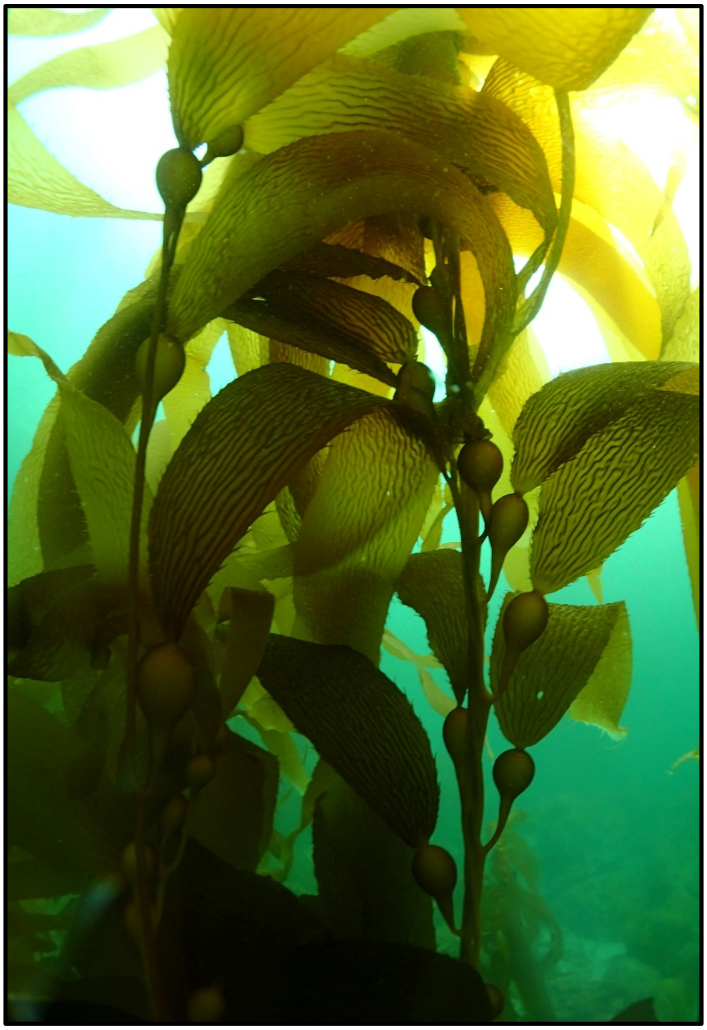
Palos Verdes Kelp Forest Restoration Project

2015 Annual Report



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Thanks to our Project Partners and Supporters:

The Bay Foundation
Montrose Settlements Restoration Program
NOAA Restoration Center
Commercial Sea Urchin Harvesters
Vantuna Research Group
Los Angeles Waterkeeper
Southern California Marine Institute
California Science Center

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 76% (Figure 1).

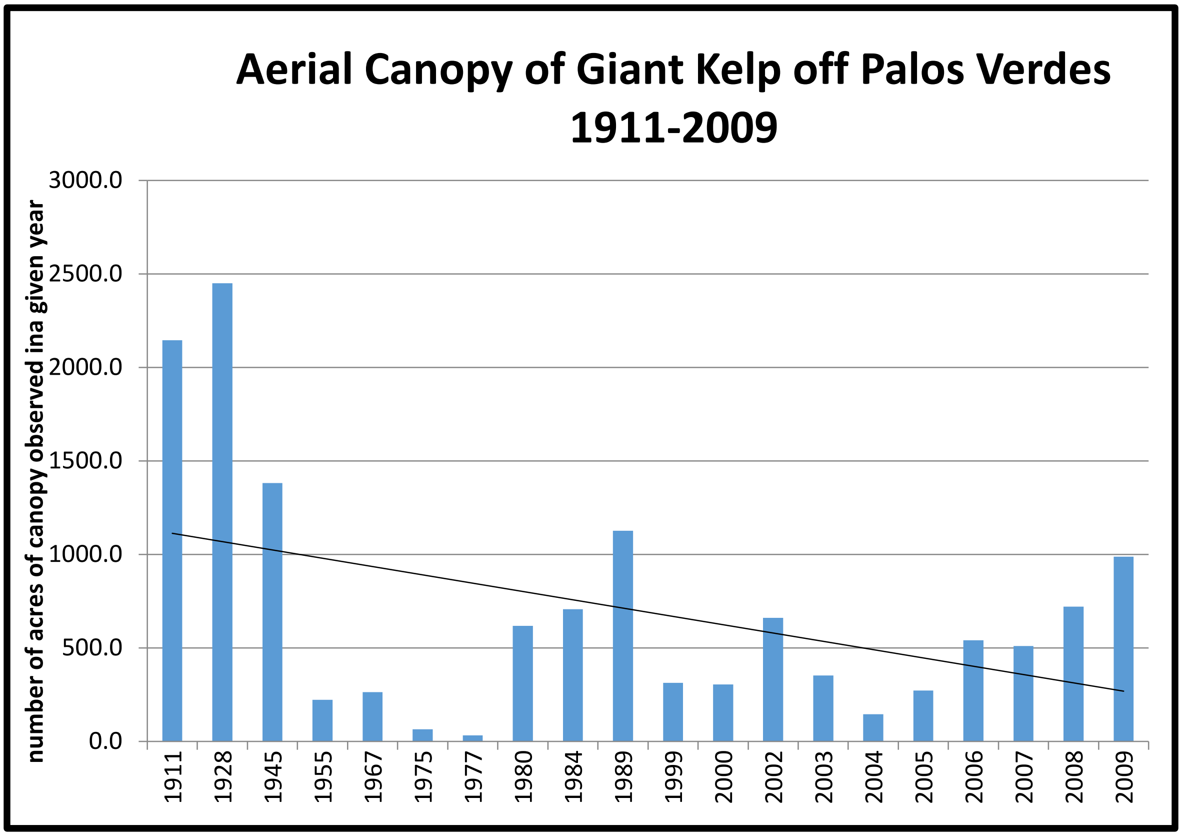


Figure 1. Status of the Kelp Beds 1911-2009, Ventura and Los Angeles Counties. Central Region Kelp Survey Consortium, June 2010. Prepared by: MBC Applied Environmental Sciences. Costa Mesa, CA 92626

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 sea urchins, *Strongylocentrotus purpuratus* and *Strongylocentrotus franciscanus.* 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 forest ecosystems are iconic and productive features along the coast of California. *Macrocystis pyrifera* (Giant Kelp) typically forms a complex 3-dimensional habitat which can support over 700 species (Graham 2004). Drift kelp and associated dissolved organic matter also provide an energetic resource to populations of species both within and around kelp beds (Harrold and Reed 1985; Duggins et al. 1989; Tegner and Dayton 2000; Graham et al. 2007). However, Sea urchins in high densities, typically *Strongylocentrotus purpuratus* (Purple Sea Urchin) and *Strongylocentrotus franciscanus* (Red Sea Urchin), can clear expanses of kelp forest, leaving the reef devoid of standing macroalgae (Harrold and Reed 1985b; Graham 2004). These urchin barrens are observed to support far fewer species and a corresponding decrease in biomass (Bradley and Bradley 1993; Graham 2004; VRG unpublished data). This reduction in ecosystem structure and function leads to spatially and temporally unstable kelp forests and reduces production.

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 conducted by The Los Angeles Waterkeeper (LAW), Santa Monica Bay Restoration Commission (SMBRC) and The Bay Foundation (TBF). To enable the recovery of historical kelp forests in Santa Monica Bay, the "Kelp Project" has engaged in sea urchin relocation to reduce the density of urchins on shallow rocky reefs since 1997. 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 6 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 54 hectares of existing urchin barrens which have been identified along the Palos Verdes Peninsula (Figure 4).

Figure 2. Long Point pre-restoration in 2005.

Figure 3. Long Point post-restoration in 2008.

The Red Sea Urchin (*Strongylocentrotus franciscanus*) fishery is one of the most important commercial fisheries in the State of California. In 2009, *S. franciscanus* landings ranked 3rd by weight (over 12 million lbs or 5.4 million kg) and 4th in value (7.8 million US Dollars) (CDGF 2010). Commercial sea urchin harvesters are included in kelp restoration projects due to their peripheral interest in restoration success, namely as areas where they preferentially collect high quality *S. franciscanus* for their fishery. Therefore, information about the impact of restoration on these sea urchins is of great importance to the success of kelp restoration projects.

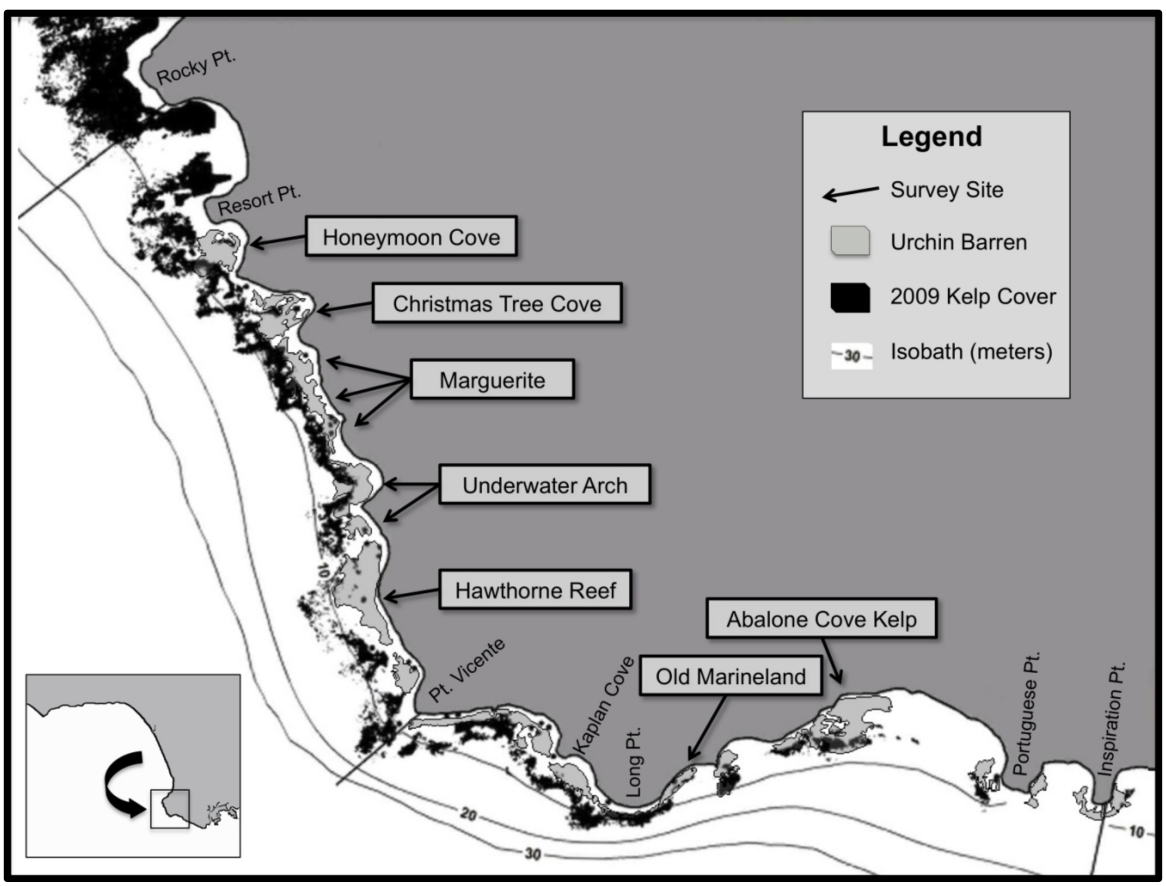


Figure 4. Map of existing urchin barrens on the southwest coast of Palos Verdes Peninsula

Kelp Restoration Goals

Over the past 100 years, the Palos Verdes Peninsula has lost approximately 75% of its giant kelp canopy. Sedimentation, development, urban runoff and storms have slowed kelp growth. At the same time, the loss of key urchin predators and competitors allowed urchins to overrun the reef and devour the remaining kelp. Subtidal observations based upon mapping efforts conducted in 2010 identified large expanses of nearshore rocky reef that were dominated by high densities of sea urchins, *Strongylocentrotus purpuratus* and *Strongylocentrotus franciscanus.* In total, 61.5 hectares were described to exist in an urchin barren state. The purpose of the project is to reduce the density of purple sea urchins (*Strongylocentrotus purpuratus*) to two per square meter within the boundaries of sea urchin barrens on the Palos Verdes Peninsula. This will allow for the recruitment and development of giant kelp, (*Macrocystis pyrifera*) 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.

