Palos Verdes Kelp Forest Restoration Project

Annual Report July 2013 – June 2014

Commercial Sea Urchin Harvesters and Los Angeles Waterkeeper working in Underwater Arch Cove. Palos Verdes, California, May 24, 2014

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Background:

This project has 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)

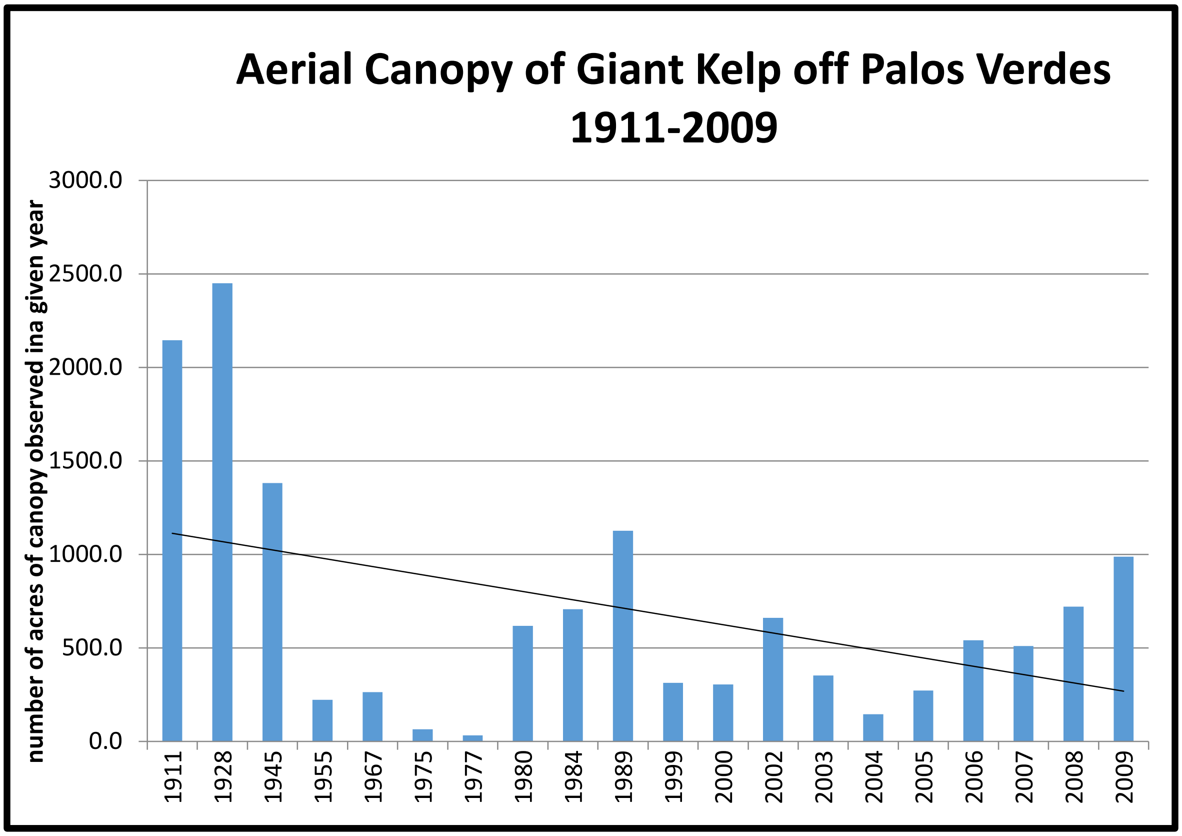

Figure 1. Status of the Kelp Beds 2009, Ventura and Los Angeles Counties. Central Region Kelp Survey Consortium, June 2010. Prepared by: MBC Applied Environmental Sciences. Costa Mesa, CA 92626

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 1985a: 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.

