UPPER NEWPORT BAY EELGRASS RESTORATION PROJECT

Final Report

August 2015

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Introduction

Orange County Coastkeeper (Coastkeeper) and Coastal Resources Management, Inc. (CRM) implemented a native eelgrass, *Zostera marina*, restoration project in Upper Newport Bay (UNB), Newport Beach, California (33°37'13.89"N, 117°53'43.08"W, Figures 1 and 2). Eelgrass in Newport Bay has been an important component of the estuary ecosystem dating back to 600 A.D. (Wiede 1981 in Coastal Resources Management, 2010). Over the last 40 years, however, eelgrass habitat has dramatically declined due to increased urban runoff and coastal development activities, especially in UNB.

Eelgrass has extremely high light requirements and significant decreases in light reaching beds has been a consistent problem as a result of increased water turbidity from sediment inputs and the persistence of harmful algal blooms resulting from excess nutrients. The effects of climate change (e.g., sea level rise and increasing water temperatures) compounded with these stressors, can have a negative synergistic effect on eelgrass, resulting in large-scale habitat loss. This combination of threats most likely has been the cause of the decline of eelgrass habitat in UNB.

As water quality and clarity have improved in recent years due to increased regulation of sediments and nutrients entering the Bay (County of Orange 2003; CRM 2009), it was an ideal time to restore eelgrass in UNB. In addition, the Army Corps of Engineers had recently completed a large-scale ecosystem restoration, which aimed to have created a more suitable environment for multiple species, including eelgrass. Our restoration project aimed to take advantage of these recent ecosystem improvements to not only restore eelgrass in an area well-suited to support seagrass, but also use innovative restoration methods that have not yet been tested in Newport Bay. It was our intent to determine whether eelgrass can persist within this newly-restored location, what environmental factors contribute specifically to the growth and survival of restored habitat, and evaluate new methods of restoration that will help inform management and future restoration projects in Newport Bay.

In the long term, we predicted a greater colonization of the remaining potential eelgrass habitat to be colonized once eelgrass areas were established by transplant and seeding methods. Although small in total size, we expected restoration of this eelgrass habitat to produce significant ecosystem improvements, including increased primary production, increased invertebrate and fish diversity in the Upper Bay, and increased nutrient flow within the system, and exported to nearshore fisheries along the southern California coastline.

Project Goals

The main goal of the Upper Newport Bay Eelgrass Restoration Project was to restore eelgrass habitat in Upper Newport Bay. Secondarily, we aimed to assess the effectiveness and feasibility of three different eelgrass restoration techniques, two of which had not be tested in southern California before, in Upper Newport Bay through a small scale pilot study.

Restoration Site Description

The State of California Upper Newport Bay Ecological Reserve (UNBER) encompasses over 1,000 acres of tidal and non-tidal areas and is one of the last remaining coastal wetlands in Southern California. The Reserve is home to over 935 species of plants and animals and over 200 bird species, including several endangered species. Approximately ten acres of intertidal and shallow subtidal *potential eelgrass habitat* (defined as habitat suitable for eelgrass growth but currently unvegetated) was present in Upper Newport Bay prior to project initiation.

De Anza Peninsula (Figure 2) was selected as the site with the greatest potential for restoration success based upon the historical (and current) presence of eelgrass, similar abiotic and biotic conditions, better tidal flushing, and historical water quality data for this site (Coastal Resources Management, Inc., 2010). Average salinity at the sites is 32 ppt, depths range from -1ft to -6ft MLLW (Mean Lower Low Water), and temperatures vary from 68 to 72°F. Light transmittance tends to be reduced in UNB compared to other areas of the Bay, which were monitored throughout the project. Eelgrass was transplanted between 0.0 ft and -3 ft MLLW, because any losses associated with sea-level rise is expected to occur at the deeper edges of the beds to depths below which eelgrass can survive (R. Ware, pers. Com.).