Timeline of Restoration Goals

The project is currently fully engaged in restoration and monitoring activities in restoration, control and reference sites. Urchin suppression work was initiated by The Bay Foundation and Los Angeles Waterkeeper in July of 2013 in Underwater Arch Cove. Commercial Urchin divers began restoration work in Honeymoon Cove in October 2013. Restoration activity progress and diving effort for July 2013 through June 2014 and July 2014 through June 2015 are shown in Tables 1 and 2.

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 1 is projected for this coming operational year, July 1, 2015 through June 30, 2016, listed in Table 3. Much of the area yet to be monitored and restored in these sites is 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. With the presence of a strong ENSO signature and the potential for large storm events progress in these areas in the foreseeable future may be quite limited. When conditions are favorable, these challenging areas will receive preferential or high priority from an operational standpoint.

Table 1. Restoration Progress July 1, 2013 through June 30, 2014 and July 1, 2014 through June 30, 2015

Site Name	Area Cleared (Acres) Year 1 July 2013 - June 2014	Area Cleared (Acres) Year 2 July 2014 - June 2015	Total Area (acres)
Honeymoon Cove	6.77	1.56	8.33
Underwater Arch Cove	5.91	2.46	8.37
Marguerite	0.00	6.53	6.53
Hawthorne	0.00	4.29	4.29
Total Area	12.68	14.84	27.52

Table 2. Total effort diving towards project goals July 1, 2014 through June 30, 2015.

Effort (dive hours)	Monitoring	Restoration
The Bay Foundation	630.40	71.93
LA Waterkeeper	133.37	942.08
Commercial Sea Urchin Harvesters	-	3674.95
Total Dive Hours	763.77	4688.96

Table 3. Work will target these areas July 1, 2015 through June 30, 2016.

Site Name	Total Area Acres	Start Date	Area Cleared (Acres)	Status	Centroid
Honeymoon Cove	10.05	July-13	8.33	In Progress	33.764, -118.423
Underwater Arch Cove	13.24	October-14	8.37	In Progress	33.752, -118.415
Marguerite	12.82	August-14	6.53	In Progress	33.757, -118.418
Hawthorne	22.14	January-15	4.29	In Progress	33.747, -118.414
Point Fermin	10.80	July-15			33.704, -118.291
Total	**69.05**		**27.52**		

Pre Restoration Monitoring

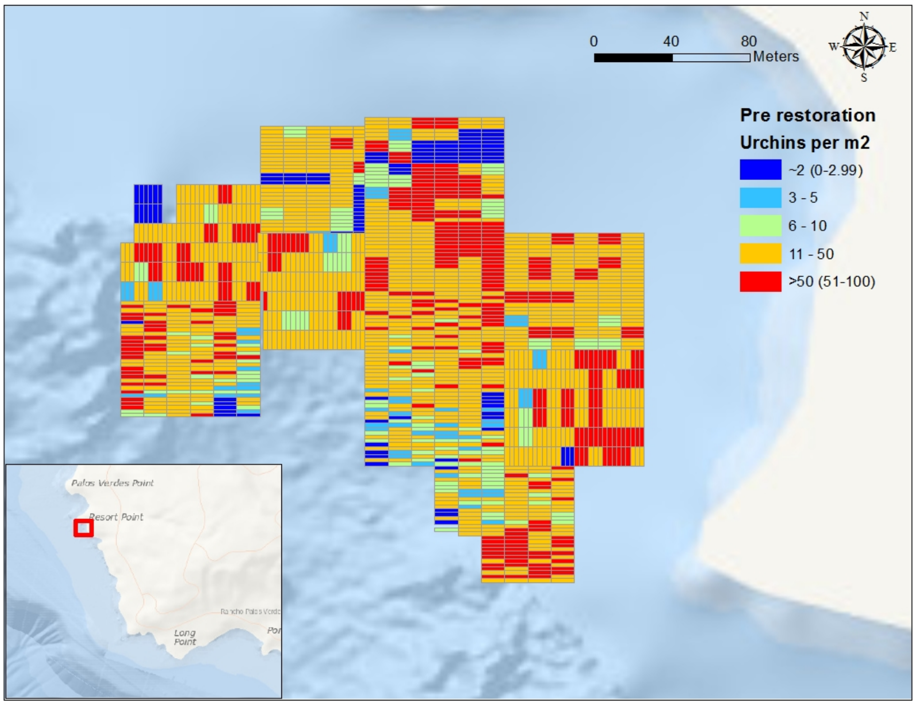
Restoration sites have been established in 4 sites off Palos Verdes: Honeymoon Cove, Marguerite, Underwater Arch Cove, and Hawthorne. Pre-restoration monitoring is conducted on all sites according to DFW standards stipulated in the terms of the SCP. Restoration sites are divided into 30m by 30m blocks each comprised of 15 transects (2m by 30m swath) monitored by divers. Each transect is divided into 10m 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. During the initial phase of the project (July 2013 to March 2014), all 15 transects (per block), covering 100% of the restoration block were monitored.

Field staff engaged in the adaptive management of the project noted the time consuming nature of pre-monitoring transects in comparison to post monitoring. To continue to make progress in a manner consistent with contracts, keeping restoration teams engaged and most importantly the ecology of the region; program management staff at TBF in consultation with NOAA biologists conducted an applied power analysis on the pre-monitoring data set from July 2013 through February 2014. This analysis described no loss in statistical strength and conversely no gain in accuracy in continuing to pre-monitor all of the transects within any given restoration block. A more precise description of the process involved in this determination is provided in the following paragraph.

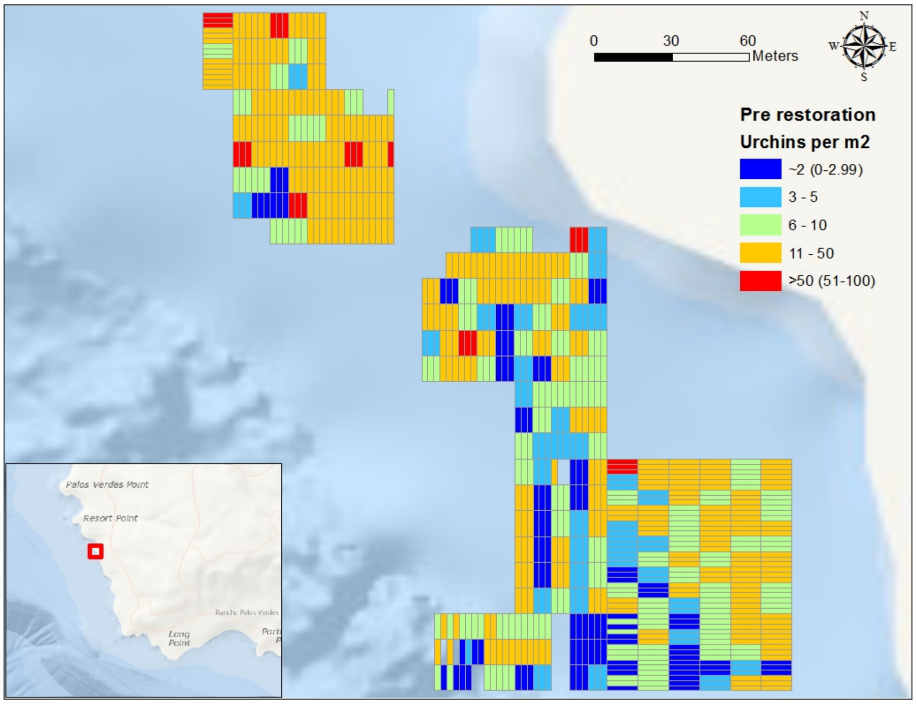
Restoration blocks are still each comprised of a 30m by 30m area unless truncated due to natural topography. Each block is made up of 15 transects covering a 2m wide swath of area -- or 1m on either side of the deployed 30m transect tape. However, based on an applied power analysis, a reduction of sampling area by 66% allowed for the same statistical results, or no significant difference in the data. This power analysis compared pre-restoration data on blocks with the full number of transects against the same data using only 5 transects per block. As the data exhibited the same results, a reduction in the number of pre-monitoring transects was possible, reducing effort and increasing the efficiency of the overall project. Therefore, sampling was only conducted on every third transect for a total of 5 pre-restoration transects monitored on every 30m by 30m restoration block instead of 15 transects. These 5 transects still accurately represent, statistically, the full 30m by 30m block. The reduction in pre-monitoring allowed for a substantial increase in restoration efforts, while making the pre-restoration monitoring more cost-effective. Because the maps (see Appendix 1) are representative of the pre-monitoring efforts, and because there were no significant differences in evaluating the data on 5 versus 15 transects, the same data can still be displayed on the map for each restoration block. Now each transect accurately represents a 6m swath rather than a 2m swath, and thus the data can be displayed spatially without showing breaks within each individual restoration block. Additionally, each transect is still broken up into 10m segments, and those continue to be analyzed and displayed the same way for both pre and post monitoring maps.

All data collected (i.e., date, area, team members, level of effort, density of urchins pre and post restoration, giant kelp density and size characterization, and substrate) are entered, QAQC'd and managed utilizing a georeferenced database. Maps 1 through 5 display the estimated purple urchin densities before restoration activities [within each 10m segment for Honeymoon Cove, Marguerite, Underwater Arch Cove and Hawthorne]. Marguerite is divided into north and south sections due to its orientation, (Marguerite is more linear and difficult to display with the same resolution as the other sites).