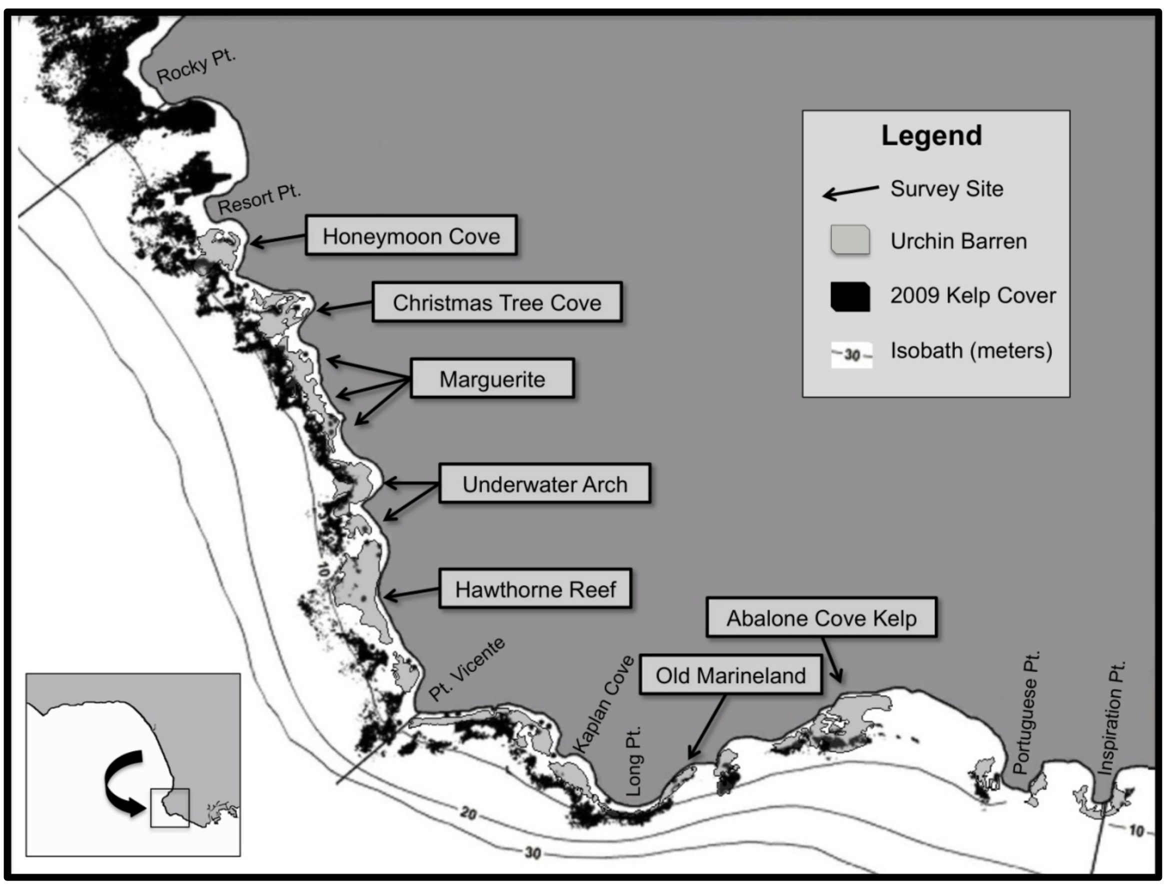

Figure 4. Map of existing urchin barrens on the southwest coast of Palos Verdes Peninsula

Kelp Restoration Goals

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 both restoration 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 1, 2013 through June 30, 2014 are shown in Tables 1 and 2. Urchin suppression activities from July 2014 through July 2015 will target the areas identified in Table 3 as Honeymoon Cove, Underwater Arch, Marguerite, and Hawthorne Reef.

Table 1. Restoration Progress July 2013 through July 2014.

Area Name	Total Area (Acres)	Area Cleared (Acres)
Honeymoon Cove	10.05	6.77
Underwater Arch	13.24	5.91
Total	**23.29**	**12.68**

Table 2. Total effort diving towards project goals July 1, 2013 through June 30, 2014.

Effort (dive hours)	Monitoring	Restoration
The Bay Foundation	258.87	43.5
LA Waterkeeper	-	479
Comm Urchin divers	-	1384.1
	258.87	1906.6

Table 3. Work will target these areas July 2014 through July 2015.

Site Name	Total Area Hectares	Total Area Acres	Start date	Cleared Year 1	Status	Centroid (Lat., Long)
Underwater Arch	5.36	13.24	Jul. 2013	5.91	In Progress – (to be complete early 2015)	33.752, -118.415
Honeymoon Cove	4.07	10.05	Oct. 2014	6.77	In progress – (to be complete early 2015)	33.764, -118.423
Marguerite	5.19	12.82	Jul. 2014	_	In Progress	33.757, -118.418
Hawthorne Reef	8.96	22.14	To begin early 2015	_	_	33.747, -118.414

Pre Restoration Monitoring

Pre-restoration monitoring is conducted on all sites according to DFW standards stipulated in the terms of the SCP. Restoration blocks are 30m on each side 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. 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, all 15 transects (per block), covering 100% of the restoration block were monitored. Pre-monitoring transects require more time to complete than post-monitoring transects as data is recorded that characterizes existing giant kelp, substrate and relief and the estimated density of purple and red sea urchins. A power analysis was applied to 12 blocks of data and determined that a 66% reduction in monitoring effort could be conducted while maintaining accurate characterization of pre-monitoring metrics. This new pre-monitoring scheme covers 33% of the block via 5 transects, pre restoration, allowing blocks to be set up for clearing more quickly and freeing divers to spend more time on restoration efforts.

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. Figures 5 and 6 display the estimated purple urchin densities before restoration activities [within each 10m segment for Underwater Arch and Honeymoon Coves].

