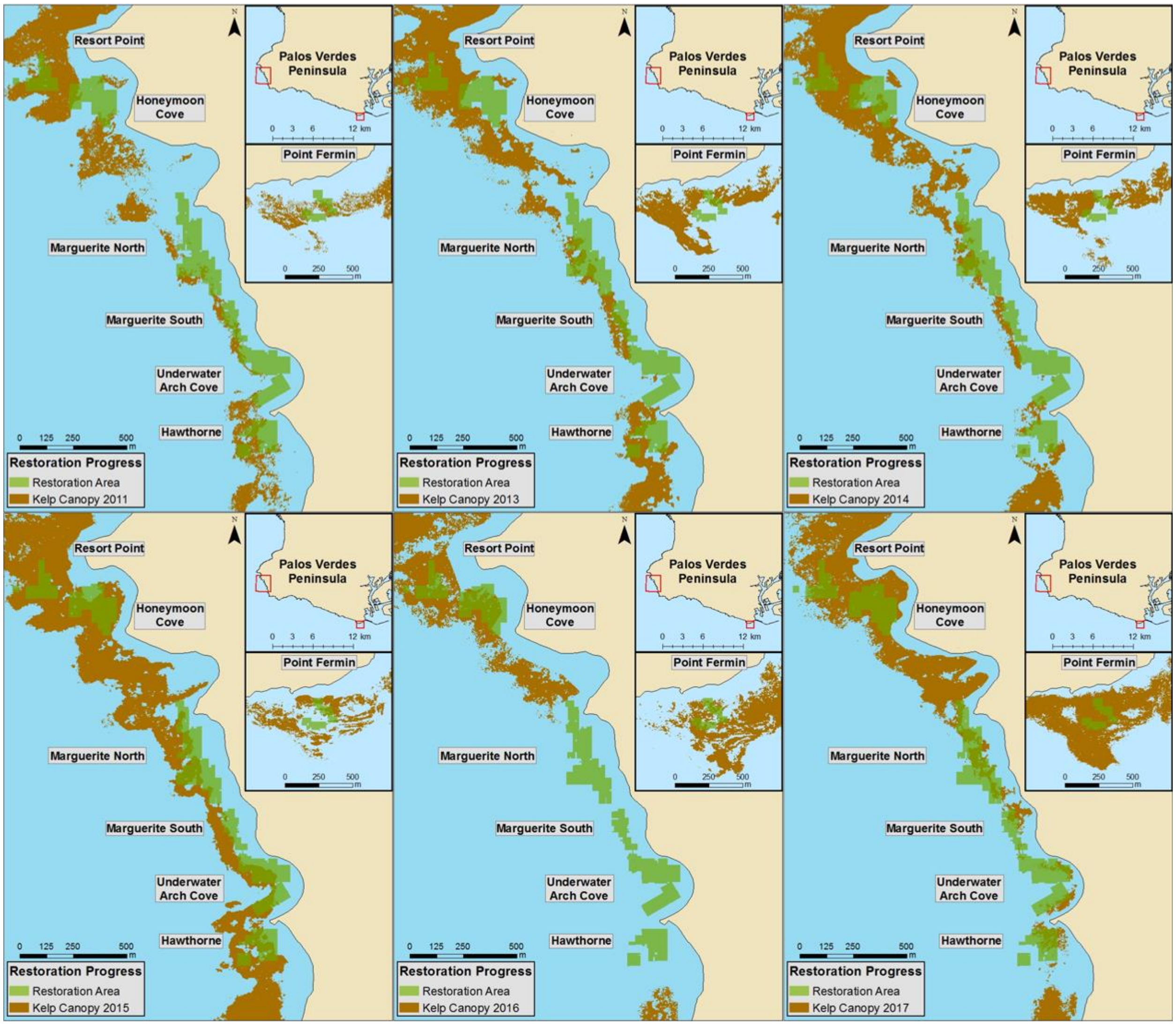


Figure 17. Aerial kelp canopy coverage (*Macrocystis pyrifera*) from 2011 – 2017. Data provided by MBC Applied Environmental. Canopy coverage is represented in brown while restoration areas are in green. The map shows the western side of the Palos Verdes Peninsula and the area inside Point Fermin.

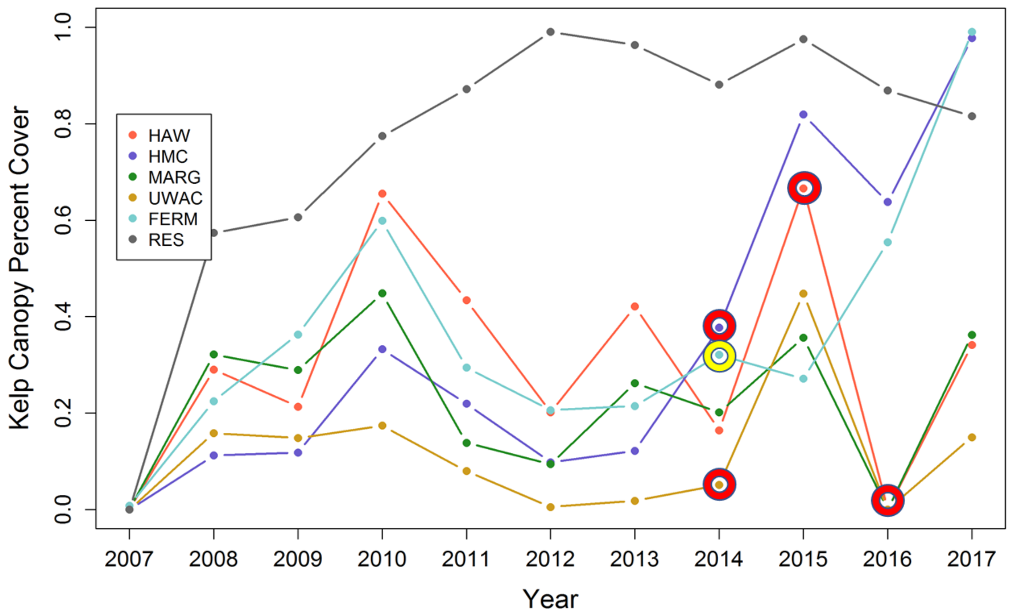


Figure 18. Annual kelp canopy percent cover from 2007 – 2017 per restoration site. Red circles indicate completed restoration sites Underwater Arch (brown), Honeymoon Cove (purple), Marguerite (MARG – green) and Hawthorne (HAW - orange) a year after restoration finished. Restoration efforts began at Point Fermin (FERM – light blue) in 2014 and is represented in a yellow circle. Data provided by MBC Applied Environmental. Monitoring and restoration efforts are expected to continue for White Point and Resort Point.

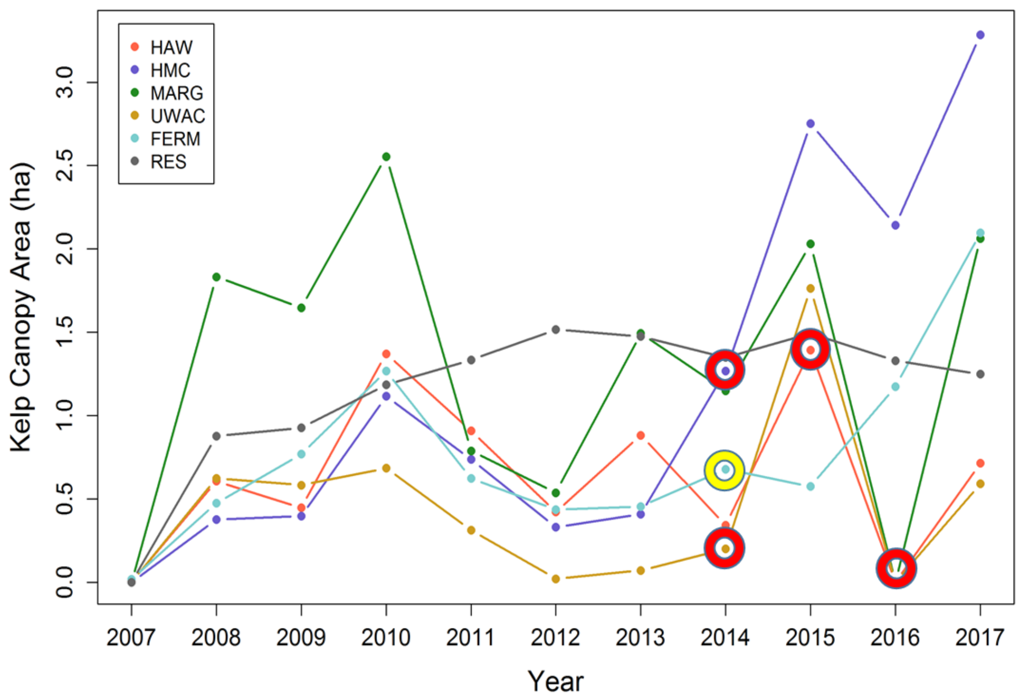


Figure 19. Annual total kelp canopy area from 2007 – 2017. Red circles indicate completed restoration sites Underwater Arch (brown), Honeymoon Cove (purple), Marguerite (MARG – green) and Hawthorne (HAW - orange) a year after restoration finished. Restoration efforts began at Point Fermin (FERM – light blue) in 2014 and is represented in a yellow circle. Data provided by MBC Applied Environmental. Monitoring and restoration efforts are expected to continue for White Point and Resort Point.