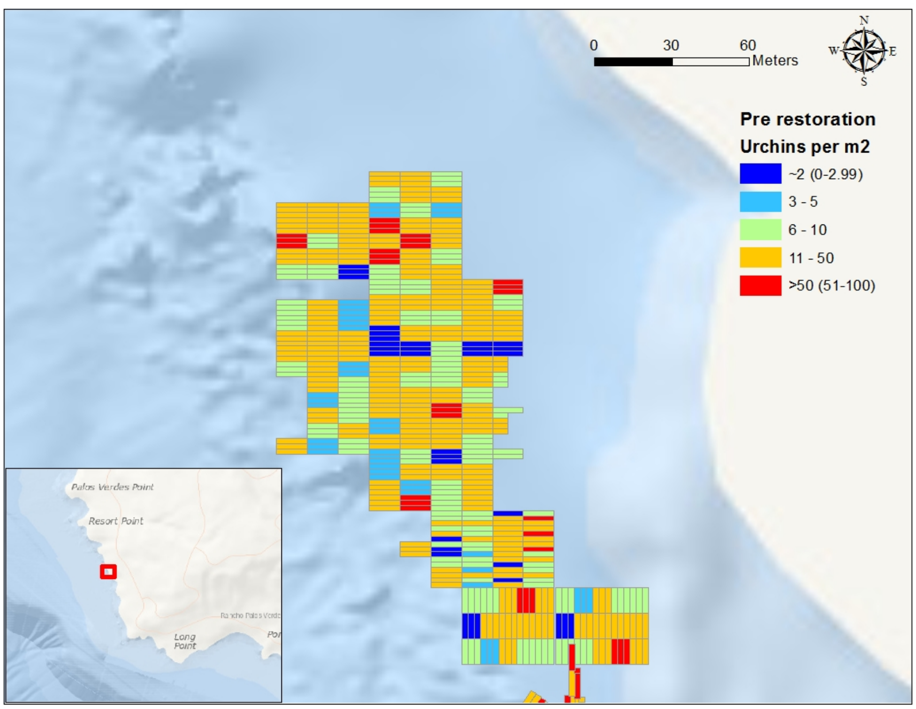
Note: The scales for the maps are not identical; Honeymoon Cove and Underwater Arch Cove are displayed at 40 meter scale and Marguerite (north and south) and Hawthorne are at a 30 meter scale. The maps are presented in a descending order from the north to south along the Palos Verdes Peninsula.



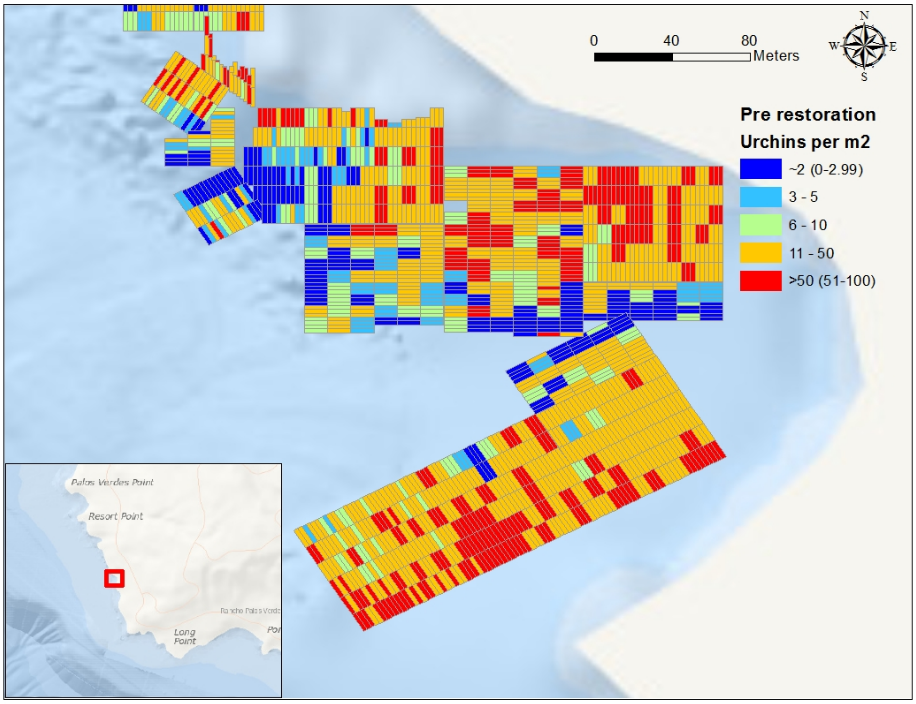
Map 1. Density of *S. purpuratus* (individuals per square meter) pre-restoration in Honeymoon Cove, Palos Verdes, California. See Appendix 1 for larger map images.



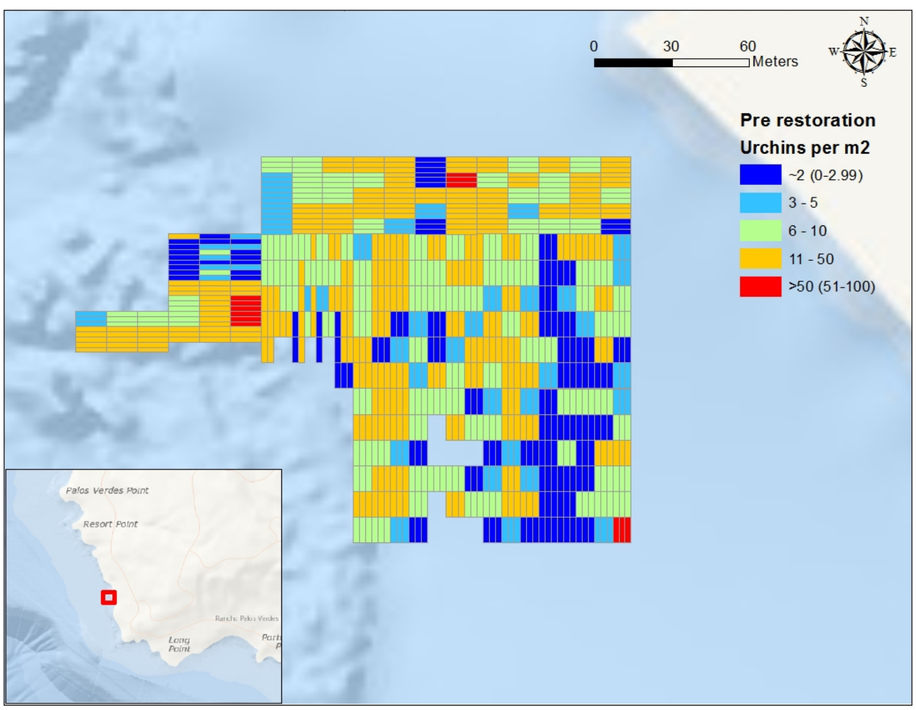
Map 2. Density of *S. purpuratus* (individuals per square meter) pre-restoration in Marguerite (north), Palos Verdes, California. See Appendix 1 for larger map images.



Map 3. Density of *S. purpuratus* (individuals per square meter) pre-restoration in Marguerite (south), Palos Verdes, California. See Appendix 1 for larger map images.



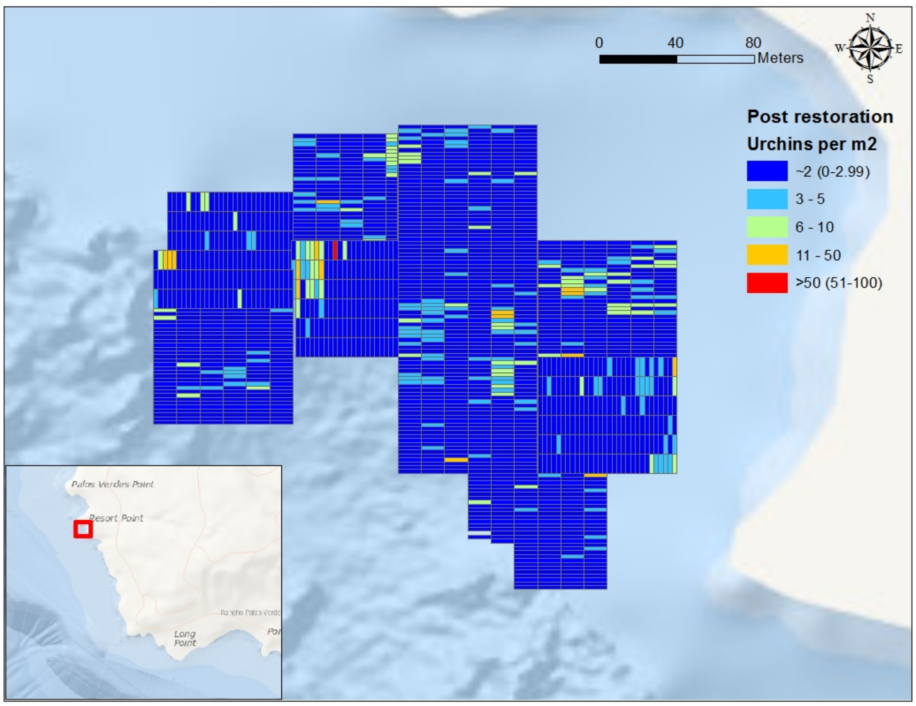
Map 4. Density of *S. purpuratus* (individuals per square meter) pre-restoration in Underwater Arch Cove, Palos Verdes, California. See Appendix 1 for larger map images.



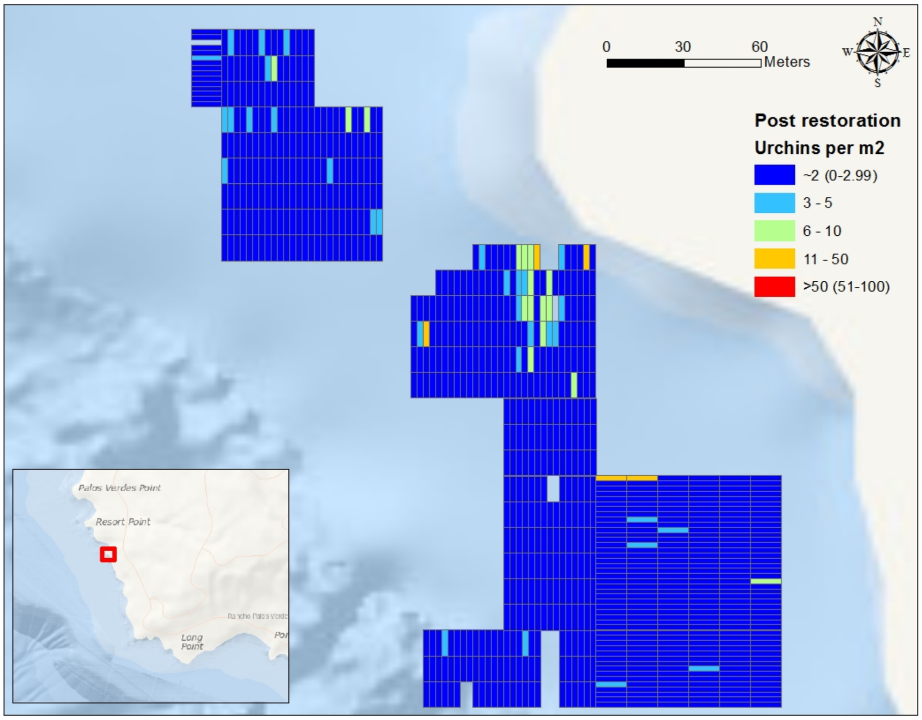
Map 5. Density of *S. purpuratus* (individuals per square meter) pre-restoration in Hawthorne, Palos Verdes, California. See Appendix 1 for larger map images.