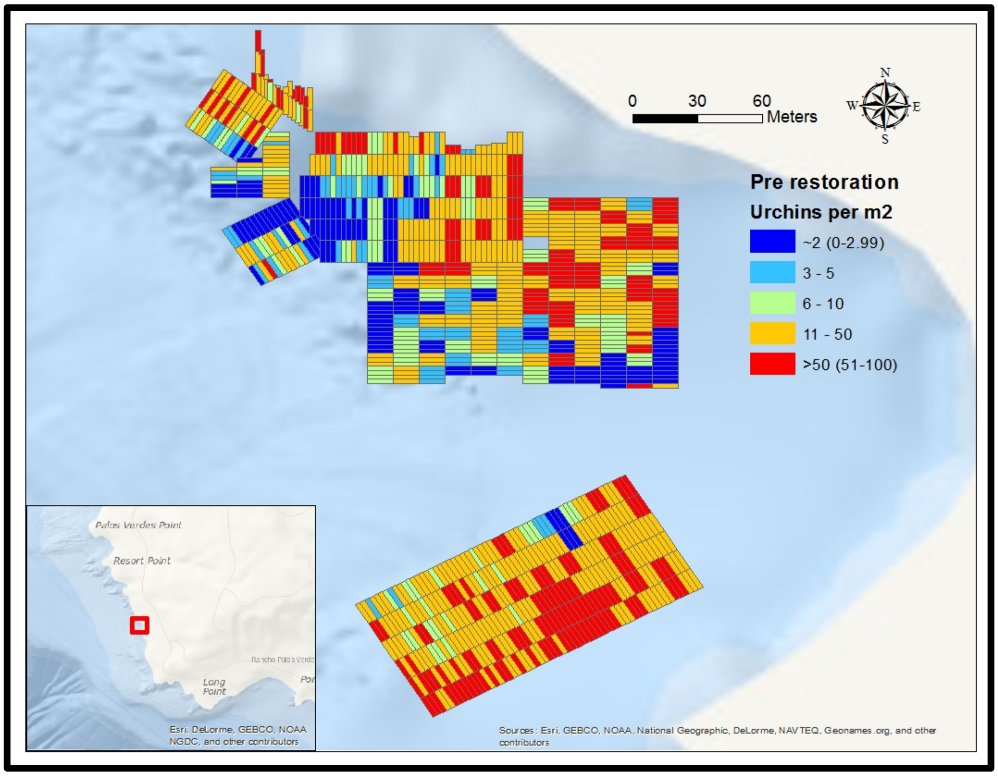

Figure 5. Density of *S. purpuratus* (individuals per square meter) pre-restoration in Underwater Arch Cove, Palos Verdes, California. Total Area: 5.91 acres. See Appendix 1 for larger map images.

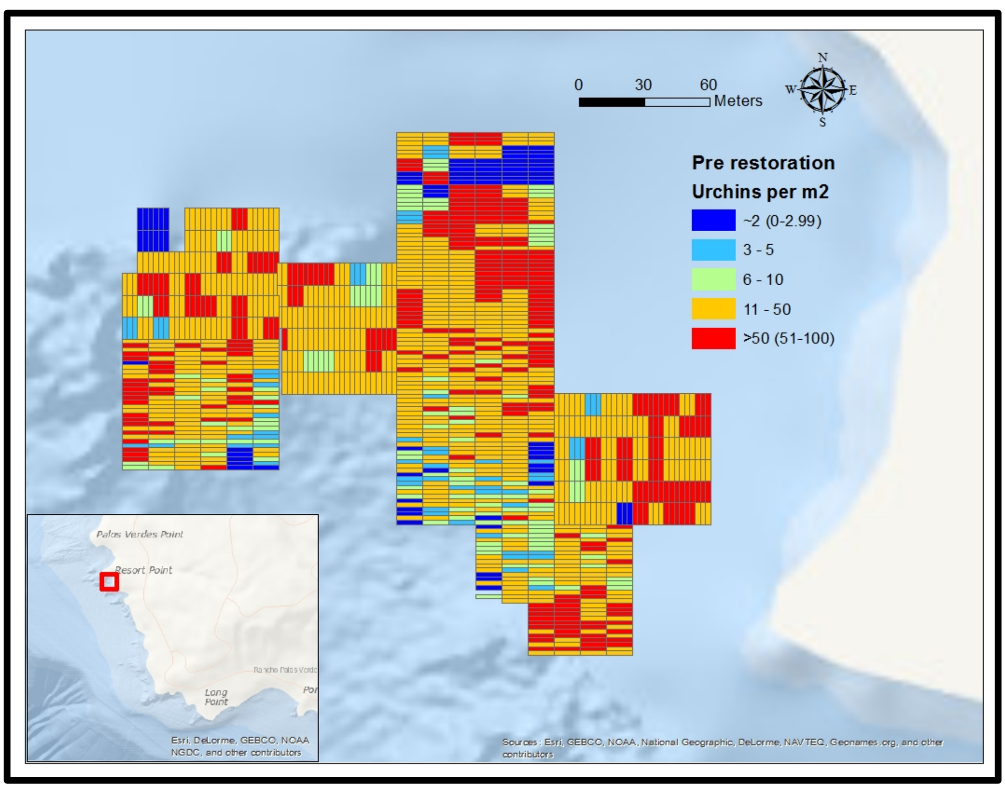

Figure 6. Density of *S. purpuratus* (individuals per square meter) pre-restoration in Honeymoon Cove, Palos Verdes, California. Total Area: 5.91 acres. See Appendix 1 for larger map images.

Compliance Monitoring

Monitoring is conducted weekly to bi-weekly depending upon the rate of activity of urchin removal in the preceding week. This work is performed by The Bay Foundation and Los Angeles Waterkeeper 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. Figures 7 and 8 display the estimated purple urchin densities after restoration activities within each 10m segment for Underwater Arch and Honeymoon Coves. 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.