Giant Kelp Density by Site

As a measure of kelp forest density, we use the number of stipes per 100 meters squared. The kelp stipe density is provided by VRG during their annual CRANE surveys. The years after post restoration activities (2014-2015) showed an immediate increase in the kelp stipe density for all three restoration sites (Figure 20). During the warm water event of 2015 and ENSO of 2016 the kelp densities in the reference sites decreased compared to previous years. This trend was also seen in the three restored sites, where two sites lost almost all their kelp in 2016. Kelp densities increased in all three restored sites in 2017 and 2018, which are orders of magnitudes of difference compared to the years prior to restoration (2011-2013).

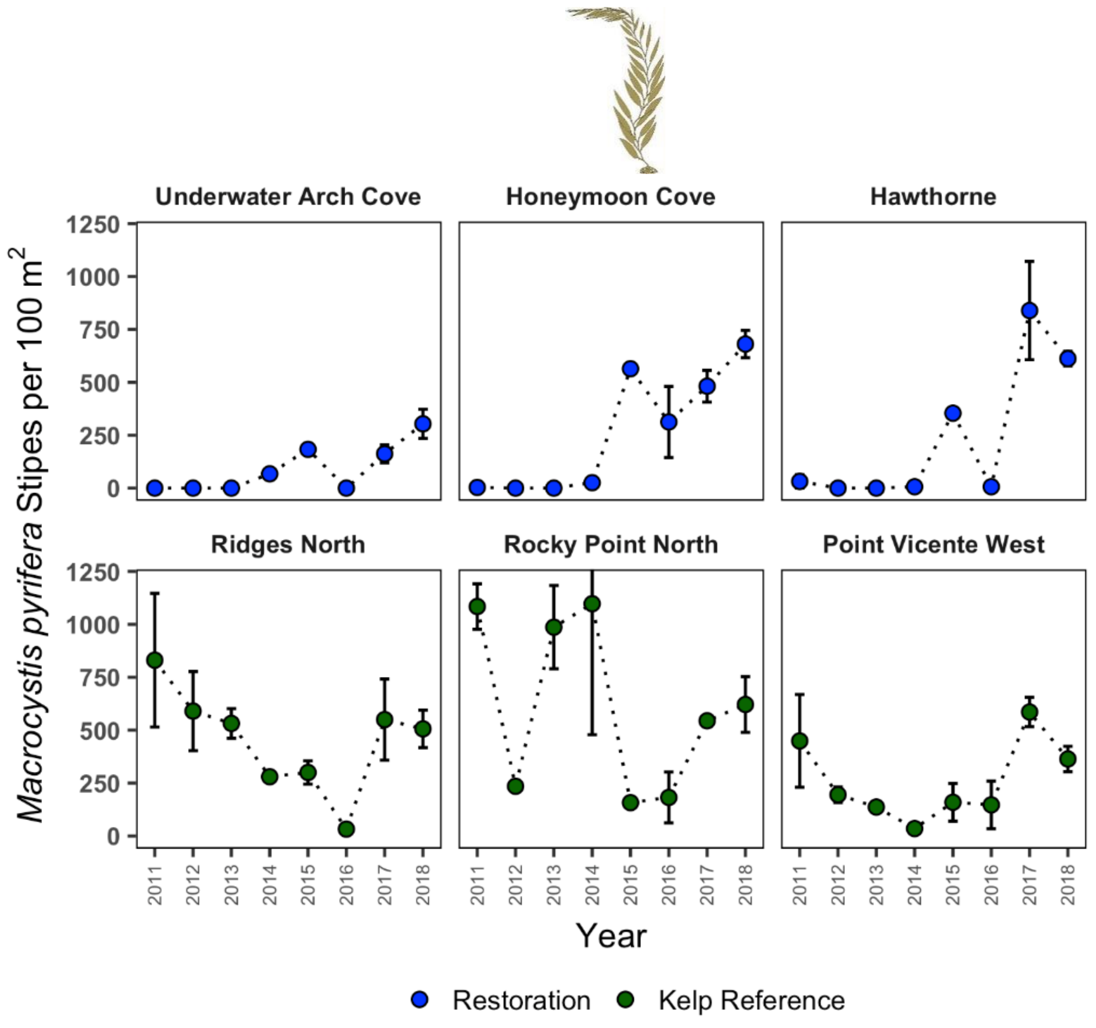


Figure 20. *Macrocystis pyrifera* density (individuals/100 m^2). Sites Underwater Arch, Honeymoon Cove, and the majority of Hawthorne were restored as of 2014. Restoration began in 2015 at the site Marguerite Central (previously a control site) and was completed in the fall of 2016. Kelp was significantly different by site designation in 2018(t=0.25, p=0.81).

Density of Kelp Bass and California Sheephead

Because sites were sampled over a period of several months and seasons, young-of-the-year (YOY) were removed prior to fish 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, except for some smaller species, where they were defined as individuals less than between 1.5 and 5 cm based on published species-specific growth rates and expert opinion. Total length (TL) estimates were converted to biomass using standard species-specific length-weight conversions from the literature. YOY were not excluded from biomass calculations, as their small size will influence biomass estimation less than abundance estimation. Density/biomass density was then summed across all three portions (bottom, midwater and canopy) of each transect, except for when the water depth is less than 6 m, meaning that the volumes of the canopy and midwater portions would overlap, in which case no midwater portion was included. Density values were then scaled to the number per $100m^2$.

Paralabrax clathratus (kelp bass) abundance and biomass has gradually increased in restoration sites post restoration efforts (Figures 21 & 23). In the survey's conducted in 2018, kelp bass density and biomass indicate a trend of increase since being restored and are on par with kelp forest reference sites. This increased number of kelp bass could be due to a multiyear increase and persistence of *Macrocystis pyrifera* within these restoration sites (Figures 16-20). Kelp bass recruit to kelp canopy and use kelp as a refuge to hide from predators or to ambush prey. Biomass of kelp bass from 2018 shows that the largest biomass of kelp bass is within Point Vicente MPA site, although density of kelp bass within Point Vicente West is similar to the other sites. This is expected as fishing is not allowed within this area, allowing for fish to grow larger without fishing pressure. All current restoration sites are not within MPAs, therefore fishing is permitted.

Semicossyphus pulcher (California sheephead) abundance and biomass has been variable among monitoring years for all sites (Figures 22 & 24) This result could be due to the larger home ranges of CA sheephead and their ecological behavior being more generalist than kelp bass.