Compliance Monitoring

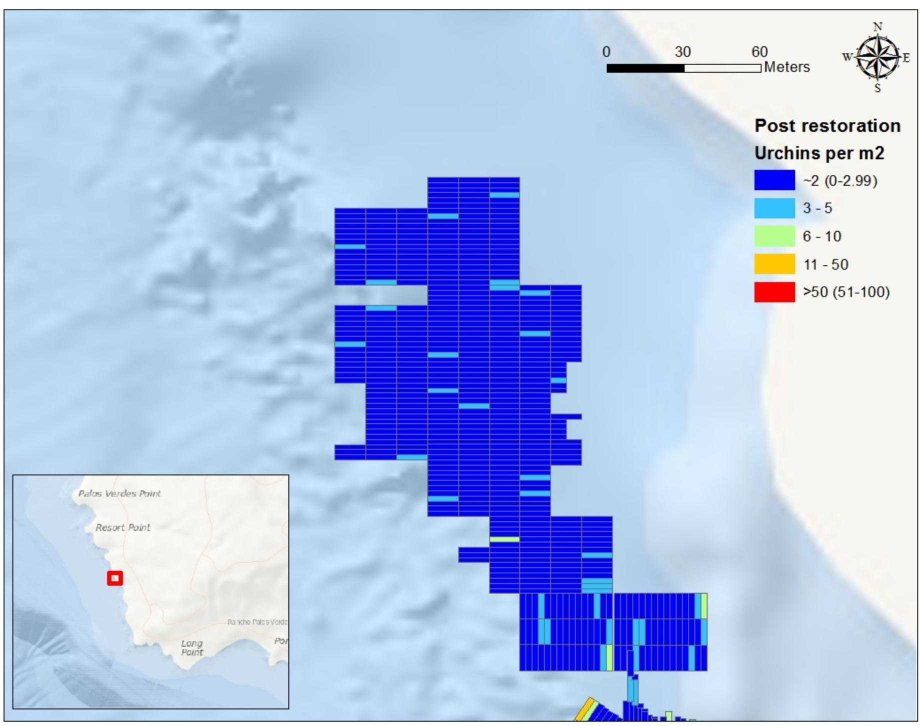
Monitoring is conducted weekly to bi-weekly depending upon the rate of activity of restoration teams in the preceding week. This work is performed by The Bay Foundation staff to ensure that restoration work is achieving performance standards. The standards are 1) the initial reduction of sea urchins 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 patches and pockets of high urchin density. 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 transects, covering 100% of the block are surveyed during post-monitoring to ensure that no pockets of high density urchins are left in the site. Maps 6 through 10 display the estimated purple urchin densities after restoration activities within each 10m segment for Honeymoon Cove, Marguerite, Underwater Arch Cove and Hawthorne. These areas 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.



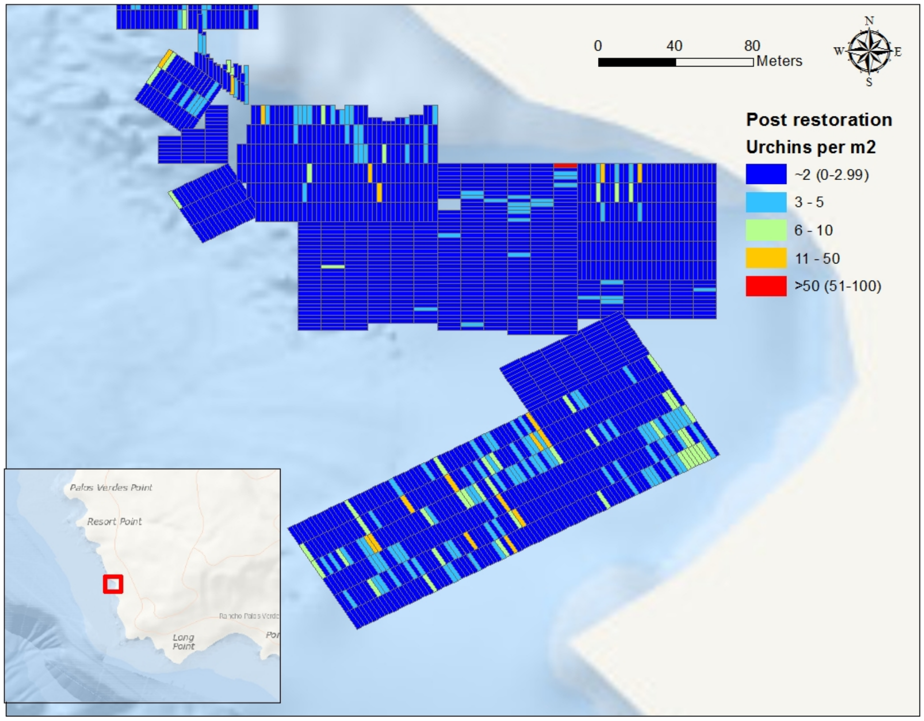
Map 6. Density of *S. purpuratus* (individuals per square meter) post-restoration in Honeymoon Cove, Palos Verdes, California. See Appendix 1 for larger map images.



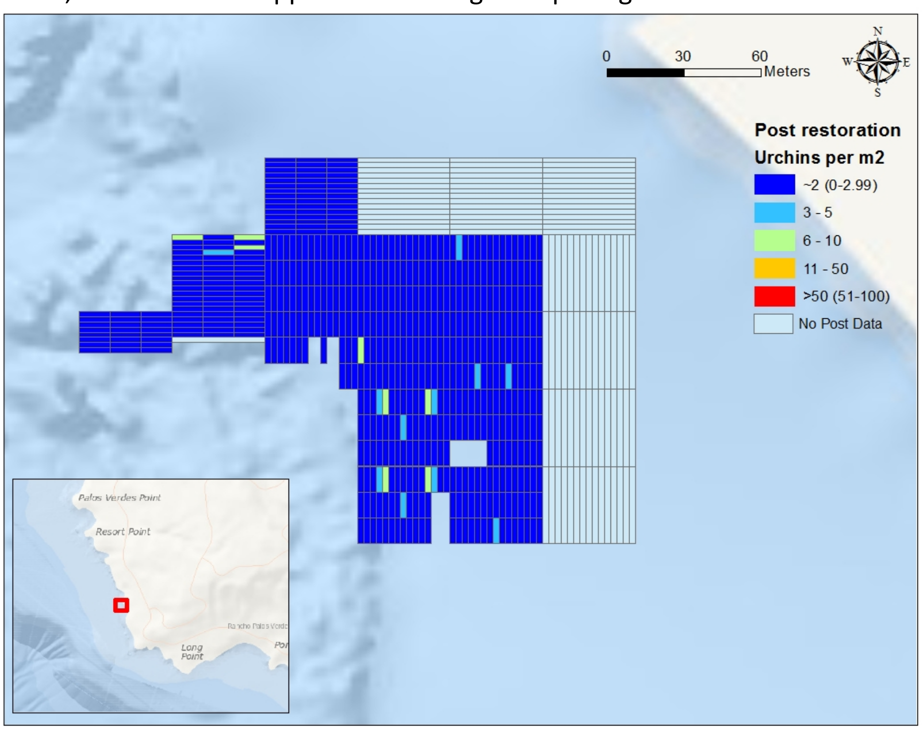
Map 7. Density of *S. purpuratus* (individuals per square meter) post-restoration in Marguerite (north), Palos Verdes, California. See Appendix 1 for larger map images.



Map 8. Density of *S. purpuratus* (individuals per square meter) post-restoration in Marguerite (south), Palos Verdes, California. See Appendix 1 for larger map images.



Map 9. Density of *S. purpuratus* (individuals per square meter) post-restoration in Underwater Arch Cove, Palos Verdes, California. See Appendix 1 for larger map images.



Map 10. Density of *S. purpuratus* (individuals per square meter) post-restoration in Hawthorne, Palos Verdes, California. See Appendix 1 for larger map images. Note – the 7 blocks missing post data (light blue/gray) are explained in Section G. <u>Evaluation of successes and failures of restoration activities for each site.</u>

Response Monitoring

This monitoring focuses on responses of the natural community to restoration activities. The focus of this effort is subtidal utilizing an adapted 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 *Strongylocentrotus franciscanus* and *Strongylocentrotus purpuratus* specific to the Palos Verdes Peninsula will be 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. Urchins were collected and dissected for this study in fall 2014.

As indicated elsewhere in this report and in other communication with CADFW; field conditions, e.g., sea state, visibility and ocean climate, (temperature and swell) have been challenging for the restoration and monitoring efforts for much of 2015. It is also important to note that the timing of the compliance monitoring for fishes and other community responses to the restoration efforts were conducted in the late spring and early summer in 2011-2014, with only two exceptions in 2011, (i.e., Honeymoon Cove and Point Vicente West were monitored on 1-28-2011 and 10-12-2011 respectively). In 2015, the surveys were conducted within the month of September with the exception of Honeymoon Cove which was surveyed on 8-19-2015. This shift in seasonality may affect some species differentially skewing the data. Perhaps more significant is the strong ENSO signature this year, sea surface temperatures have been elevated throughout 2015, with persistent sea surface temperatures off of Palos Verdes neighboring 20 degrees Celsius. These abnormally high temperatures are known to affect species composition within southern California rocky reef systems.

Table 7. Fish Species Richness (total number of species)

Designation	*Site*	**2011**	**2012**	**2013**	**2014***	**2015**
Control	Abalone Cove Kelp West	7	7	10	9	8
	Marguerite Central	6	10	10	9	11
Restoration	Underwater Arch Cove	6	9	6	12	8
	Honeymoon Cove	0	2	4	8	5
Reference	Point Vicente West	8	6	10	11	12
	Rocky Point North	8	8	8	9	7

*Note: *2014 is the first post-restoration year*

Density of Kelp Forest Ecosystem Species

Table 8. Density (individuals/ 100 m^2) of Kelp and related understory algal species, Red Urchins *(Strongylocentrotus franciscanus),* purple urchins (*Strongylocentrotus purpuratus)* and Lobster *(Panulirus interruptus)*