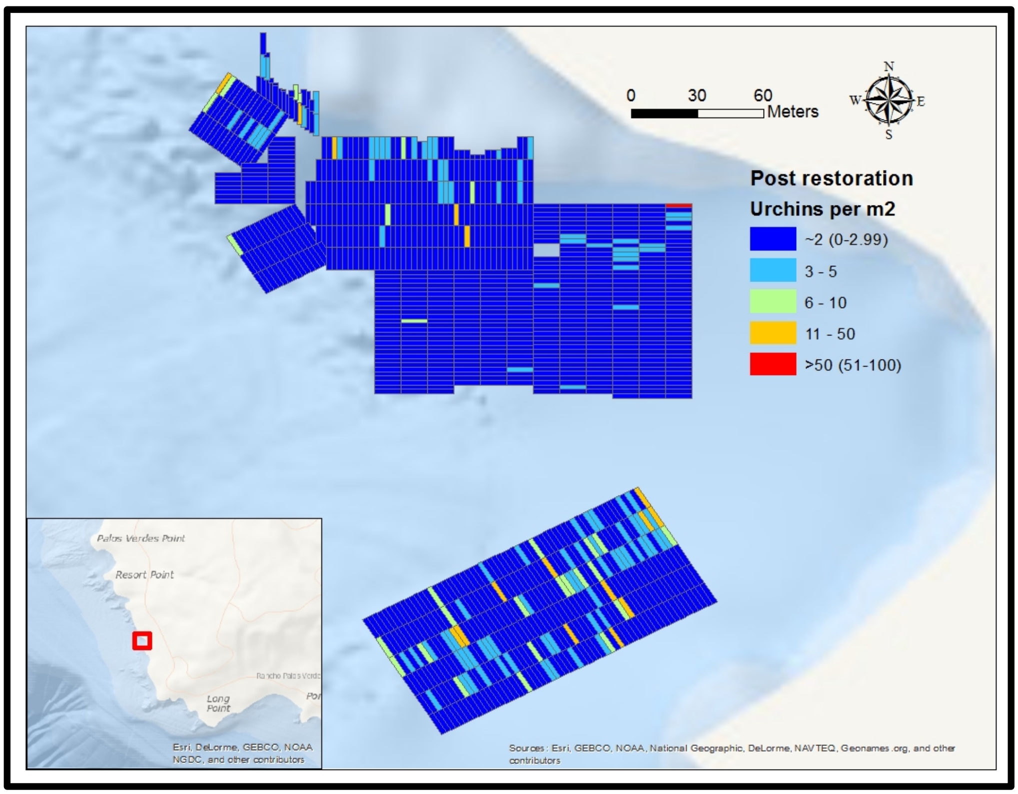

Figure 7. Density of *S. purpuratus* (individuals per square meter) post-restoration in Underwater Arch Cove, Palos Verdes, California. Total area: 6.77 acres. See Appendix 1 for larger map images.

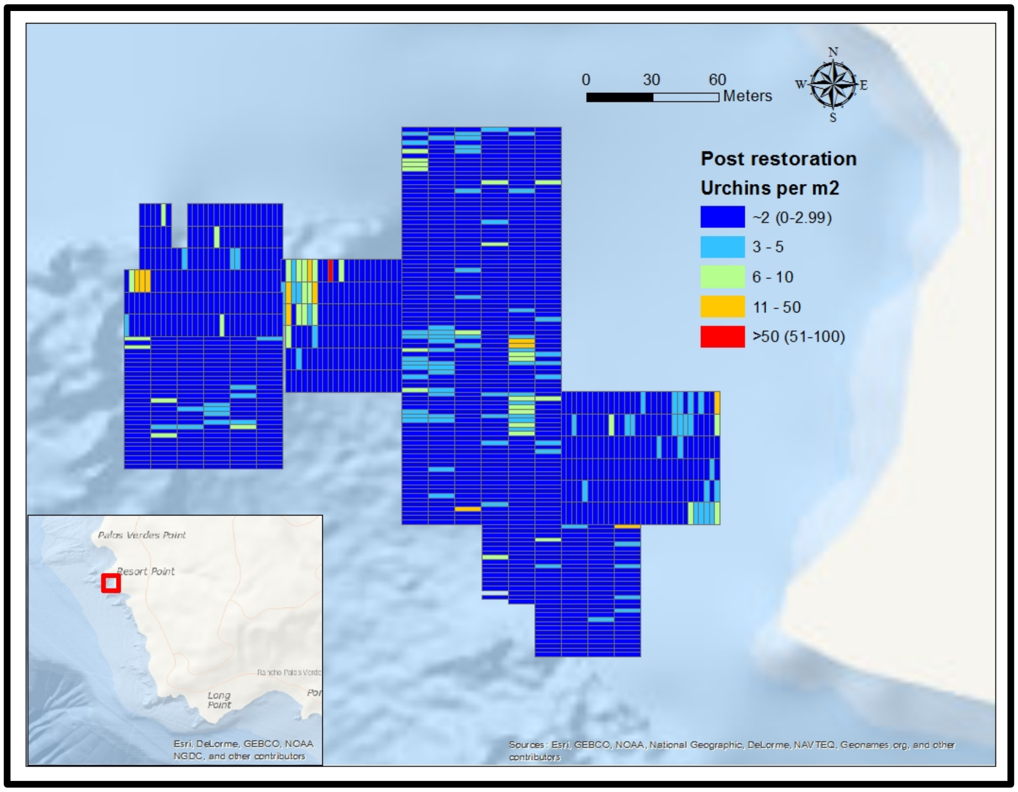

Figure 8. Density of *S. purpuratus* (individuals per square meter) post-restoration in Honeymoon Cove, Palos Verdes, California. Total area: 6.77 acres. See Appendix 1 for larger map images.

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 (Tables 5-8). 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. 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. Urchins were collected and dissected for this study in spring and summer 2014. Results from this study are shown in Figures 9-11.

Table 4. Fish Species Richness (total number of species)

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

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

All restoration and reference sites show an increase in fish species richness over time. The three site types, control, restoration, and reference are not very different from each other in 2014. However, the number of fish species observed in the restoration sites doubled from 6 to 12 in Underwater Arch Cove and 4 to 8 in Honeymoon Cove in 2014 from the previous year.