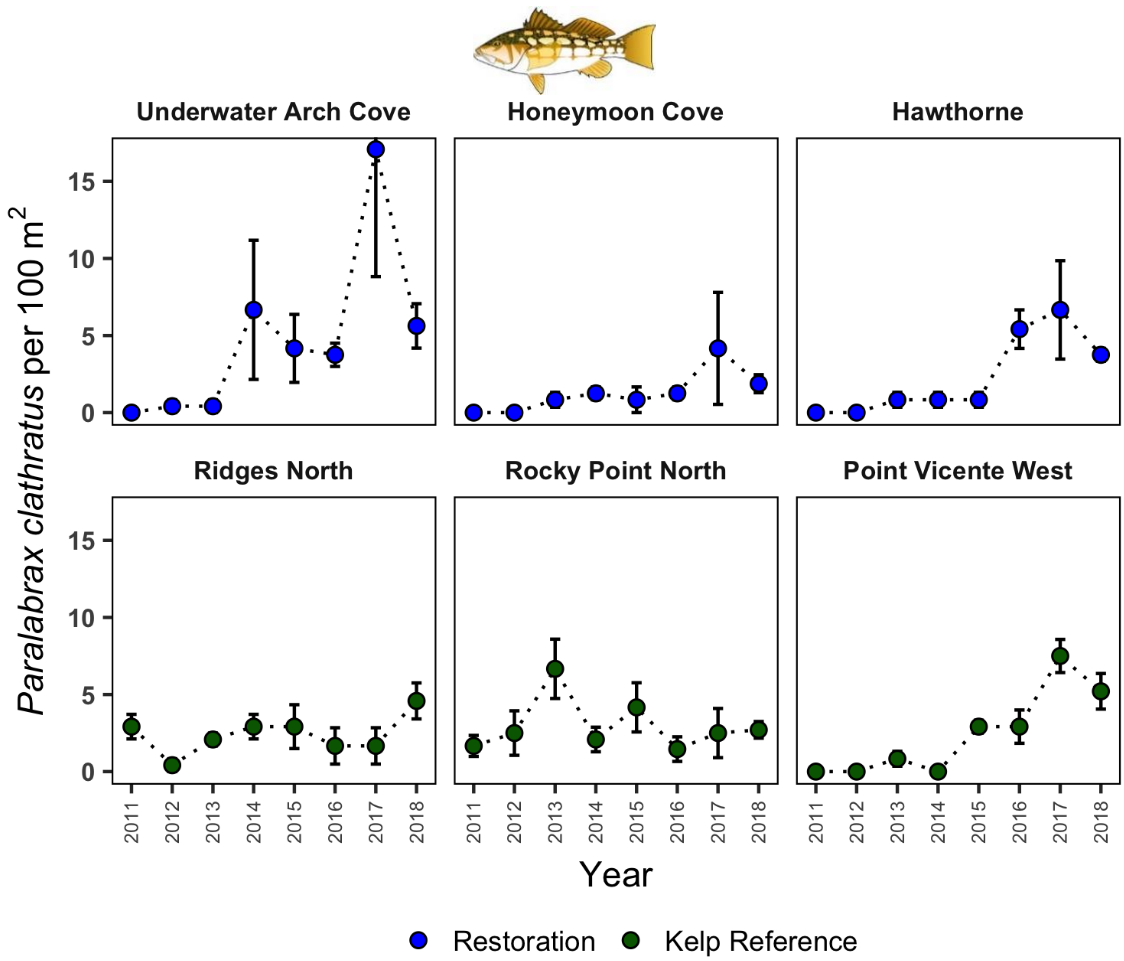


Figure 21. Density of *P. clathratus* by site type; control, restoration, and reference. Sites Underwater Arch and Honeymoon Cove were restored as of 2014. The majority of Hawthorne was restored in 2014. *Paralabrax clathratus* density was not significantly different by site designation in 2018 ($t = -0.32$, $p = 0.77$).

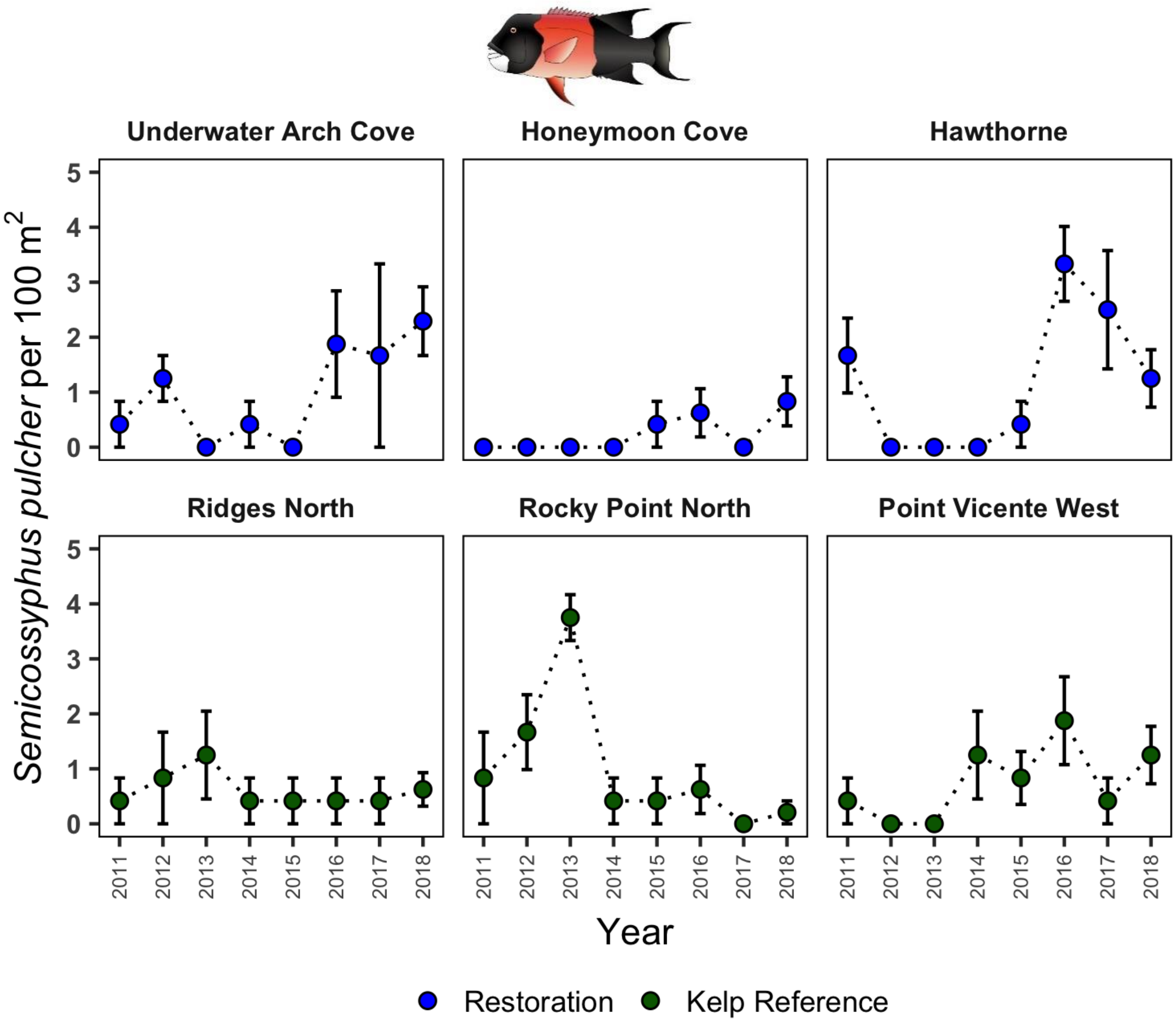
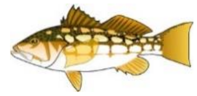


Figure 22. Density of *S. pulcher* by site type; restoration, and reference. Sites Underwater Arch and Honeymoon Cove were restored as of 2014. The majority of Hawthorne was restored in 2014. *Semicossyphus pulcher* density was not significantly different by site designation in 2018 ($t = 1.44$, $p = 0.23$).