Transplanted eelgrass was collected from an established eelgrass site in lower Newport Bay, Inner Linda Isle, approximately 600 meters (2,000 feet) south of the southernmost transplant site and outside of Reserve boundaries (Figure 3). We chose this donor site based on the following criteria developed from eelgrass restoration research performed in the bay: similar biotic and abiotic characteristics – depth/light, sediment type, current velocity, water quality, tidal flushing rates (Pers. Com. Rick Ware, CRM, Inc., March 11, 2010); close proximity to restoration site; morphologically similar eelgrass; historical water quality, eelgrass abundance and distribution data available (R. Ware, pers. Com. March 11, 2010). While Inner Linda Isle was the primary donation site, two other beds were monitored as additional potential donor sites should the need arise, Harbor Island and Outer Linda Isle. Donor material was taken based upon the guidelines outlined in the *Southern California Eelgrass Mitigation Policy*: "No more than 10 percent of an existing bed shall be harvested for transplanting purposes. Plants harvested shall be taken in a manner to thin an existing bed without leaving any noticeable bare areas." In addition, we monitored the density of all donor and potential donor sites throughout the study period to endure no detrimental impacts caused by collection.

In addition to monitoring donor and potential donor eelgrass beds, we also monitored a control eelgrass bed which was present before project initiation and was approximately five meters downstream of the restoration area, for comparison (Figure 3).

Importance of Eelgrass

Eelgrass (*Zostera marina*) is one of 60 species of seagrasses—a unique group of aquatic flowering plants that grow fully submersed in shallow coastal waters worldwide. Eelgrass meadows provide many important ecological services, including habitat and foraging grounds for many invertebrate, fish, and bird species (Appendix E); nutrient cycling; carbon sequestration; sediment stabilization; and water quality improvement (Costanza et al. 1997; Orth et al. 2006). Several studies of eelgrass in Southern California have found that the diversity and abundance of marine life is increased within eelgrass habitat in comparison to unvegetated soft bottom habitat (MBC, 1986; Hoffman, 1986; Hoffman, 1990;

Hoffman, 1991).

This report represents the final progress report and includes analysis on eelgrass transplant efforts in Upper Newport Bay since 2012 and associated water quality studies.