Table 5. Density (individuals/ 100 m^2) of Kelp and related understory algal species, Red Urchins *(Strongylocentrotus franciscanus)* Lobster *(Panulirus interruptus)*

			2011		2012		2013		2014	
Species	*Designation*	*Site*	Density /100m2	SE	Density /100m2	SE	Density /100m2	SE	Density /100m2	SE
Cystoseira osmundacea	Control	Abalone Cove Kelp West	0	0	0	0	0	0	0	0
		Marguerite Central	0	0	0.8	0.8	0	0	0	0
	Restoration	Underwater Arch Cove	0	0	0	0	11.7	1.7	10.8	4.2
		Honeymoon Cove	2.5	2.5	0	0	0	0	0	0
	Reference	Point Vicente West	0.8	0.8	0	0	0	0	0	0
		Rocky Point North	0	0	0	0	0	0	2.5	0.8
Egregia menziesii	Control	Abalone Cove Kelp West	2.5	2.5	0	0	0	0	0	0
		Marguerite Central	0	0	0	0	0	0	0	0
	Restoration	Underwater Arch Cove	0	0	0	0	0	0	0	0
		Honeymoon Cove	0	0	0	0	0	0	0	0
	Reference	Point Vicente West	19.2	13	13.3	8.3	10	10	3.3	1.7
		Rocky Point North	0	0	0	0	5	0	12.5	5.8
Eisenia arborea	Control	Abalone Cove Kelp West	0	0	0	0	0	0	0	0
		Marguerite Central	11.7	12	3.3	3.3	12.5	5.8	0	0
	Restoration	Underwater Arch Cove	0	0	0	0	0	0	0	0
		Honeymoon Cove	0	0	0	0	0	0	0	0
	Reference	Point Vicente West	226.7	80	253.3	25	291.7	8.3	39.2	18
		Rocky Point North	0	0	2.5	2.5	18.3	12	28.3	6.7
Pterygophora californica	Control	Abalone Cove Kelp West	0	0	0	0	0	0	0	0
		Marguerite Central	0	0	0	0	0	0	0	0
	Restoration	Underwater Arch Cove	0	0	0	0	0	0	0	0
		Honeymoon Cove	0	0	0	0	0	0	0	0
	Reference	Point Vicente West	0	0	0	0	0.8	0.8	0	0
		Rocky Point North	0	0	0	0	0	0	0	0
Macrocystis pyrifera	Control	Abalone Cove Kelp West	4.2	4.2	0	0	0	0	0	0
		Marguerite Central	0	0	0	0	0	0	10	10
	Restoration	Underwater Arch Cove	0	0	0	0	0	0	25	0
		Honeymoon Cove	1.7	1.7	0	0	0	0	7.5	7.5
	Reference	Point Vicente West	28.3	6.7	27.5	10.8	12.5	0.8	5.8	2.5
		Rocky Point North	110	15	20	3.3	76.7	15	319.2	169
Panulirus interruptus	Control	Abalone Cove Kelp West	0.8	0.8	0	0	0	0	0	0
		Marguerite Central	0	0	0	0	0	0	0	0
	Restoration	Underwater Arch Cove	0	0	0	0	0.8	0.8	0	0
		Honeymoon Cove	0	0	0	0	0	0	0	0
	Reference	Point Vicente West	2.5	0.8	0.8	0.8	1.7	1.7	0.8	0.8
		Rocky Point North	0	0	0	0	1.7	1.7	2.5	2.5
Strongylocentrotus franciscanus	Control	Abalone Cove Kelp West	464.2	221	165.8	129.2	110	10	50	12
		Marguerite Central	45	17	58.3	30	12.5	0.8	8.3	3.3
	Restoration	Underwater Arch Cove	54.2	18	33.3	13.3	23.3	18	42.5	7.5
		Honeymoon Cove	63.3	1.7	44.2	0.8	34.2	4.2	11.7	1.7
	Reference	Point Vicente West	31.7	10	55.8	27.5	32.5	4.2	26.7	10
		Rocky Point North	5	5	9.2	9.2	1.7	1.7	0.8	0.8
Strongylocentrotus purpuratus	Control	Abalone Cove Kelp West	1250	250	902.5	267.5	462.5	88	1567.5	318
		Marguerite Central	2450	900	5765	1527	1499.2	81	1705.8	303
	Restoration	Underwater Arch Cove	2195.8	471	939.2	349.2	1008.3	465	24.2	11
		Honeymoon Cove	1541.7	142	1222.5	215.8	1223.3	303	325	298
	Reference	Point Vicente West	247.5	76	490.8	369.2	535.8	48	185.8	5.8
		Rocky Point North	15.8	7.5	30.8	12.5	10	8.3	3.3	0

Table 6. Density (individuals per 100 meters squared) of *P. clathratus* (kelp bass) and *S. pulcher* (California Sheephead)

			2011		2012		2013		2014	
Species	Designation	Site	Density /100m2	SE	Density /100m2	SE	Density /100m2	SE	Density /100m2	SE
Paralabrax clathratus	Control	Abalone Cove Kelp West	0.4	0.4			0.8	0.5	0.4	0.4
		Marguerite Central			1.2	1.2	1.7	1.2	3.3	0.7
	Restoration	Underwater Arch Cove			0.4	0.4	0.4	0.4	6.7	4.5
		Honeymoon Cove					0.8	0.5	1.2	0.4
	Reference	Point Vicente West					0.8	0.5		
		Rocky Point North	1.7	0.7	2.5	1.4	6.7	1.9	2.1	0.8
Semicossyphus pulchei	Control	Abalone Cove Kelp West			0.4	0.4	0.4	0.4		
		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								
	Reference	Point Vicente West	0.4	0.4					1.2	0.8
		Rocky Point North	0.8	0.8	1.7	0.7	3.8	0.4	0.4	0.4

Table 7. Biomass (grams per 100 meters squared) of *P. clathratus* kelp bass) and *S. pulcher* (California Sheephead)