			2011		2012		2013		2014		2015	
Species	*Designation*	*Site*	Mean Density (#/100m^2)	SE	Mean Density (#/100m^2)	SE	Mean Density (#/100m^2)	SE	Mean Density (#/100m^2)	SE	Mean Density (#/100m^2)	SE
Cystoseira osmundacea	Control	Abalone Cove Kelp West	—	—	—	—	—	—	—	—	—	—
		Marguerite Central	—	—	0.8	0.8	—	—	—	—	—	—
	Restoration	Underwater Arch Cove	—	—	—	—	11.7	1.7	10.8	4.2	22.5	13.5
		Honeymoon Cove	2.5	2.5	—	—	—	—	—	—	0.8	0.5
	Reference	Point Vicente West	0.8	0.8	—	—	—	—	—	—	1.7	1.0
		Rocky Point North	—	—	—	—	—	—	2.5	0.8	5.0	3.0
Egregia menziesii	Control	Abalone Cove Kelp West	2.5	2.5	—	—	—	—	—	—	—	—
		Marguerite Central	—	—	—	—	—	—	—	—	—	—
	Restoration	Underwater Arch Cove	—	—	—	—	—	—	—	—	0.8	0.5
		Honeymoon Cove	—	—	—	—	—	—	—	—	—	—
	Reference	Point Vicente West	19.2	12.5	13.3	8.3	10	10	3.3	1.7	30.0	3.0
		Rocky Point North	—	—	—	—	5	—	12.5	5.8	15.8	4.5
Eisenia arborea	Control	Abalone Cove Kelp West	—	—	—	—	—	—	—	—	—	—
		Marguerite Central	11.7	11.7	3.3	3.3	12.5	5.8	—	—	—	—
	Restoration	Underwater Arch Cove	—	—	—	—	—	—	—	—	—	—
		Honeymoon Cove	—	—	—	—	—	—	—	—	—	—
	Reference	Point Vicente West	226.7	80.0	253.3	25.0	291.7	8.3	39.2	17.5	97.5	9.5
		Rocky Point North	—	—	2.5	2.5	18.3	11.7	28.3	6.7	10.8	1.5
Pterygophora californica	Control	Abalone Cove Kelp West	—	—	—	—	—	—	—	—	—	—
		Marguerite Central	—	—	—	—	—	—	—	—	—	—
	Restoration	Underwater Arch Cove	—	—	—	—	—	—	—	—	—	—
		Honeymoon Cove	—	—	—	—	—	—	—	—	—	—
	Reference	Point Vicente West	—	—	—	—	0.8	0.8	—	—	—	—
		Rocky Point North	—	—	—	—	—	—	—	—	—	—
Macrocystis pyrifera	Control	Abalone Cove Kelp West	4.2	4.2	—	—	—	—	—	—	56.7	7.0
		Marguerite Central	—	—	—	—	—	—	10.0	10.0	7.5	1.5
	Restoration	Underwater Arch Cove	—	—	—	—	—	—	25	—	45.8	2.5
		Honeymoon Cove	1.7	1.7	—	—	—	—	7.5	7.5	222.5	62.5
	Reference	Point Vicente West	28.3	6.7	27.5	10.8	12.5	0.8	5.8	2.5	13.3	5.0
		Rocky Point North	110	15.0	20	3.3	76.7	15.0	319.2	169	25.8	1.5
Panulirus interruptus	Control	Abalone Cove Kelp West	0.8	0.8	—	—	—	—	—	—	—	—
		Marguerite Central	—	—	—	—	—	—	—	—	4.2	2.5
	Restoration	Underwater Arch Cove	—	—	—	—	0.8	0.8	—	—	—	—
		Honeymoon Cove	—	—	—	—	—	—	—	—	—	—
	Reference	Point Vicente West	2.5	0.8	0.8	0.8	1.7	1.7	0.8	0.8	14.2	8.5
		Rocky Point North	—	—	—	—	1.7	1.7	2.5	2.5	1.7	—
Strongylocentrotus franciscanus	Control	Abalone Cove Kelp West	464.2	221	165.8	129	110	10.0	50	11.7	0.8	0.5
		Marguerite Central	45	16.7	58.3	30	12.5	0.8	8.3	3.3	2.5	1.5
	Restoration	Underwater Arch Cove	54.2	17.5	33.3	13.3	23.3	18.3	42.5	7.5	2.5	0.5
		Honeymoon Cove	63.3	1.7	44.2	0.8	34.2	4.2	11.7	1.7	7.5	1.5
	Reference	Point Vicente West	31.7	10	55.8	27.5	32.5	4.2	26.7	10.0	2.5	0.5
		Rocky Point North	5.0	5.0	9.2	9.2	1.7	1.7	0.8	0.8	—	—
Strongylocentrotus purpuratus	Control	Abalone Cove Kelp West	1250	250	902.5	268	462.5	87.5	1567.5	318	11.7	1.0
		Marguerite Central	2450	900	5765	1527	1499.2	80.8	1705.8	303	193.3	30.0
	Restoration	Underwater Arch Cove	2195.8	471	939.2	349	1008.3	465	24.2	10.8	1.7	—
		Honeymoon Cove	1541.7	142	1222.5	216	1223.3	303	325	298	9.2	0.5
	Reference	Point Vicente West	247.5	75.8	490.8	369	535.8	47.5	185.8	5.8	16.7	3.0
		Rocky Point North	15.8	7.5	30.8	12.5	10.0	8.3	3.3	0.0	5.8	3.5

Fish Data Processing

Because sites were sampled over a time 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 $100m^2$.

Table 9. Density (individuals per 100 meters squared) of *P. clathratus* and *S. pulcher*

			2011		2012		2013		2014		2015	
Species	*Designation*	*Site*	Mean Density (#/$100m^2$)	SE	Mean Density (#/$100m^2$)	SE	Mean Density (#/$100m^2$)	SE	Mean Density (#/$100m^2$)	SE	Mean Density (#/$100m^2$)	SE
Paralabrax clathratus	Control	Abalone Cove Kelp West	0.4	0.4	—	—	0.8	0.5	0.4	0.4	0.8	0.3
		Marguerite Central	—	—	1.2	1.2	1.7	1.2	3.3	0.7	3.0	1.8
	Restoration	Underwater Arch Cove	—	—	0.4	0.4	0.4	0.4	6.7	4.5	2.5	1.3
		Honeymoon Cove	—	—	—	—	0.8	0.5	1.2	0.4	0.5	0.5
	Reference	Point Vicente West	—	—	—	—	0.8	0.5	—	—	1.8	0.3
		Rocky Point North	1.7	0.7	2.5	1.4	6.7	1.9	2.1	0.8	2.5	1.0
Semicossyphus pulcher	Control	Abalone Cove Kelp West	—	—	0.4	0.4	0.4	0.4	—	—	0.5	0.3
		Marguerite Central	0.4	0.4	0.4	0.4	—	—	0.8	0.5	—	—
	Restoration	Underwater Arch Cove	0.4	0.4	1.2	0.4	—	—	0.4	0.4	—	—
		Honeymoon Cove	—	—	—	—	—	—	—	—	0.3	0.3
	Reference	Point Vicente West	0.4	0.4	—	—	—	—	1.2	0.8	0.5	0.3
		Rocky Point North	0.8	0.8	1.7	0.7	3.8	0.4	0.4	0.4	0.3	0.3

Table 10. Biomass (grams per 100 meters squared) of *P. clathratus* and *S. pulcher*

			2011		2012		2013		2014		2015	
Species	*Designation*	*Site*	Mean Density (g/$100m^2$)	SE	Mean Density (g/$100m^2$)	SE	Mean Density (g/$100m^2$)	SE	Mean Density (g/$100m^2$)	SE	Mean Density (g/$100m^2$)	SE
Paralabrax clathratus	Control	Abalone Cove Kelp West	230	230	—	—	24.6	16.7	21.4	16.8	61.4	24.7
		Marguerite Central	—	—	310.6	311	373.1	319	459.7	182	309.3	171
	Restoration	Underwater Arch Cove	—	—	17.7	17.7	42.3	42.3	652.8	466	229.8	191
		Honeymoon Cove	—	—	—	—	22.8	16.7	232.6	138	37.7	35.4
	Reference	Point Vicente West	—	—	—	—	227.5	141	—	—	194.5	56.1
		Rocky Point North	160.8	115	555.8	356	634.4	317	103.3	47.5	125.7	34.7
Semicossyphus pulcher	Control	Abalone Cove Kelp West	—	—	173.3	173	56.6	56.6	—	—	73.3	60.1
		Marguerite Central	56.6	56.6	56.6	56.6	—	—	28.5	17.2	—	—
	Restoration	Underwater Arch Cove	25.7	25.7	235.1	108	—	—	104.7	105	—	—
		Honeymoon Cove	—	—	—	—	—	—	—	—	34.0	34.0
	Reference	Point Vicente West	25.7	25.7	—	—	—	—	880.1	531	125.6	72.5
		Rocky Point North	130.4	130	312.2	144	866.5	95.8	173.3	173	34.0	34.0

Gonadosomatic indices of red and purple urchins

A total of 912 *S. franciscanus* were collected for gonadsomatic study over 4 sampling dates in the spring and summer of 2014 (April 29, May 28, June 26, July 22) and 84 *S. purpuratus* were collected on July 22. In fall 2014, an additional 434 *S. franciscanus* and 162 *S. purpuratus* were collected over 2 sampling dates (October 30 and November 18). For each date, urchins were collected from 1 existing kelp site, 1 barren site and 2 restoration sites to compare gonad indices between site types. The red urchins were the focus of this first study because of their importance as a commercial fishery.

REDS

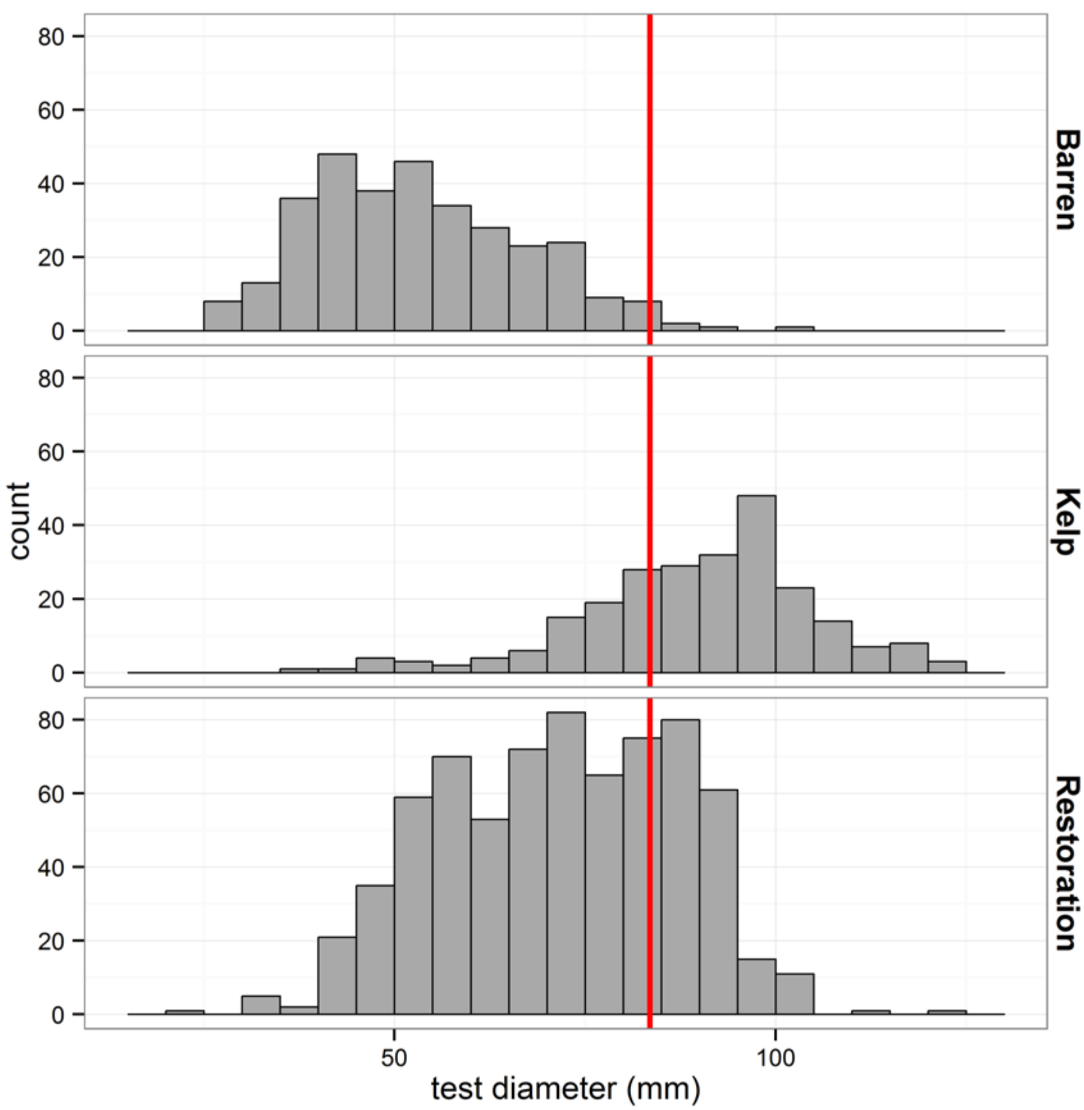


Figure 5. Histogram of Red Urchin (*Strongylocentrotus franciscanus*) test diameter for urchins collected in Barren, Kelp Forest Reference and Restoration Sites **pooling data from all 2014 collections**. The red line indicates the minimum size limit (84 mm) for the red urchin fishery. There was a significant difference among urchins collected in the three habitat types (one-way ANOVA: $p < 0.001$; mean ± SE: Barren 52 ± 1 mm, Kelp 89 ± 1 mm, Restoration 71 ± 1 mm).