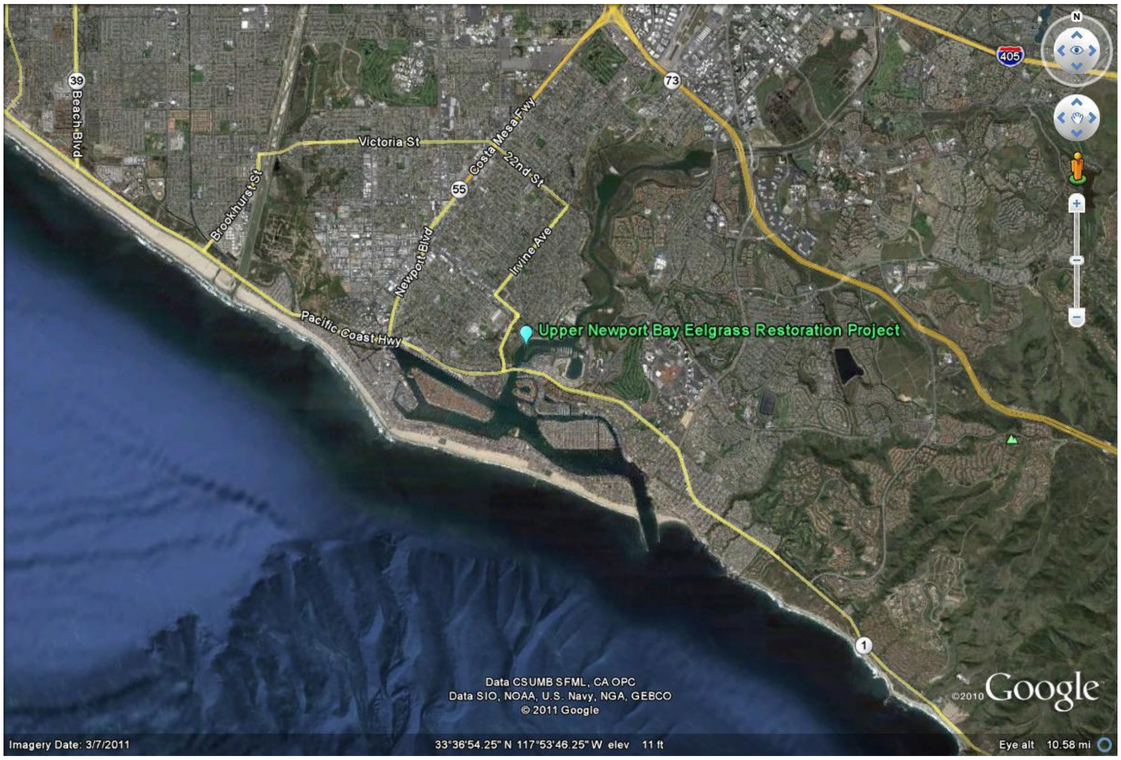

Figure 1. Project Regional Map in Upper Newport Bay, Newport Beach, CA.


Figure 2. Project Site, De Anza Peninsula in Upper Newport Bay, Newport Beach, CA.