			2011		2012		2013		2014	
Species	Designation	Site	Biomass (g)/100m2	SE	Biomass (g)/100m2	SE	Biomass (g)/100m2	SE	Biomass (g)/100m2	SE
Paralabrax clathratus	Control	Abalone Cove Kelp West	230	230			24.6	17	21.4	17
		Marguerite Central			310.6	311	373.1	319	459.7	182
	Restoration	Underwater Arch Cove			17.7	18	42.3	42	652.8	466
		Honeymoon Cove					22.8	17	232.6	138
	Reference	Point Vicente West					227.5	141		
		Rocky Point North	160.8	115	555.8	356	634.4	317	103.3	48
Semicossyphus pulchei	Control	Abalone Cove Kelp West			173.3	173	56.6	57		
		Marguerite Central	56.6	57	56.6	57			28.5	17
	Restoration	Underwater Arch Cove	25.7	26	235.1	108			104.7	105
		Honeymoon Cove								
	Reference	Point Vicente West	25.7	26					880.1	531
		Rocky Point North	130.4	130	312.2	144	866.5	96	173.3	173

Gonadosomatic indices of red and purple urchins

Following the methods in Claisse et al. (2013) we estimated the mean gonad weight at 84 mm test diameter (the minimum size limit in the fishery) and estimated 95% confidence intervals for each mean: Barren 3.3 g (95% CI: 2.6 to 4.4), Kelp 17.8 g (95% CI: 16.4 to 19.1), Restoration 15.2 g (95% CI: 14.3 to 16.2). Gonad size at 84 mm test diameter in the restoration sites was 361% higher than in barrens (95% CI: 247% to 501%).

The estimated total number of purple urchins crushed within restoration sites is 1,991,701 reducing the overall average density from 37.52/m^2 to 1.88/m^2. Table 6 below shows the number of urchins removed and density values by site.

Table 8. Estimated quantity of purple urchins *(S. purpuratus)* crushed and urchin density (individuals per square meter) pre and post restoration (July 2013 – July 2014).

Area Name	Total Area (Acres)	Area Cleared (Acres)	Estimated Number of Urchins Removed	Urchin Density Pre Restoration	Urchin Density Post Restoration
Honeymoon Cove	10.05	6.77	1,134,749	42.28	2.05
Underwater Arch	13.24	5.91	856,952	33.96	1.74
Total	**23.29**	**12.68**	**1,991,701**		

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. For each date, urchins were collected from 1 existing kelp site, 1 barren site and 2 or more 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.

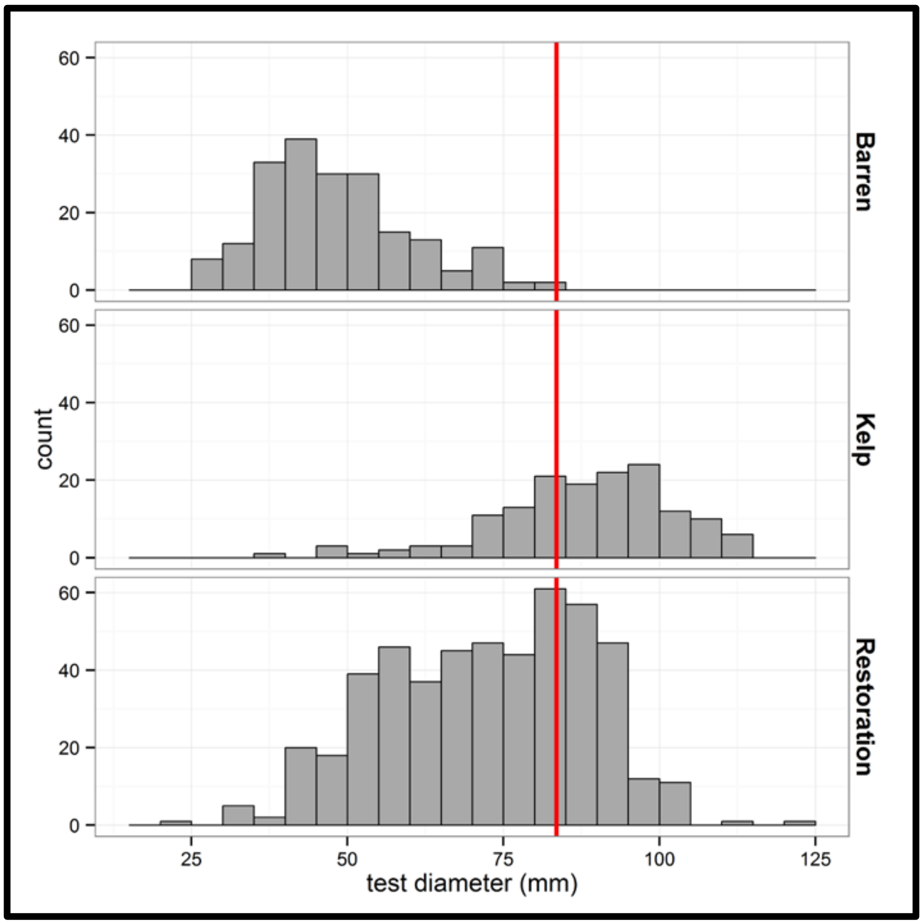

Figure 9. Histogram of *Strongylocentrotus franciscanus* test diameter for urchins collected in Barren, Kelp Forest Reference and Restoration Sites. The red line indicates the minimum size limit (84 mm) for the red urchin fishery. There was a significant difference among urchins collected in the three habitat types (one-way ANOVA: $p < 0.001$; mean ± SE: Barren 47 ± 1 mm, Kelp 88 ± 1 mm, Restoration 72 ± 1 mm)