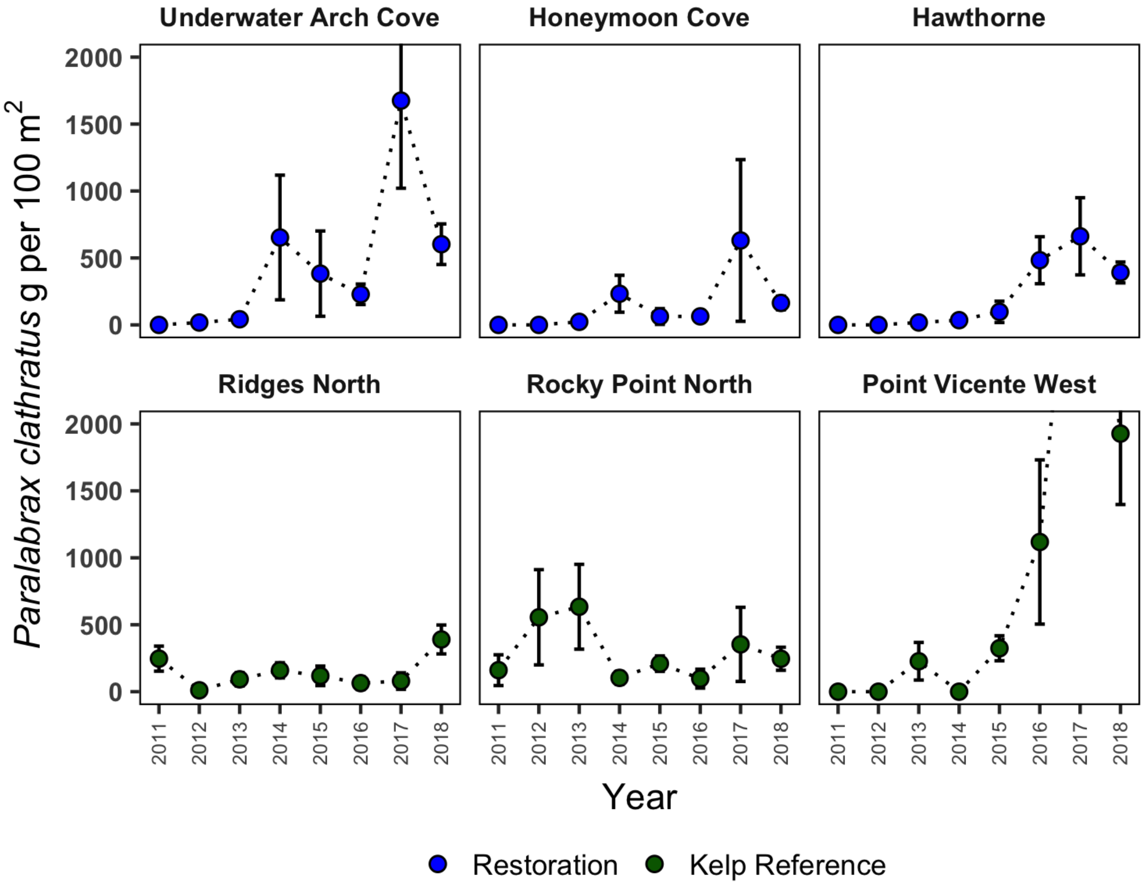
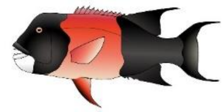


Figure 23. Biomass of kelp bass, *P. clathratus*, per 100 m^2, per site. Sites Underwater Arch and Honeymoon Cove were restored as of 2014. The majority of Hawthorne was restored in 2014. Kelp bass biomass was not significantly different between reference and restoration sites for Year 5 of the project ($t = -0.85$, $p = 0.48$)



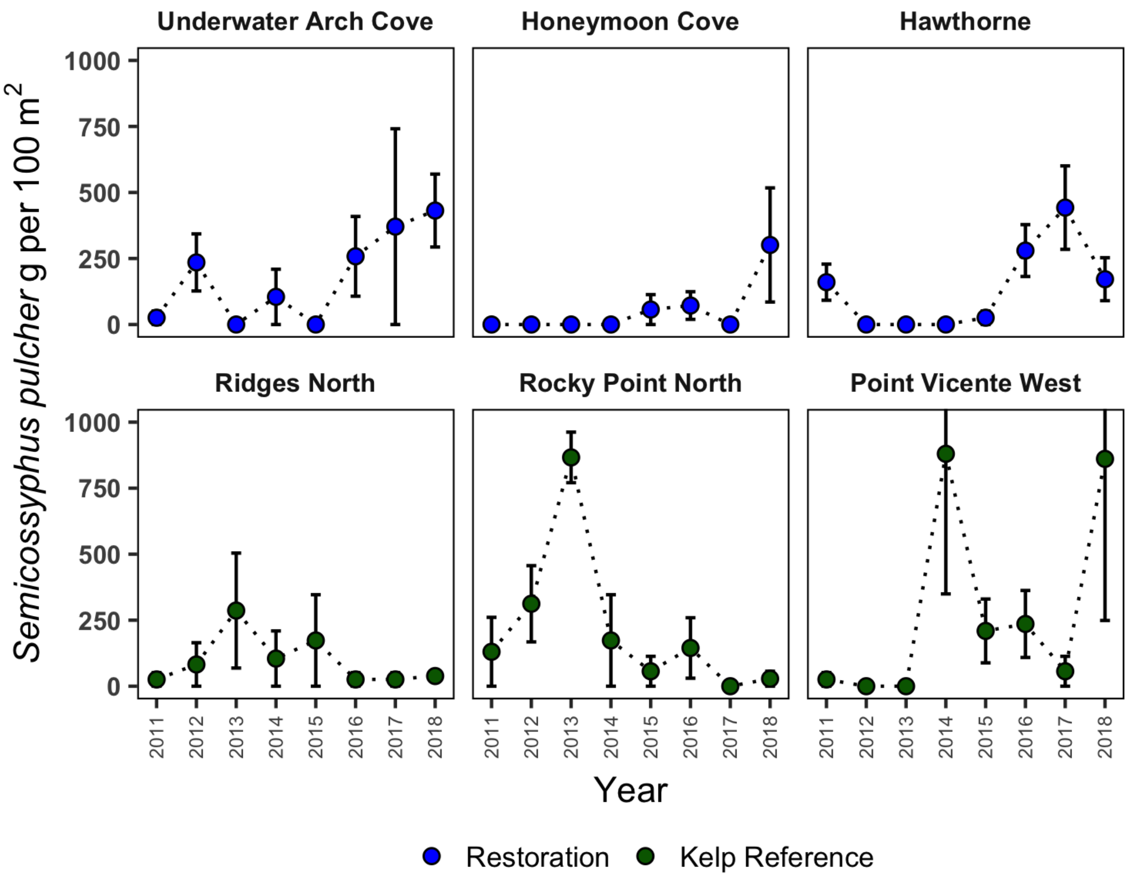
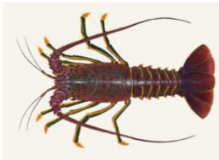


Figure 24. Biomass of sheephead, *S. pulcher*, per 100 m^2, per site. Sites Underwater Arch and Honeymoon Cove were restored as of 2014. The majority of Hawthorne was restored in 2014. *Semicossyphus pulcher* biomass was not significantly different by site designation in 2018 ($t = -0.03$, $p = 0.98$).

California Spiny Lobster Density

Panulirus interruptus (California Spiny Lobster) were quantified in CRANE invertebrate swaths. Size was not recorded for lobster counted. Prior to urchin removal in restoration sites, lobster were absent, within them (Figure 25). There has been a notable increase in the abundance of lobster within restoration sites starting in 2016. Lobster abundance is highly variable among sites and years. This could be due to three factors, 1) commercial lobster fishing pressure is heavy throughout the Palos Verdes region, 2) lobster are mobile and can select for areas based off of preferable habitat and oceanic conditions, 3) recruitment events.