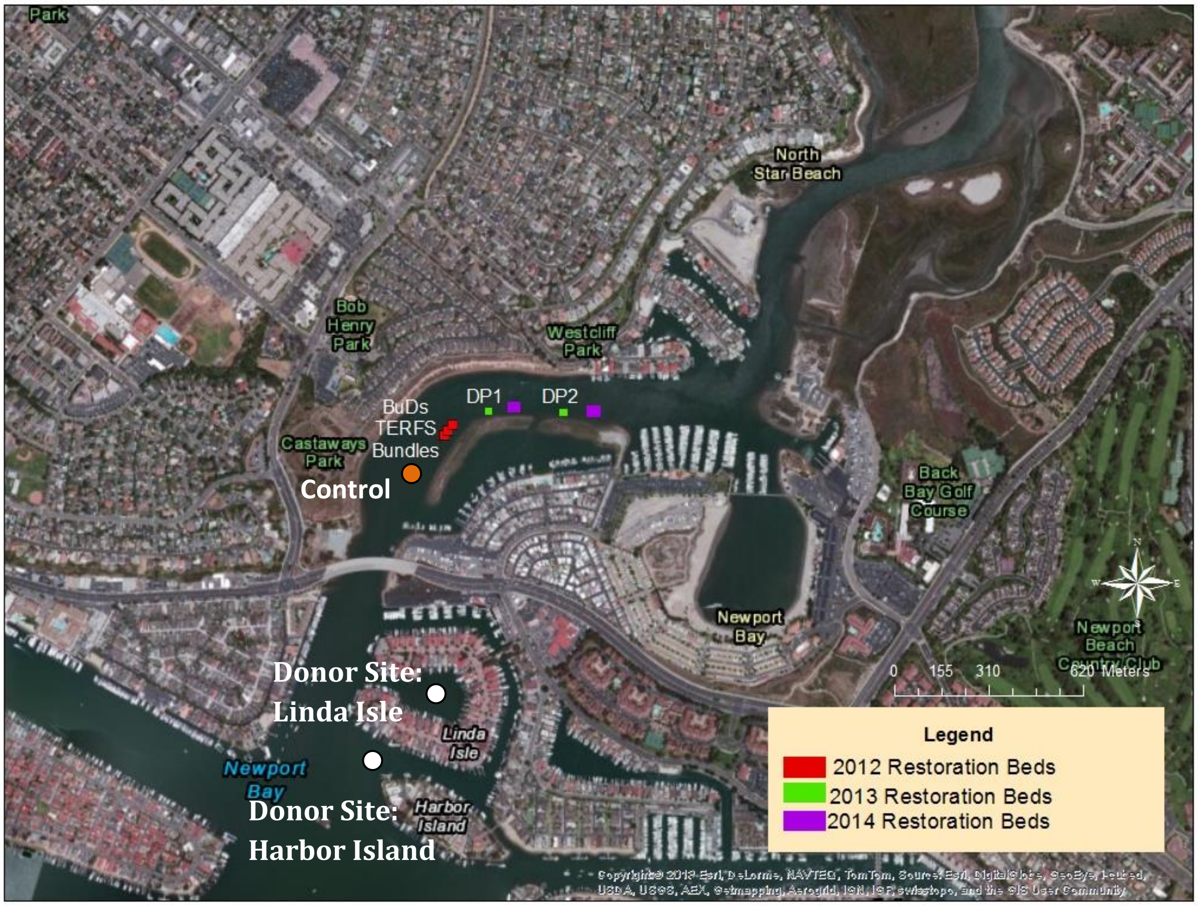

Figure 3. Donor, Control and Restoration sites (2012 to 2014). Three plots were planted in 2012 (BuDs, TERFS, Bundles); two in 2013 (DP 1 and DP 2); three in 2014 (only 2 shown in this view).

Project Success Criteria

1. Percent Survival of transplants: A minimum of 15-25% survival of transplants by the first year for Buoy Deployed Seeding (BuDS) and by 6 months for Diver transplants (DT) and Transplanting Eelgrass Remotely with Frames (TERFs).

2. Percent areal cover and density:
   - Restoration sites maintain a minimum of 50% of original planted area and 20% of the reference site density by the first year following restoration.
   - Restoration sites maintain a minimum of 60% of original planted area and 70% of the reference site density by the second year following restoration.
   - Restored sites will maintain a 75% of original planted area and 85% of the reference density for the following 2 years of monitoring.

3. Water quality and light values are within the ranges for long term eelgrass survival and growth in comparison to reference beds.

Permitting

To plant eelgrass in the Upper Newport Bay Ecological Reserve, there were multiple permits and certifications required, applied for, and obtained.

1. Land use permission/permits from the County of Orange (ownership of De Anza site) – Permit # P2010-00365
2. California Department of Fish and Wildlife (CDFW) Scientific collection permit
3. Letter of Access to Upper Newport Bay Ecological Reserve for eelgrass restoration, CDFW
4. Letter of Authorization for the Transplanting of eelgrass within Lower and Upper Newport Bay, CDFW
5. California Coastal Commission Coastal Development Permit Waiver E-11-008-W

Year 1 Pilot Study

Project objective

A primary goal of the first year of restoration was to compare the success of 3 eelgrass restoration techniques: Transplanting Eelgrass Remotely with FrameS (TERFS), Buoy-Deployed (BuDS), and Diver Transplant (DT).

Methods

Restoration Methods:

1. TERFS (Transplanting Eelgrass Remotely with FrameS) – This method of transplanting eelgrass, pioneered by Short et al. (2002), involves attaching eelgrass to frames using biodegradable materials, lowering the frames into the water from the surface, and removing the frames before roots and rhizomes overgrow the frames. Mature plants were collected and attached to frames with hemp string, which were then be deployed from the surface (Figure 4). Twenty frames were installed spaced at 1 meter intervals within an 8 m by 8 m plot (64 m^2) along De Anza Peninsula. In Short et. al., 2002, rolled crepe paper was used to tie each eelgrass rhizome to the frame. However, we found that the crepe ties were not strong enough to hold the eelgrass on the frame long enough to transport the frames by boat to the site and through strong water current before being slowly lowered by divers to the bay floor. Hemp string is biodegradable and was left over from the Diver Transplant method. The frames were meant to keep the transplants in place and protected from erosion, until the plants took root; however, the frames were never removed in this project.

2. BuDS (Buoy-Deployed Seeding) – This method relies on dispersal of seeds from suspended mesh bags containing eelgrass inflorescences (which contain the eelgrass flowers and seeds) at the water surface, in an attempt to maximize seed dispersal and seedling establishment (Pickerell et a., 2005). Fertilized eelgrass flowers containing seeds were collected from Inner Linda Isle donor bed and added to small 9 mm mesh bags. Each mesh bag held up to 100 flowering shoots. The mesh bags were attached to lobster pot buoys so they floated just below the water surface and anchored in place using rope attached to a heavy cement block (Figure 5). Twenty BuDS units were deployed at 3 meter intervals within a 12 m by 9 m plot (108 m^2) along De Anza Peninsula.