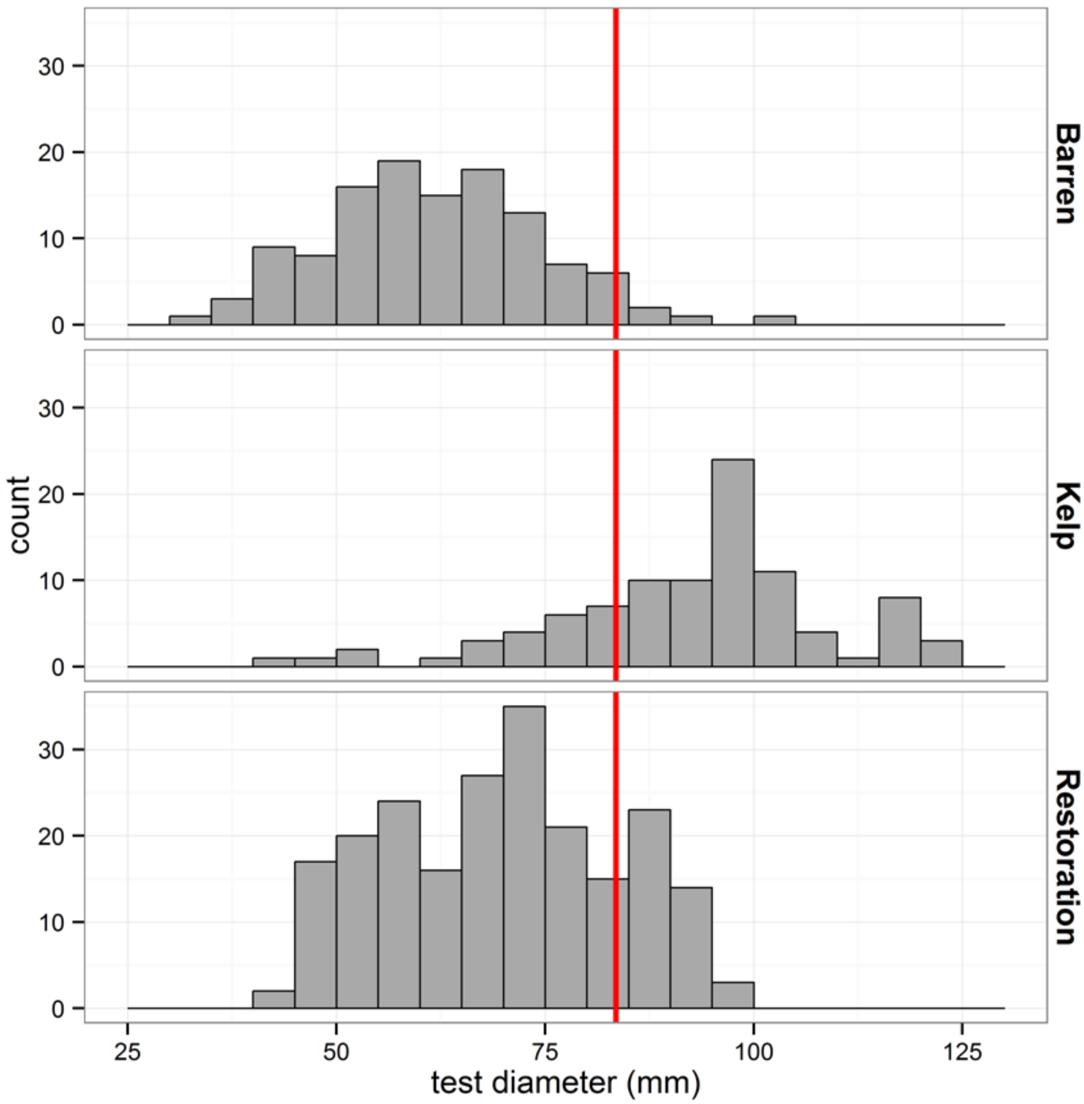


Figure 6. Histogram of Red Urchin (*Strongylocentrotus franciscanus*) test diameter for urchins collected in Barren, Kelp Forest Reference and Restoration Sites **with data from collections during Fall 2014 (30 Oct and 18 Nov)**. The red line indicates the minimum size limit (84 mm) for the red urchin fishery. There was a significant difference among urchins collected in the three habitat types (one-way ANOVA: $p < 0.001$; mean ± SE: Barren 61 ± 1 mm, Kelp 92 ± 1 mm, Restoration 69± 1 mm).

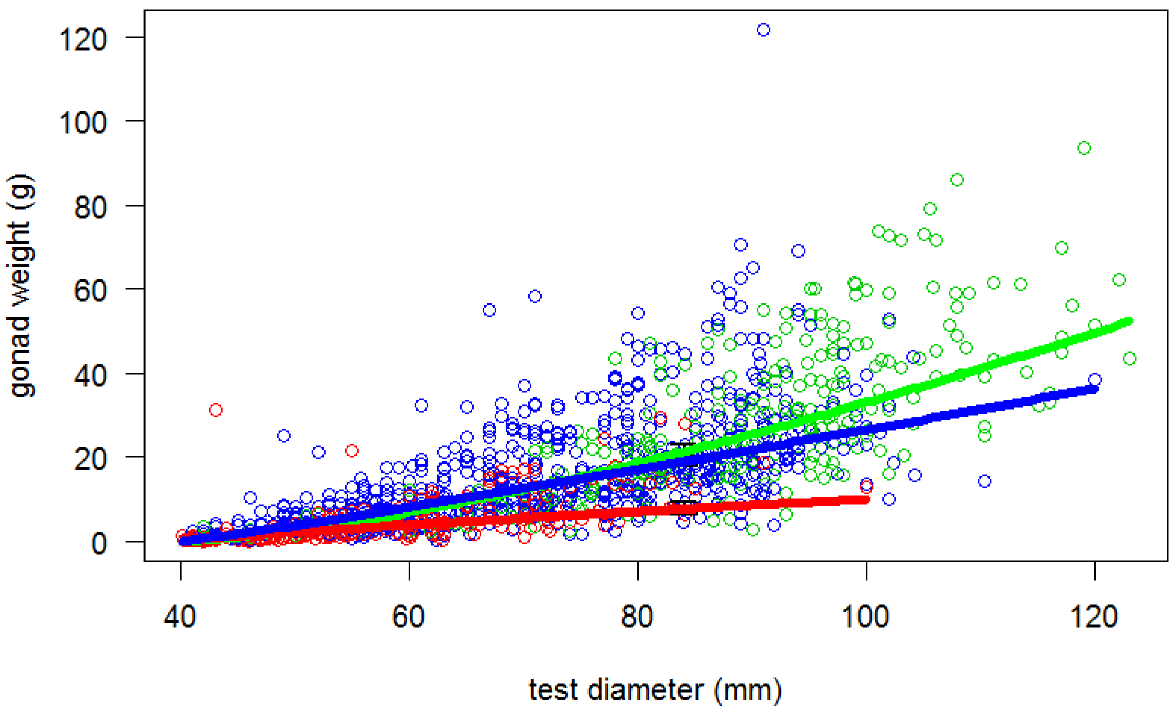


Figure 7. Relationship between Red Urchin (*Strongylocentrotus franciscanus*) gonad weight and urchin test diameter in the three site types: Barren (red), Kelp Forest Reference (green) and Restoration (blue) **pooling data from all 2014 collections**.

Following the methods in Claisse et al. (2013) and **pooling data from all 2014 collections** we estimated the Red Urchin (*Strongylocentrotus franciscanus*) mean gonad weight at 84 mm test diameter (the minimum size limit in the fishery) and estimated 95% confidence intervals for each mean: Barren 7.5 g (95% CI: 6.2 to 9.1), Kelp 21.3 g (95% CI: 19.7 to 22.9), Restoration 19.0 g (95% CI: 17.9 to 20.0). Gonad size at 84 mm test diameter in the restoration sites was 152% higher than in barrens (95% CI: 104% to 208%).

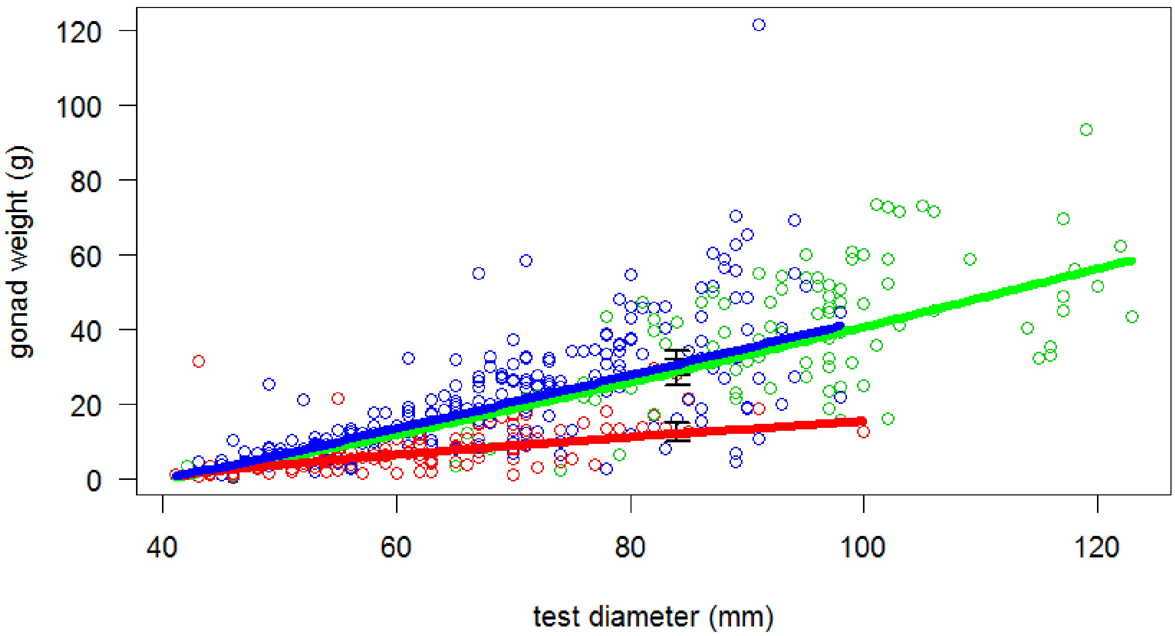


Figure 8. Relationship between Red Urchin (*Strongylocentrotus franciscanus*) gonad weight and urchin test diameter in the three site types: Barren (red), Kelp Forest Reference (green) and Restoration (blue) **with data from collections during Fall 2014 (30 Oct and 18 Nov)**.