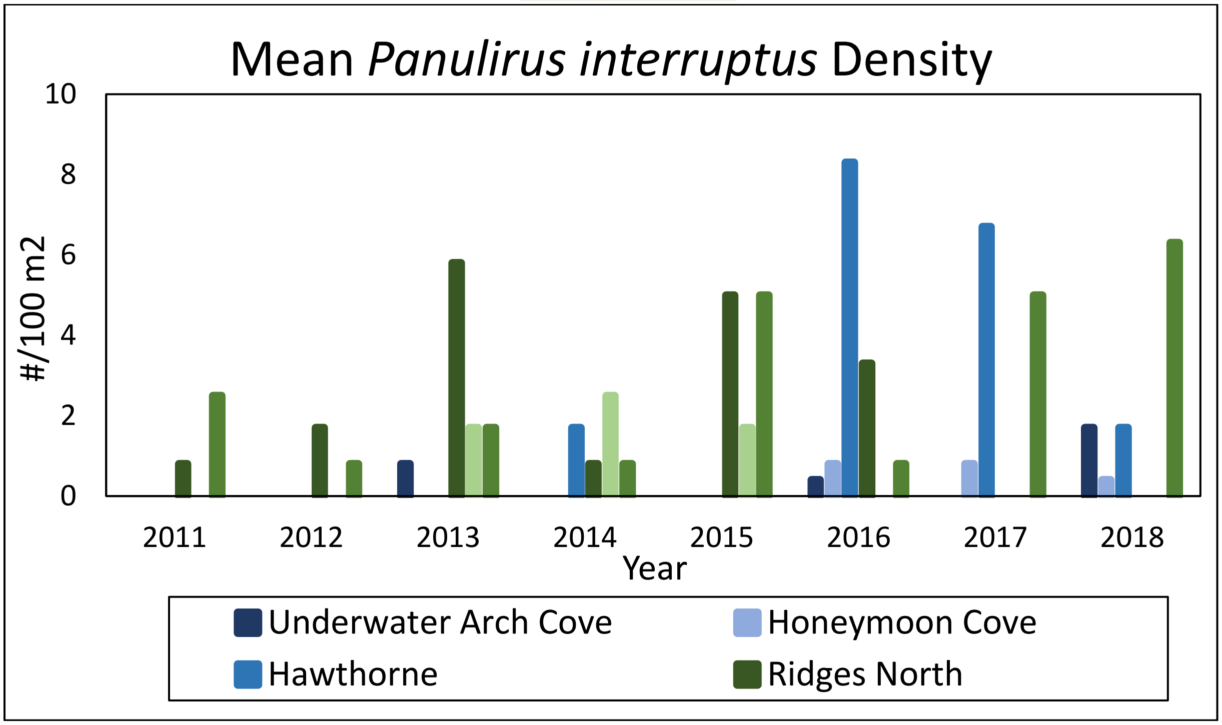


Figure 25. Mean *Panulirus interruptus* (California spiny lobster) density (#/100 m^2) at Restoration sites shown in various shades of blue (Underwater Arch, Honeymoon Cove, and Hawthorne), and kelp forest reference sites shown in various shades of green (Ridges North, Rocky Point North, and Point Vicente West). Survey dates in 2014 within restoration sites for that year occurred after restoration was completed.

Species Richness

Species richness is the number of unique species found at a site. The species richness values are derived from the CRANE surveys provide by VRG. Since restoration events, species richness has increased in all restored sites (Table 9). Though these values are slightly variable from year to year, the restored sites do have similar richness values when compared to reference sites post 2013.

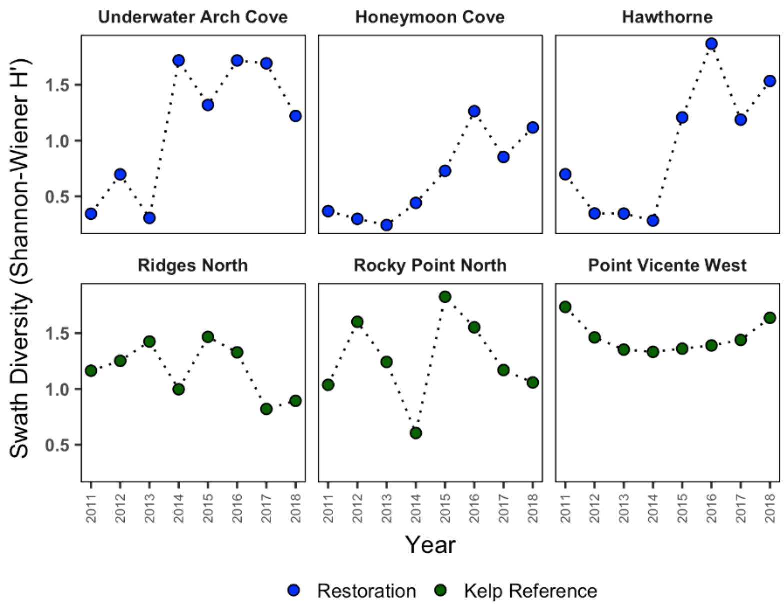
Table 9. Fish Species Richness (total number of species).

Designation	*Site*	2011	2012	2013	2014	2015	2016	2017	2018
	Underwater Arch Cove	6	9	6	12	8	8	11	9
Restoration	**Honeymoon Cove**	0	2	4	8	5	12	7	8
	Hawthorne	10	6	8	7	10	13	12	12
	Ridges North	6	11	7	6	5	10	5	12
Reference	**Rocky Point North**	8	8	8	9	6	7	9	11
	Point Vicente West	8	6	10	11	12	14	9	11

Note: 2014 is the first post-restoration year. Restoration began at the control site Marguerite Central in August 2014. However, urchin suppression was not done at the response monitoring location for this site. In the future, barren control sites will become restoration sites once these barrens are restored and analyses will compare differences between reference and restoration sites.

Community Analyses

The Shannon-Wiener diversity index came from information theory and measures the order (or disorder) observed within a particular system. The Simpson's index of diversity accounts for both richness and proportion of each species. It has been a useful tool to terrestrial and aquatic ecologists. Both diversity measures show a rapid increase of algal/invertebrate diversity once restoration was completed in Underwater Arch, Honeymoon Cove, and Hawthorne (Figure 26). After restoration diversity measures show little fluctuation. Honeymoon Cove was the only site where we observed an increase in fish diversity measures (Figure 27).



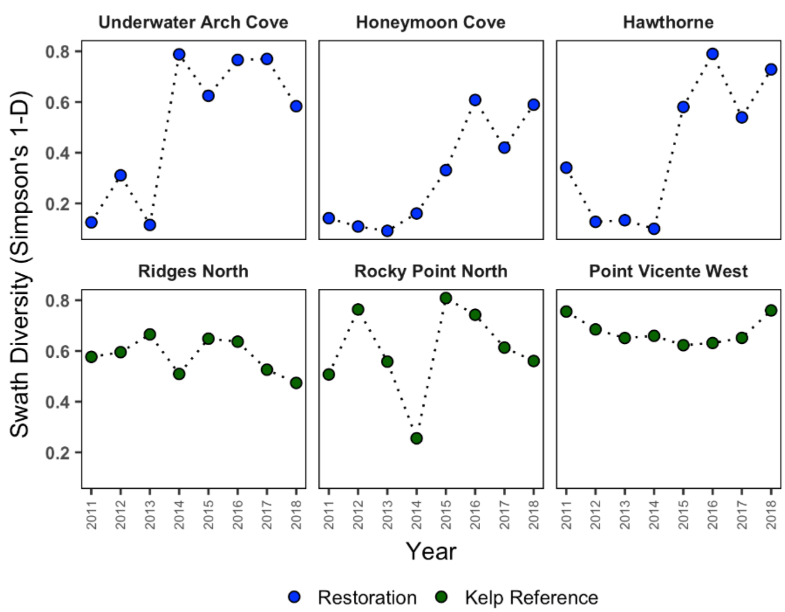


Figure 26. Algal and invertebrate diversity at Restoration (Underwater Arch, Honeymoon Cove, and Hawthorne) and Reference (Ridges North, Rocky Point North, and Point Vicente West) sites. Restoration sites were restored in 2014. Diversity measures used are Shannon-Wiener (above) and Simpson's Diversity (below).