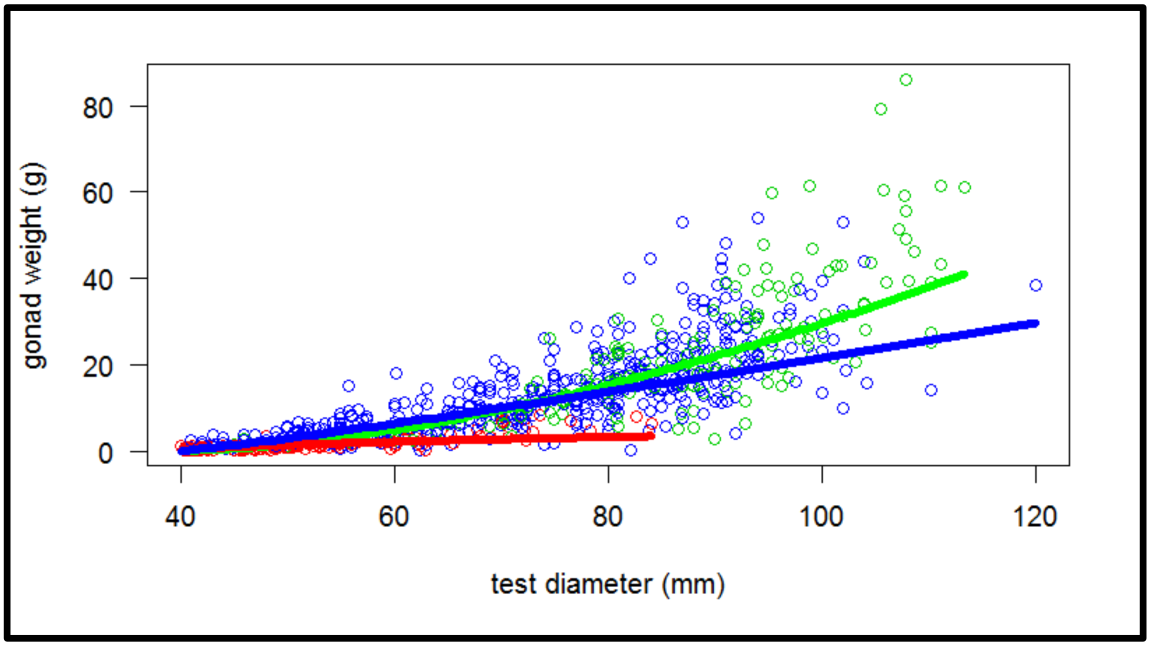

Figure 10. Relationship between *S. franciscanus* gonad weight and urchin test diameter in the three site types: Barren (red), Kelp Forest Reference (green) and Restoration (blue).

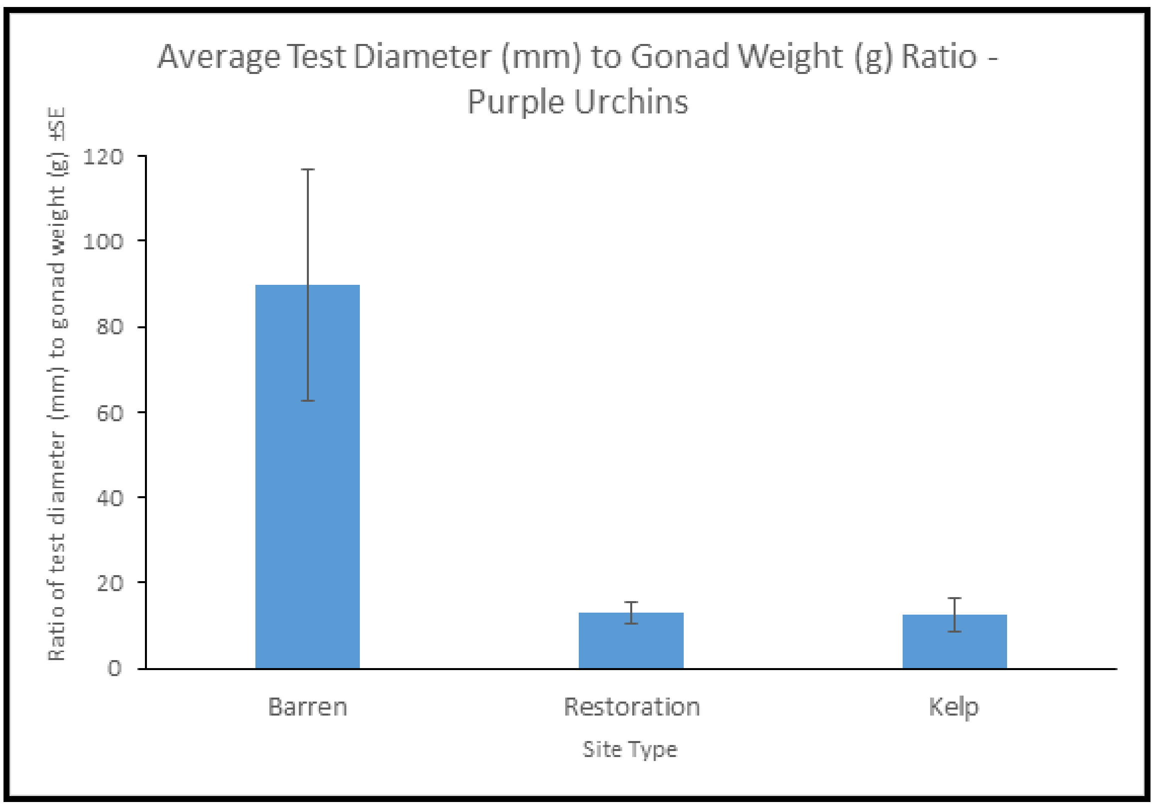

Figure 11. Average test diameter in relation to gonad weight for *S. purpuratus*. 84 urchins were collected on July 22, 2014. This small sample size showed significant difference between urchins collected in the barren compared to urchins found in the restoration and kelp sites (one-way ANOVA: $p < 0.001$). There were no significant differences between restoration sites and the kelp reference site.