Following the methods in Claisse et al. (2013) **with data from collections during Fall 2014 (30 Oct and 18 Nov)** we estimated the Red Urchin (*Strongylocentrotus franciscanus*) mean gonad weight at 84 mm test diameter (the minimum size limit in the fishery) and estimated 95% confidence intervals for each mean: Barren 11.9 g (95% CI: 9.8 to 14.8), Kelp 28.7 g (95% CI: 25.0 to 31.9), Restoration 30.7 g (95% CI: 27.5 to 34.3). Gonad size at 84 mm test diameter in the restoration sites was 158% higher than in barrens (95% CI: 102% to 229%).

PURPLES

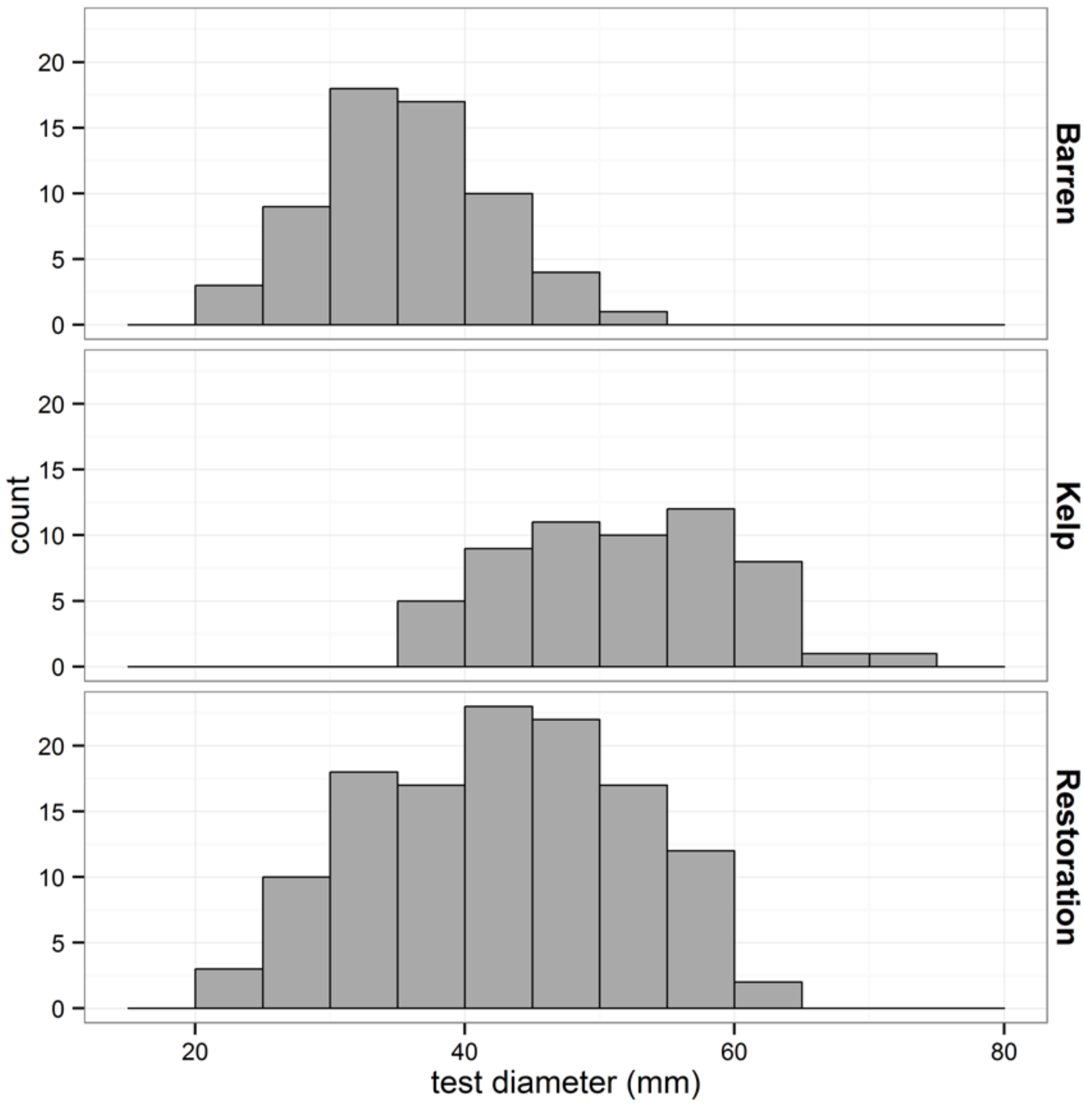


Figure 9. Histogram of Purple Urchin (*Strongylocentrotus purpuratus*) test diameter for urchins collected in Barren, Kelp Forest Reference and Restoration Sites **pooling data from 2014 collections (purple urchins collected on 22 July, 30 Oct, 18 Nov)**. There was a significant difference among urchins collected in the three habitat types (one-way ANOVA: $p < 0.001$; mean ± SE: Barren 35 ± 1 mm, Kelp 51 ± 1 mm, Restoration 42 ± 1 mm).

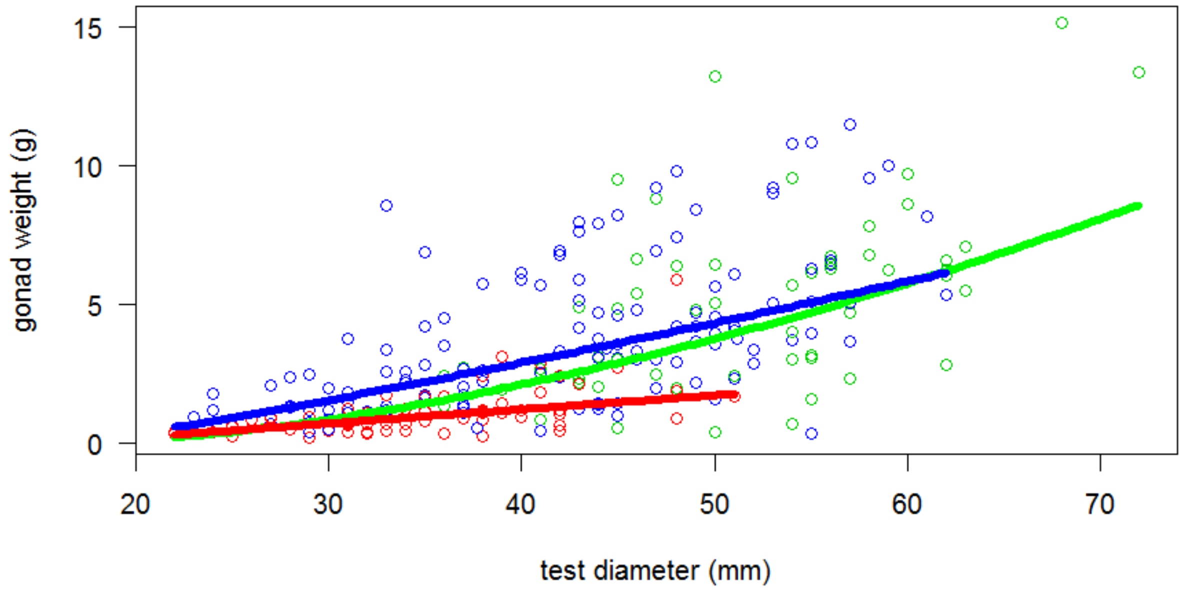


Figure 10. Relationship between Purple Urchin (*Strongylocentrotus purpuratus*) gonad weight and urchin test diameter in the three site types: Barren (red), Kelp Forest Reference (green) and Restoration (blue) **pooling data from 2014 collections (purple urchins collected on 22 July, 30 Oct, 18 Nov)**.

Claisse JT, Williams JP, Ford T, Pondella DJ, Meux B, Protopapadakis L (2013) Kelp forest habitat restoration has the potential to increase sea urchin gonad biomass. Ecosphere 4: art38 doi 10.1890/ES12-00408.1

Analysis of the ecosystem response to the restoration activities at the restoration site, including species that are key indicators of a healthy and persistent kelp forest ecosystem.

The data and summaries presented in *section E* demonstrate responses in the kelp forest community to the restoration actions undertaken from July 2013 to July 2015. Several key metrics show increases in response to kelp forest restoration, i.e., gonadosomatic indexes for red and purple sea urchins, fish species richness, and biomass as indicated by kelp bass and sheephead. These trends describe strong, and in some cases significant, increases in value in response to kelp restoration actions.

Monitoring associated with this project will continue for a minimum of five years post-restoration. Additional pre- and post-restoration is being conducted as required as the project continues the systematic reduction of purple urchins in the permitted barrens off the Palos Verdes Peninsula. Early results demonstrate increases in gonad production relative to size of the individuals, in both red and purple sea urchins in restored areas, meaning areas encompassing 27.74 acres where the average density of purple sea urchins was reduced from $28.32/m^2$ to $1.54/m^2$. The values for red sea urchins entering the fishery at 84 mm in diameter within restoration sites displayed gonadosomatic values roughly 150% greater than the reds collected in the barrens/controls for this report period.

For finfish as indicated by kelp bass, (*Paralabrax clathratus*) we still see increases in density and biomass within all habitat types over time, (2011-2015). The data for the same metrics for Sheephead, (*Semicossyphus pulcher*) are very noisy and no trend is readily identifiable at this time. For species richness in fin fish, we see increases in both Underwater Arch Cove and Honeymoon Cove (restoration sites) and an increase in Point Vicente West within the MPA.

Giant kelp, the competitive dominant macroalgae in this system, has also responded favorably, with increases in density of two to three orders of magnitude in Underwater Arch Cove and Honeymoon Cove, respectively. Sub-canopy macroalgae are also responding positively to the reduction in herbivory and abrasion ascribed to the reduction in sea urchin density, with significant increases of Cystoseira osmundacea in both Underwater Arch Cove and Honeymoon Cove and Egregia menziesii in Underwater Arch Cove.

These data suggest that the kelp forest community is responding positively to the reduction in sea urchin density in the barrens that have been restored in the previous years. The recruitment and development of macroalgae in these sites serve as the basis for bottom up forcing of production and changes in biogenic community structure. The functionality and persistence of these changes will be determined by further monitoring and analysis as required by this permit. In summary, the results are encouraging but are to be considered preliminary. Further efforts will provide a more accurate understanding of the strength and persistence of the ecosystem responses to this work in the coming years.

Evaluation of successes and failures of restoration activities for each site

Four active restoration sites have been established, Honeymoon Cove, Marguerite, Underwater Arch Cove and Hawthorne, Palos Verdes California. In all four locations purple sea urchins (*Strongylocentrotus purpuratus)* have been reduced in density in waters ranging from 40 feet to 2 feet in depth. The development of a variety of macroalgae are occurring on the reefs in all four sites. In some locales, giant kelp *(Macrocystis pyrifera)* has reached impressive lengths exceeding twenty five feet in length. Because of poor ocean conditions, accurate, replicable data could not be collected in 7 restoration blocks in the Hawthorne site. Our monitoring teams will focus on entering these blocks as soon as conditions are permissible.