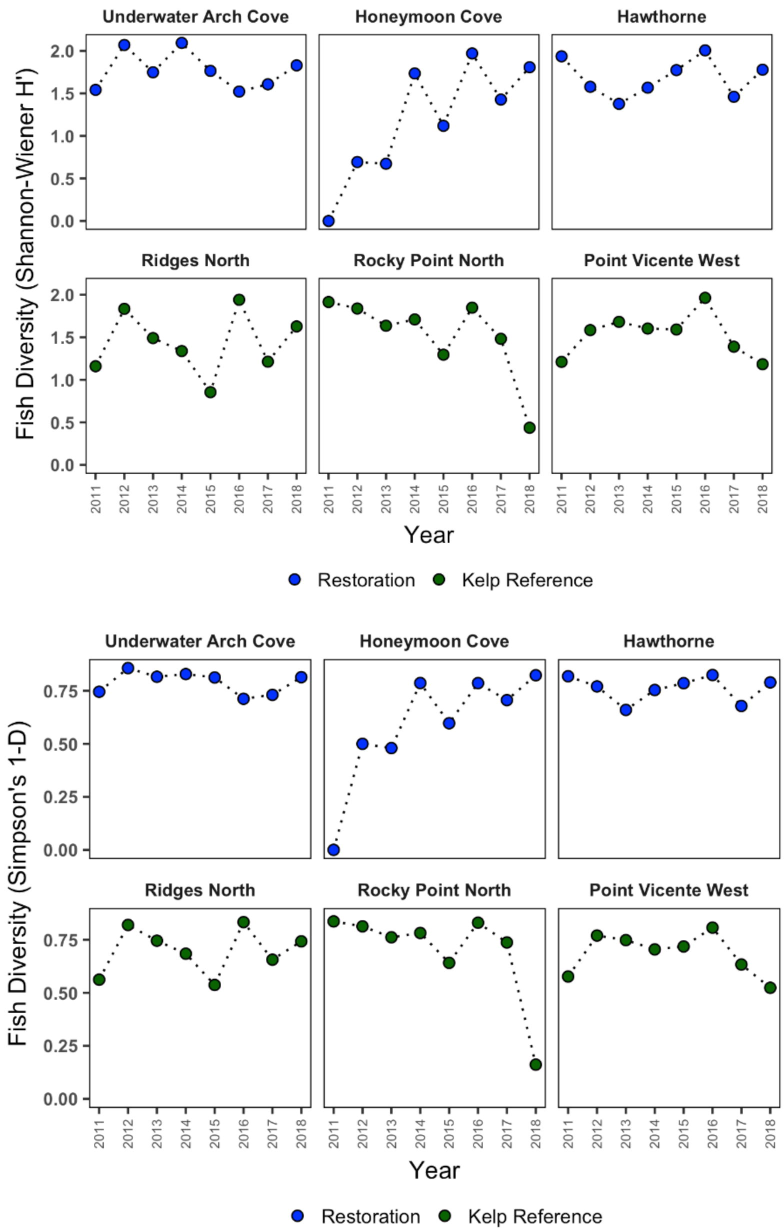


Figure 27. Fish diversity at Restoration (Underwater Arch, Honeymoon Cove, and Hawthorne) and Reference (Ridges North, Rocky Point North, and Point Vicente West) sites. Restoration sites were restored in 2014. Diversity measures used are Shannon-Wiener (above) and Simpson's Diversity (below).

As part of the quantitative characterization of the community structure of the reefs, we examined patterns in the overall kelp forest community using UPC (percent cover) data as well as the fish and swath (benthic macroinvertebrates and kelps) data combined. Density metrics were square root transformed (fish and swath data), while percent-cover metrics (UPC benthic cover data) were arcsine square root transformed. Two-dimensional, non-metric multidimensional scaling (nMDS) was used to examine patterns among kelp forest communities (Figure 28) and benthic cover (Figure 29) at sites using the ‘metaMDS’ function in the ‘vegan’ package (Oksanen et al. 2016) in R (R Core Team 2016). A similarity matrix constructed with transformed taxon-specific values (site means for each site/sampling period combination) and the Bray-Curtis similarity. To provide context to the observed relationships amongst sites, patterns of taxa densities were visualized across the nMDS ordination plots using the ‘ordisurf’ function in the R package ‘vegan’ (Oksanen et al. 2016) which fits a smooth surface using generalized additive modeling (GAM) with thin plate splines (Wood 2003, Oksanen et al. 2016). These visualizations help inform drivers of community structure as seen in nMDS plots.

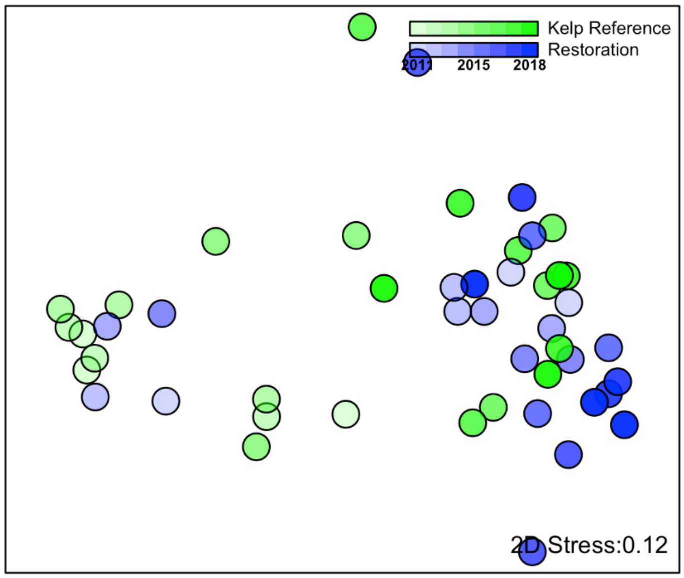


Figure 28. Non-metric multidimensional ordination plot of kelp forest communities (numerical density of fishes, invertebrates, and kelps) using Bray-Curtis similarity based on the square-root transformed mean taxa density for each site/sampling period combination. Site designation is indicated by color, survey year is indicated by the transparency of each point with earlier dates more transparent and later dates nearly opaque. Sites with larger numbers of echinoderms are present at the left side of the plot while sites that have larger numbers of kelps are present on the right.

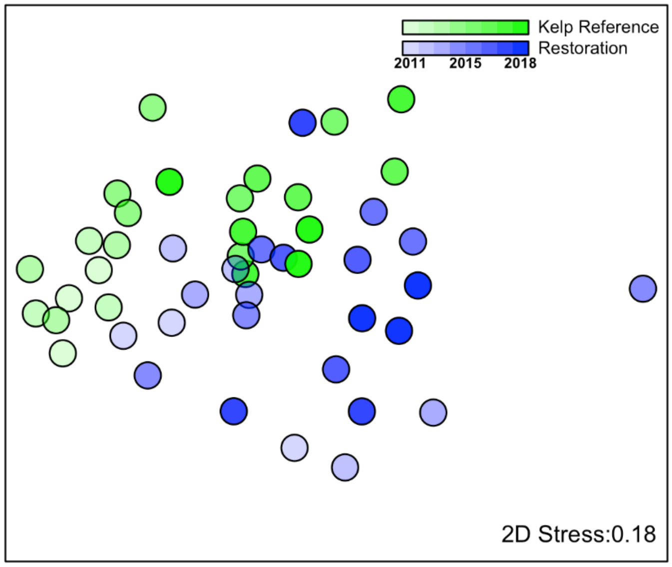


Figure 29. Non-metric multidimensional ordination plot of benthic cover using Bray-Curtis similarity based on the arcsine-square-root transformed mean taxa density for each site/sampling period combination. Site designation is indicated by color, survey year is indicated by the transparency of each point with earlier dates more transparent and later dates nearly opaque. Sites with higher bare rock and crustose coralline algae appear on the left of the plot, sites with *Eisenia arborea* holdfasts and erect red algae present towards the bottom-right, sites with more red turf erect coralline algae are placed in the middle, and sites with more giant kelp holdfasts are placed towards the bottom.

Community Analyses Results

The two plots presented above display a convergence over time in which restoration sites begin to resemble, (structurally), the reference sites. The earlier years depicted in these plots show that the converse was true in advance of restoration efforts- that the structure of restoration sites, pre restoration, resembled control sites (sites that contained urchin barrens for comparison early in the project).

In this case the interpretation of these results allows for a finer scale evaluation of the time of the shifts in community structure displayed more clearly in figure 28 than in figure 29. What we see in figure 28 suggests the movement of the restoration sites towards a more restoration-like structure in advance of the restoration sites, which display a lag in time.

Three restoration sites were completed before 2014. The community analyses show a convergence of restoration and reference sites in 2014 as the restoration sites changed from barrens to young kelp forests. The occurrence of a mass wasting event of red and purple sea urchins happened with considerable severity on the Palos Verdes Peninsula impacting reference and restoration sites in 2015. This further loss of top down pressure from urchins on the development of giant kelp and other macroalgae and the freeing from competition, of other grazers, likely caused this progression to continue from 2015-2016.

These plots indicate with confidence that the loss of sea urchins, i.e. a reduction in their density, allows for the growth and development of other benthic organisms that are no longer limited by the direct and indirect impacts of sea urchin grazing. Further monitoring of these sites may, over time, detect trends that elucidate more subtle or developing relationships in community structure. Likely these characteristics will be displayed via divergence of these site types over time or in response to other forms of disturbance and other stressors. Fortunately, this project will provide that opportunity to collect data informing those potentials over time.