3. Diver transplant (DT) – This method is currently the only method that has been used in Newport Bay. It involves the bundling of 10 – 15 shoots in a Turion Planting Unit (Figure 6) which is then transplanted in an evenly spaced grid in the unvegetated restoration site. Mature plants were collected by divers in Inner Linda Isle and separated within seawater trays on land into Turion Planting Units and attached to biodegradable anchors. Using hand-methods, the divers planted the Turion Planting Units by excavating holes within the restoration site no deeper than six inches deep and buried the biodegradable anchors in the sediment. Divers transplanted 170 total bundles within an 8 m x 8 m plot (64 m^2) at 0.5 meter intervals.

Each test plot was spaced 10 m apart from each other (Figure 7) and 10 m away from the De Anza Peninsula Control site (Figure 3).


Figure 4. TERFS units being constructed on land and deployed in the bay.

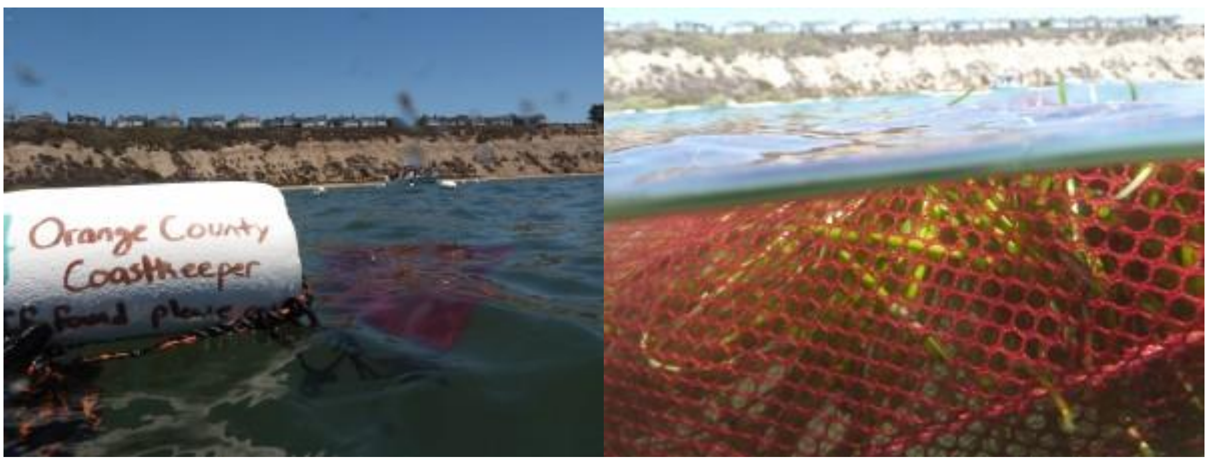

Figure 5. BuDS units floating at the water surface.


Figure 6. Bundling of Eelgrass into Turion Planting Units.