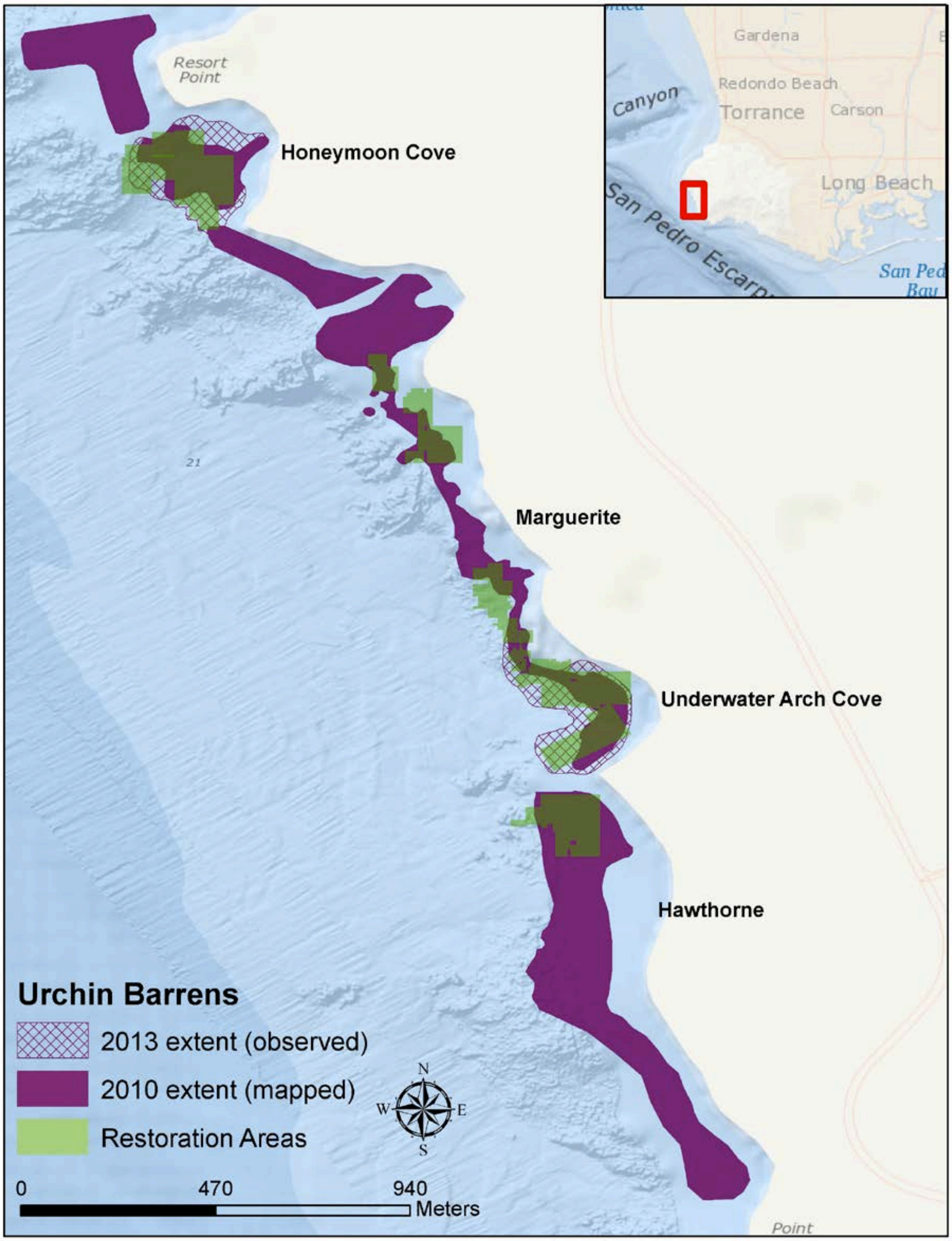
These poor oceanographic conditions affected all sites but not to the extent as described for Hawthorne, where persistent poor visibility coupled with high surge made highly accurate and replicable scientific monitoring impossible to conduct. Other restoration sites; Honeymoon Cove, Marguerite and Underwater Arch Cove were also difficult to access during much of 2015. This prevented the monitoring teams from consistently entering these areas within the two week post-restoration window, thus deviating from the preferred standard operating procedure.

Restoration teams maintained high levels of production per unit of effort and only modest changes to site set up and delineation of the restoration blocks were incorporated this year. These changes were universally applied throughout the four restoration sites as the use of temporary surface buoys for restoration block identification were often found off station. The response from project management has become a stronger reliance on GPS coordinates, derived from temporary surface markers, to identify restoration blocks for the restoration teams and subsequent monitoring.

Per the last report, in regards to observed increases in the expanse of some restoration sites compared to the maps made based upon 2010 observations. The trend of expansion versus shifting boundaries has been challenging for the restoration and monitoring teams for this report period. In the first year report we clearly saw increases in the expanse in overall urchin barren extent in Honeymoon Cove and Underwater Arch Cove. Barring the very shallow and high relief expanses of urchin barren remaining in these two sites, we are confident we've captured the seaward extent of the urchin barrens.

In contrast, what we are witnessing in Marguerite and Hawthorne appears to be a shift in the location of the barrens. Generally speaking, where they were inshore in 2010 they appear to be offshore in 2014 and vice-versa. In other places the shift in the boundary seems clear but less apparent in which direction(s) it has moved. The overall patterns of shifting urchin barren boundaries may not be clear until restoration and monitoring teams have moved comprehensively throughout a given site. Certainly the migration or expansion and contraction of urchin barrens on a given reef is well documented if not well understood by science.

The map on the following page illustrates the shifts in barren extent from the originally mapped values in 2010 to the observed barrens in 2013, and finally to the plots of the restoration sites that we have monitored and restored.



Map 11. Urchin barrens as mapped in 2010 and observed in 2013, representing a possible expansion and/or shift of urchin barrens. Overview of the project area along the Palos Verdes Peninsula showing the urchin barren extent mapped in 2010 and the observed expansion of the urchin barrens in Honeymoon and Underwater Arch Coves from a series of surveys conducted in summer and fall of 2012. The locations of current restoration activity are in green.

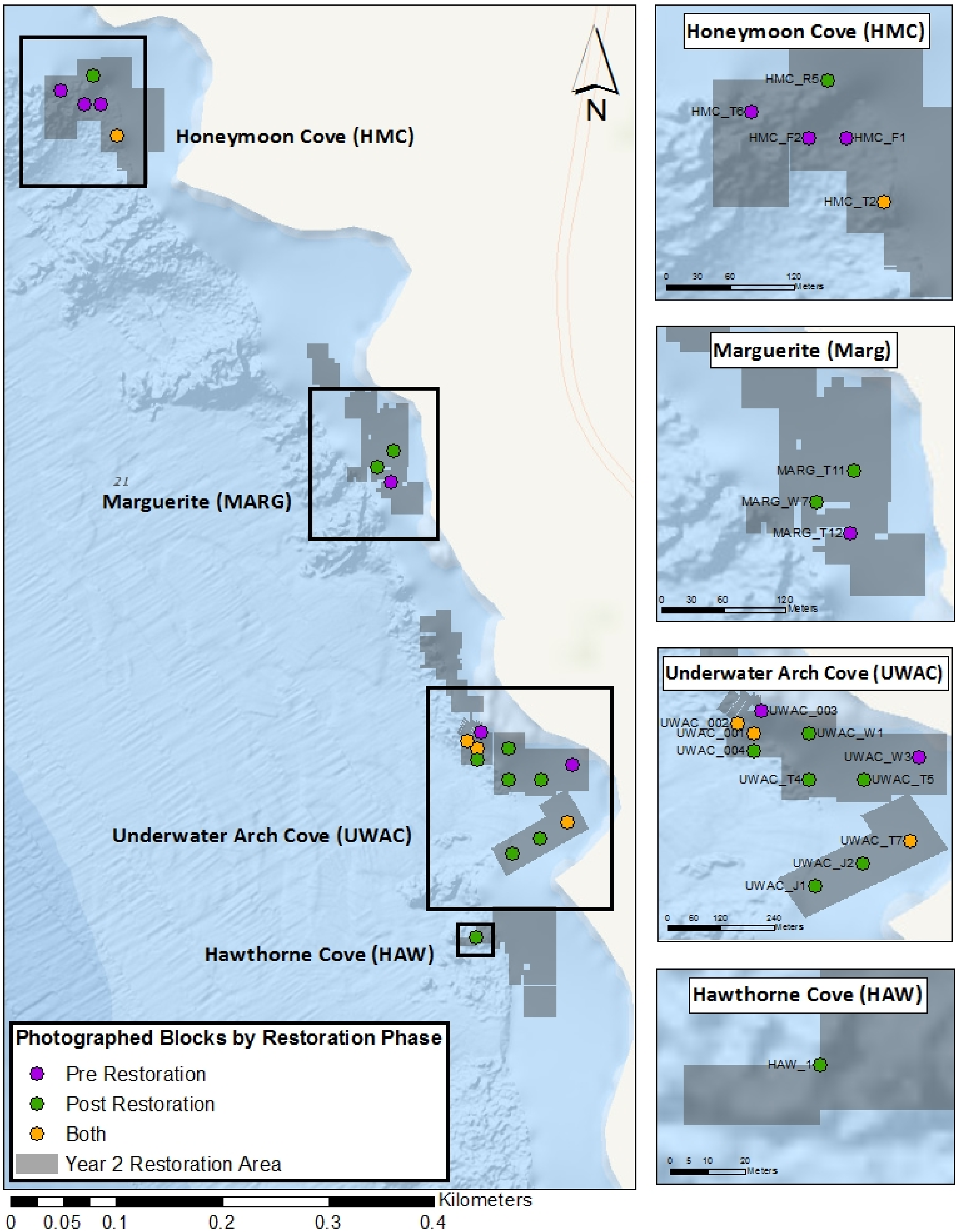
Geo-referenced images before and after restoration activities
See Appendices 2, 3 and 4 – Photos and video shared on Google Drive

Between July 1, 2013 and June 30, 2015, photos were taken at various locations within each of the 4 restoration sites both pre and post restoration efforts. The locations of these photos are displayed below (Map 12). All report photos and video files are titled according to the following format: "Figure/Video Number"_"Site Name"_"Block Code Start – Block Code Finish (if different)"_"Restoration Status (Pre/Post)"_"Date (year-month-day)"_"Number in Series". GPS coordinates for each photo and video are listed in Appendices 2 and 3. After receiving comments from DFW staff, photo and video documenting has been increased and consistently applied during pre and post monitoring surveys. Photos are taken along the baseline and within the 30m by 30m block. Due to low visibility days, some blocks have not been photographed well. In many circumstances the photos from adjacent blocks may serve as reasonable proxies for adjacent blocks.

We would like to include an increased amount of underwater video in future reports. For year three of this project we hope to capture pre and post restoration videos for each restoration block with the compass heading and transect tape delineating the baseline, and a subset of the transects extended, for the given block in the frame. We have included as an addendum to this report some of the video that has been shot in existing restoration sites described within this report. With the addition of replication, geo-referencing and consistency we feel that these videos will be a beneficial source of information to illustrate the changes that result from this project.

Conditions in Hawthorne in spring 2015 did not allow for any photos or video. Figure 66 in Appendix 2 is indicative of the dive conditions experienced at this site. Some blocks will have distinct, recognizable rock structures but once kelp recruits back into the area these features are often not visible. Efforts will be made this coming year to identify unique rock formations in sites to be photographed over time. The Bay Foundation also conducts quarterly aerial surveys during which aerial photography of the kelp canopy can be captured (Appendix 4). Over the next year, photo points that were taken in previous years will be revisited and continue to build the photo and video library of project progress.

Reference Map of Photographed Restoration Blocks by Site



Map 12. Reference Map of Photographed Restoration Blocks by Site.

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