The plots also support the following that sea urchin suppression creates similar near-term changes in community structure to widespread reductions in urchins due to disease. These different causes of urchin density reduction (i.e. suppression and natural loss due to disease) have both driven formerly barren reef states to resemble reference sites (i.e. sites with persistent kelp and more complex community structure). These results suggest that in the near-term urchin suppression is a fair mimic for natural losses in urchin populations driving kelp forest community structure on a local scale.

It is also important to note which drivers within the community explain the bulk of the transitions/progression in each of the figures. In figure 25, sites with larger numbers of echinoderms are present at the left side of the plot while sites that have larger numbers of kelps are present on the right. In figure 26, sites with higher bare rock and crustose coralline algae appear on the left of the plot, sites with *Eisenia arborea* holdfasts and erect red algae present towards the bottom-right, sites with more red turf erect coralline algae are placed in the middle, and sites with more giant kelp holdfasts are placed towards the bottom.

Evaluation of Restoration Activities

A few statements can be made that generally describe conditions during this report period that directly impacted the amount, type, and accuracy of work conducted. 2015-2016 proved to be one of the most powerful El Niño signatures recorded on the west coast of the United States. This El Niño event followed and was perhaps strengthened by the persistence of “the blob”, a large area of atypically warm ocean surface water that impacted the California Current. For Palos Verdes and elsewhere in southern California, these environmental factors resulted in abnormally high sea surface temperatures, which were only punctuated periodically by localized upwelling events. The thermal related stress associated with the confluence of these stressors slowed or prevented the development of giant kelp and other macroalgae and may have contributed to the virulence and mass wasting of several genera of sea stars and in the fall of 2015 a seemingly similar yet less widespread wasting of sea urchins. In 2016, the project failed to collect sufficient numbers of red sea urchins and urchins were not collected from barren sites for dissections. There are currently no signs of further mass wasting disease off Palos Verdes and numerous juvenile and adult purple and some red sea urchins are making a comeback. During pre and post monitoring surveys, divers have begun utilizing flashlights to more accurately and efficiently quantify red and purple urchins in active restoration sites.

During the 2017-2018 year of the project urchin densities rose noticeably, and TBF chose several areas of concern to begin restoration efforts. These sites (Resort Point and a new area of Hawthorne) consisted of high purple urchin densities, but also supported high biomass of fish, invertebrates, and giant kelp. The work done in these sites were to cull urchin numbers to prevent these reefs from reverting back to pre-2015 barrens. Near the beginning of summer 2018 more reefs were identified as having high urchin densities, and White Point was chosen as the most problematic as this cove had developed into an urchin barren, devoid of macroalgae besides coralline algae, and averaging 67.8 urchins per m^2. TBF began monitoring and restoring this site. Restoration at at White Point is underway but incomplete as of the close of the 5 time-frame. Furthermore, while monitoring previous restoration sites a few problem areas were identified at Underwater Arch. During Year 4 of the project, we had to return to maintain an area of Underwater Arch that contained high purple urchin densities. This year we observed a barren east of the area we revisited in Year 4 that will need to be reworked this coming year of the project. We, as well as our partners, attribute this reoccurrence of high urchin densities, at Underwater Arch, being due to the extensive tidepools and large mussel beds contiguous with the northerly aspect of this site.

Honeymoon Cove

Honeymoon cove was determined to contain no remaining expanses of urchin barren in November of 2014. No restoration actions, i.e. urchin suppression, was performed during this report period. Surveys were conducted by TBF personnel on a periodic basis to quickly assess the condition of the reefs found in this cove. This will continue in the coming year to determine that restoration targets of two sea urchins per square meter are maintained and that giant kelp and other biota are persisting in the area. Related work was conducted by The Bay Foundation and NOAA biologists to outplant green abalone onto a section of reef in Honeymoon Cove. These 827 juvenile green abalone were outplanted in June 2015. Subsequent, frequent and comprehensive monitoring was conducted and in March of 2017 a number of emergent green abalone were found on site. The last survey completed in July 2018 found approximately 150 green abalone within the 10 by 10 meter outplant site. Prior to outplanting only 10 green abalone were found within the site. Genetic analysis based upon tissue samples taken in situ is ongoing to determine whether these emergent green abalone are in whole or in part some of the same organisms that were outplanted. This site was restored in advance of November 2014 and the improved condition of the substrate and biological community resulting from the restoration efforts was key in selecting this site for having the right characteristics to support juvenile green abalone.

Monitoring targets were met for this year, meaning surveys were conducted by Vantuna Research Group in July to assess the condition of the community in Honeymoon Cove. The product of these data are presented elsewhere in this report. The increase in biomass of kelp bass in Honeymoon Cove has been one trend that is discernable. Pre restoration surveys documented zero biomass for this species and though levels have fluctuated over the past four years, post-restoration, the biomass levels remain higher than in the pre restoration condition.

Georeferenced photos and video were collected to document conditions within the site over time. See appendix C.

Underwater Arch Cove

Underwater Arch Cove was similarly considered restored prior to this report period, being that no expanses of the reef were observed to support densities of purple urchins in excess of two per square meter in fall of 2015. However, in Year 4 of the project, one locale within Underwater Arch Cove showed higher than two purple urchins per square meter during the summer of 2016. The Bay Foundation re-monitored Underwater Arch to determine the reappearance - expansion of urchins in the area and if restoration, i.e. urchin suppression, should be undertaken. The expansion of urchins was found to be relatively contained near the large tidepool at the north edge of the site. The renewed restoration of this section of Underwater Arch took place from 1/4/17 – 7/6/17 during the same time as other sites, on the peninsula, were being restored. Purple urchin densities were reduced from 5.3 m^2 to 1.2 m^2 in a total area of 2.64 acres.

In Year 5 of the project Underwater Arch looked to be on track with giant kelp, fish biomass, and invertebrates with lowered purple urchin densities. However, during annual monitoring at the end of Year 5 a section further east of the area revisited in Year 4 was observed. This area will be surveyed in the fall of 2018 and may require sea urchin suppression to reestablish the kelp forest.

We have a few hypotheses of what could have led to the resurgence of urchins at Underwater Arch. First being that it was early in this project's inception when Underwater Arch was restored, and steady work in urchin suppression by commercial sea urchin harvesters was limited. Additionally, this site was largely restored by volunteer divers who were on SCUBA not hooka and lacked the same amount of continuity of effort and experience as the sea urchin harvesters contracted elsewhere. It is possible that urchins were missed under boulders and in cryptic crevices during this period. Another possibility, the region of Underwater Arch inhabiting the resurgence of urchins is surrounded the largest tidepool on the peninsula. It is possible this tidepool acted as a refuge for urchins during restorative urchin suppression and the recent wasting event. Lastly, there is a possibility that there was a recruitment event of purple sea urchins to Underwater Arch Cove. If this is the case these urchins recruited and grew to an adult size within a years time.

As with Honeymoon Cove increased efforts were made to collect georeferenced photos and video to visually represent the changes overtime in the same if not similar locations.

Marguerite

Marguerite is an expansive area of reef located between Honeymoon Cove to the north and Underwater Arch Cove to the south. Restoration actions were initiated in August of 2014 at the southern and northern terminuses of this site. At times, three restoration teams were working in this area weekly as they progressed towards one another reducing the gap between them, a southerly progression for the northerly operations and the northerly progression to the teams working to the south. This site is openly exposed to northerly and westerly swell energy and receives some wrap around from south westerly energy. This site is comprised of high relief reefs with semi vertical walls, 20-30 feet in height extending from the sea floor to the surface. Between these reefs expansive boulder fields and some sandy expanses exist. The shore line is defined by bench-like bedrock or cobble beaches. This site has had more deep area to be restored than others with some efforts occurring at the ocean-ward reef margins in depths of 40 to 45 feet. The physical structure of this site will likely support higher rates of fish production and increased diversity of benthic organisms due to the heterogeneity of the substrate. From an aesthetic perspective it's beautiful to dive.

In year 4, 5.1 acres were restored for a total of 13.9 acres in Marguerite since August 2014. Restoration actions have been completed at this site as of March 2017.

Photos and videos for marguerite were collected in summer 2018 and will continue to visit the site at least annually.