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 2014. 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 areas that have been restored, meaning areas where the average density of purple sea urchins was reduced from $37.52/m^2$ to $1.88/m^2$. Fish species richness doubled in both restoration sites, Honeymoon and Underwater Arch Cove, over the past year. Biomass of kelp bass in these same areas during the past year increased by an order of magnitude.

Giant kelp, the competitive dominant macroalgae in this system, has also responded favorably, with increases in density of one to two orders of magnitude in Honeymoon Cove and Underwater Arch Cove, respectively. 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 year. The recruitment and development of macroalgae in these sites serve as the basis for bottom up forcing of changes in community structure. The functionality and persistence of these changes will be determined by further monitoring as required by this permit. In summary, the results are encouraging but are to be considered preliminary, and further efforts will provide a more accurate understanding of the strength of the ecosystem responses to this work.

Evaluation of successes and failures of restoration activities for each site

Four active restoration sites have been established, two each in Honeymoon Cove and Underwater Arch Cove, 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.

Increases in the efficacy of restoration activities were largely the result of familiarity of approaches to systematically clearing area of sea urchins assuring high levels of clearing per unit of effort. In addition, better navigational aids and improved accuracy by restoration teams navigating on the ocean floor has greatly reduced time searching, leading to more rapid starts to the day's work.

Due to the low levels of intra-block variance in the density of sea urchins, pre-monitoring efforts for the coming scope of work, 2014-2015 will include only 5 transects rather than 15. This reduction in pre-monitoring effort will reduce the total area of a given site pre-restoration from 100% to 33%. The hours saved through this work will be directly transferred to restoration work, creating a significant increase in restoration effort for 2014-2015 and beyond.

Urchin barrens are not static and the values ascribed to the extent of barrens from mapping conducted in 2010, which were the basis for the original project, underrepresent the current expanse of the barrens. A series of surveys were conducted in the summer and fall of 2012 to inform the start of restoration actions in 2013. The values associated with these 2012 surveys represent an expansion of the barrens in the two coves, Honeymoon and Underwater Arch (Figure 12). If these observations are suggestive of an overall increase of barren extent throughout the Palos Verdes Peninsula our efforts may not address all of the barrens as we had once anticipated.

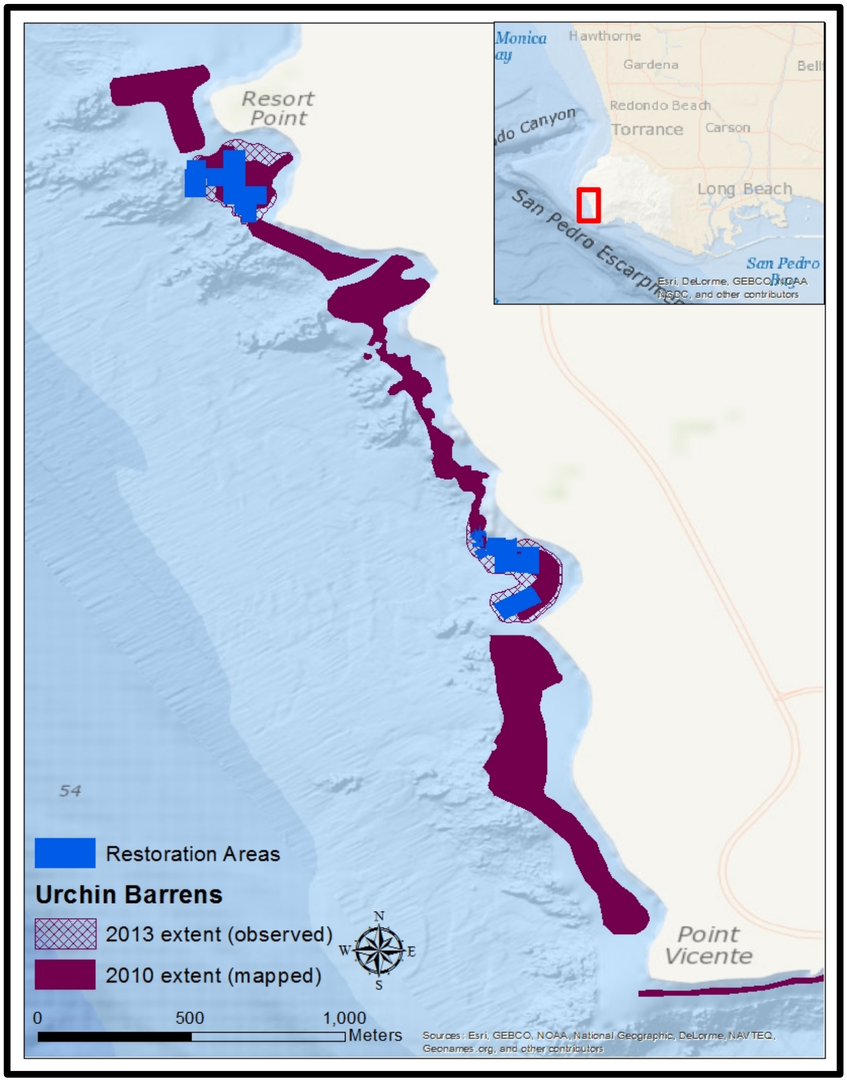

Figure 12. Urchin barrens as mapped in 2010 and observed in 2013, representing a possible expansion of urchin barrens. Overview of the project area along the Palos Verdes Peninsula showing the urchin barren extent mapped in 2010 and the observed expansion of the urchin barrens in Honeymoon and Underwater Arch Coves from a series of surveys conducted in summer and fall of 2012. The locations of current restoration activity in Honeymoon and Underwater Arch Coves are in blue.

Geo-referenced images before and after restoration activities

See Appendix 1

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