Additional research associated with this project was started in this site in summer 2016. This effort attempts to describe some of the physical and chemical changes associated with the presence or absence of kelp on the reef at Marguerite. Working with Brain Gaylord, a professor at UC Davis Bodega Marine Laboratory, Kerry Nickols, assistant professor at CSU Northridge, and Kristen Elsmore, a Ph.D. candidate at UC Davis, the research program has deployed pressure sensors, acoustic doppler current profilers, and thermistor strings to measure the effects of kelp canopy on sediment transport, wave energy and advective currents. In addition to understanding the physical changes to the environment, chemical properties associated with pH and dissolved oxygen will be collected in concert with biomass assessments of the kelp to evaluate chemical changes to the sea water that may result from the development and persistence of giant kelp. Other partnerships with UCLA's Institute of the Environment are in development which will further enhance the capacity of this research effort in the way of chemical analyses and biomass estimates via drone based multispectral imagery respectively.

Hawthorne

This restoration site exists south of Underwater Arch Cove. It is a section of exposed coast comprised of a few large emergent bedrock shelves or prominences and otherwise comprised of boulders forming low lying expanses of unconsolidated reef. An area slightly less than an acre outside of the previous restored area was found supporting high densities of purple sea urchins and was cleared during this year of the project. Further surveys and monitoring to the south and east of the existing restoration site will be conducted this coming year as conditions allow. Hawthorne has proven to be a very dynamic site with high wave energy, a discernable amount of sediment movement and suspended sediment, and in 2015-2016 there were long periods of poor visibility. In Year 5 of the project a deeper section adjacent to the previously restored area was identified with high urchin densities and was restored.
Video and photos were captured this reporting period and dive conditions have improved greatly in recent months. Restoration efforts in this area will be a priority in the coming year.

Point Fermin

Point Fermin is near the southeasterly terminus of the Palos Verdes Peninsula. Restoration actions were started in July of 2015 and were suspended in September 2015. Greater than 3.9 acres were restored in those few months clearing an urchin barren that is roughly central to the shallow expanses of the reef complex. Restoration activities resumed in September 2016 clearing 1.35 acres of reef. This reef is low relief, largely tabular and soft sedimentary rock, making it very different than the other restoration sites. In addition, Point Fermin is sheltered from northerly and westerly swells but is directly exposed to southerly and some south westerly energy. The restoration efforts at Fermin have resulted in the development of kelp, other macroalgae and several phyla of sessile life on the reef. The photos and videos from Point Fermin quite convincingly display the changes resulting from the urchin suppression in that site.

More area at Point Fermin will be targeted during Year 6 of the project.

Surveys and photographic and video documentation will continue in the coming years to ensure that the purple urchin densities remain at no more than two per square meter. There are areas of Point Fermin that haven't been surveyed by project staff. Efforts to more comprehensively explore and understand the condition of Point Fermin will commence in the coming year.

Resort Point

Resort Point is a reef further offshore Honeymoon Cove in 40-60 ft. depth. Restoration efforts began during this reporting period (Year 5). High purple urchin densities were discovered at this site alongside a persistent and dense kelp forest. The restoration efforts at this site were to thwart off a possible shift to a barren state once the giant kelp senesced. Therefore, this site was worked as a preventative effort. Currently, the reef has been restored to the 60' bathymetry line although more reef and urchins exist deeper. Year 6 efforts have shifted to the urchin barren located at White Point. However, further monitoring of Resort Point and work will likely continue during year 6 of the project.

References

Bradley, RA, and Bradley, DW 1993. Wintering shorebirds increase after kelp (Macrocystis) recovery. The Condor, 95: 372-376

Californian Department of Fish and Wildlife 2005. Abalone Recovery and Management Plan. www.dfg.ca.gov/mrd/armp/index.html.

Californian Department of Fish and Wildlife 2016. Marine Region 2015 By the Numbers. https://www.wildlife.ca.gov/Fishing/Ocean/Year-In-Review

Claisse et al. 2013. Kelp forest restoration has the potential to increase sea urchin gonad biomass. Ecosphere 4(3):38

Cowen, RK 1983. The effects of sheephead (Semicossyphus pulcher) predation on red sea urchin (Strongylocentrotus franciscanus) populations: an experimental analysis. Oecologia, 58: 249-255.

Dayton, PK 1985. Ecology of Kelp Communities. Annual Review of Ecology and Systematics, 16: 215-245.

Dayton, P, Tegner, M, Edwards, P, and Riser, K 1998. Sliding baselines, ghosts, and reduced expectations in kelp forest communities. Ecological Applications, 8: 309-322.

Dojiri M, Yamaguchi M, Weisberg SB, Lee HJ 2003. Changing anthropogenic influence on the Santa Monica Bay watershed. Marine Environmental Research 56: 1-14

Duggins DO, Simenstad CA, Estes JA 1989. Magnification of secondary production by kelp detritus in coastal marine ecosystems. Science 245: 170-173

Edwards, M 2004. Estimating scale-dependency in disturbance impacts: El Niños and giant kelp forests in the northeast Pacific. Oecologia, 138: 436-447.

Erisman BE, Allen LG, Claisse JT, Pondella DJ, Miller EF, Murray JH, Walters C 2011. The illusion of plenty: hyperstability masks collapses in two recreational fisheries that target fish spawning aggregations. Canadian Journal of Fisheries and Aquatic Sciences 68: 1705-1716

Ford T, Meux B 2010. Giant kelp community restoration in Santa Monica Bay. Urban Coast 2: 43-46

Foster MS, Schiel DR 2010. Loss of predators and the collapse of southern California kelp forests (?): Alternatives, explanations and generalizations. Journal of Experimental Marine Biology and Ecology 393: 59-70

Graham MH 2004. Effects of local deforestation on the diversity and structure of southern California giant kelp forest food webs. Ecosystems 7: 341-357

Graham MH, Vasquez JA, Buschmann AH 2007. Global ecology of the giant kelp Macrocystis: from ecotypes to ecosystems. Oceanography and Marine Biology: An Annual Review 45: 39-88

Harrold C, Reed DC 1985. Food availability, sea urchin grazing, and kelp korest community structure. Ecology 66: 1160-1169

Jackson, JBC 2001. What was natural in the coastal oceans? Proceedings of the National Academy of Sciences of the United States of America, 98: 5411-5418.

Kildow, J, and Colgan, CS 2005. California's ocean ecology. Report to the Resources Agency, State of California. Prepared by The National Ocean Economics Program. http://resources.ca.gov/press_documents/CA_Ocean_Econ_Report.pdf.

Lafferty, KD 2004. Fishing for lobsters indirectly increases epidemics in Sea Urchins. Ecological Applications, 14: 1566-1573.

Love, M 2006. Subsistence, Commercial, and Recreational Fisheries. In: Allen L, Pondella II D, Horn M (eds) Ecology of Marine Fishes. University of California Press, Berkeley, pp 567-594

Norderhaug, KM, and Christie, HC 2009. Sea urchin grazing and kelp re-vegetation in the NE Atlantic. Marine Biology Research, 5: 515-528.

Pondella D, II 2009. Science Based Regulation: California’s Marine Protected Areas. Urban Coast 1: 33-36

Pondella DJ, Williams JP, Claisse JT, Schaffner B, Schiff K 2011. Physical and biological characteristics of nearshore rocky reefs in the Southern California Bight: A report the to the Southern California Water Research Project. 26 pp.

Schiff K 2003. Impacts of stormwater discharges on the nearshore benthic environment of Santa Monica Bay. Marine Environmental Research 56: 225-243

Sikich S, James K 2010. Averting the scourge of the seas: Local and state efforts to prevent plastic marine pollution. Urban Coast 1: 35-39

Smith, JR, Reed, BJ, Mohajerani, L, and Fong, P 2004. Influence of abiotic factors on the persistnce of kelp habitats along the north coast of Santa Monica Bay. Bulletin of the Southern California Academy of Sciences, 103: 79-92.

Steneck, RS, Graham, MH, Bourque, BJ, Corbett, D., Erlandson, J. M., Estes, J. A., and Tegner, M. J. 2002. Kelp forest ecosystems: biodiversity, stability, resilience and future. Environmental Conservation, 29: 436-459.

Tegner MJ, Dayton PK 2000. Ecosystem effects of fishing in kelp forest communities. ICES Journal of Marine Science 57: 579-589