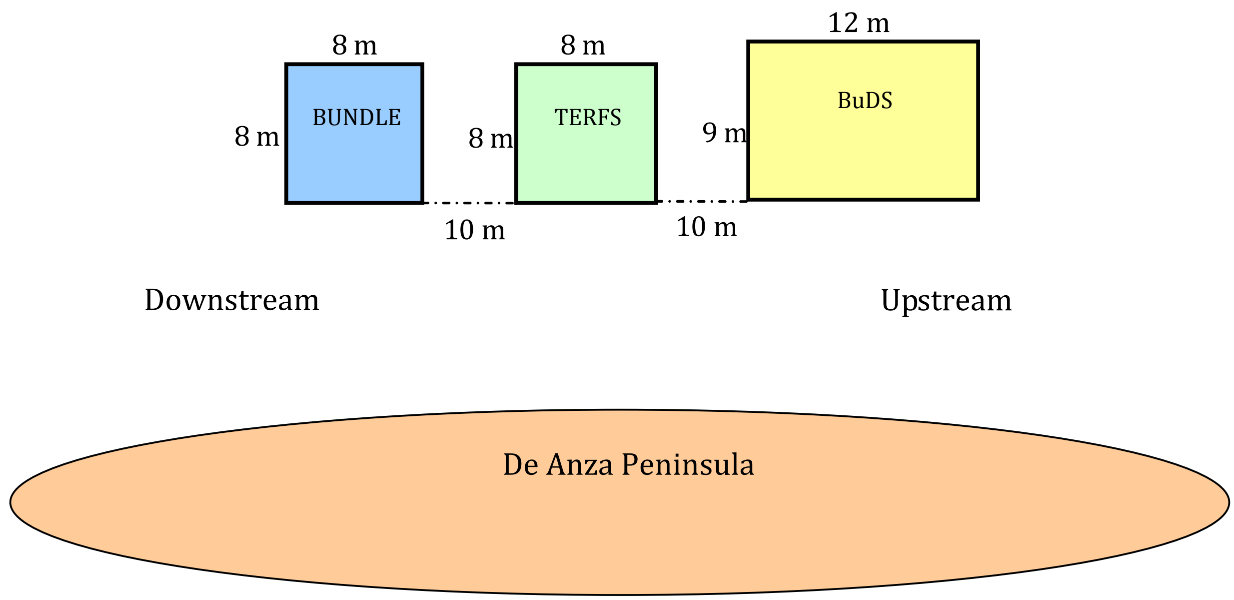

Figure 7. Year 1 experimental restoration plot Diagram.

Monitoring Methods

Eelgrass Survival and Areal Cover

The restored area was surveyed for survival and areal extent of transplants for the bundles, TERFS starting 6 months after restoration and after one year in the BuDS areas. By December 2012, 6 months after restoration, researchers observed that the transplants within the Diver Transplant area had spread enough to map the restored area as a bed (e.g., little to no un-vegetated patches), so areal cover was measured instead of counting the number of surviving transplants. TERFS were monitored similarly to those methods outlined by Short et al, 2002, by counting a) the number of TERFS patches with remaining shoots and b) how many shoots remain within each TERFS patch. Each patch was initially located by a diver and mapped as a patch (e.g., single point) using GPS. Once each TERF patch was mapped, the diver counted the total number of turions/shoots within the patch and then additionally measured the distance of spreading around each of the four sides of the frame in order to determine increases in areal cover.

The areal cover of eelgrass in the control and restoration sites was determined by Coastal Resources Management, Inc. using Wide Area Augmentation System (WAAS), GPS (Global Positioning System) technology and a Thales Mobile Mapper GPS/GIS Unit. The estimated error of the Thales Mobile Mapper GPS unit with post-processing correction was less than 1 meter. GPS data were initially entered into the Mobile Mapper Software and then transferred into GPS TRACKER and ARCVIEW GIS software. The amount of eelgrass habitat in the project area was calculated using ArcGIS 10.0 and Mobile Mapper Software. Field survey depth data were standardized to feet Mean Lower Low Water (ft, MLLW) based upon data for the Newport Bay NOAA tide station. Methods based on baywide survey methods used in CRM 2010.

Eelgrass turion density

The density of turions, individual eelgrass shoots, was assessed biannually starting in May 2012, before restoration, through January 2014 at each of the restoration plots and control site. A 30 m transect was laid at three depths within each bed (shallow, center and deep edge) and the number of turions in replicated quadrats was counted at each site (n = 14 – 125).

Results:

Percent Survival

Percent survival of diver transplanted eelgrass could not be measured because eelgrass had expanded into a continuous bed by the time of the 6 month survey, so area and density were measured instead and described below. Nineteen out of the twenty originally planted TERFS remained 6 months after transplantation, each containing an average of 31.5 shoots, ranging between 15 and 68 shoots per frame. Mean percent survival of shoots planted using the TERFS units was 60%, well above the 15-25% minimum after 6 months.

Areal Cover

Six months after restoration, eelgrass remained in each plot, though substantially more eelgrass remained in the Diver Transplant (DT) plot than in the other methods (Table 1, Figure 9). The DT plot was the only method to meet the year one success criteria (50% of original area) with 86.0% of eelgrass area remaining. The BuDS plot (20.5%) and TERFS plots (1.0%) were substantially lower than year 1 success criteria. After 1 and 1.5 years, each plot showed substantial spreading in areal cover (70-97%) (Figure 10 and 11, Table 1), but by 2.5 years after restoration in February 2015, the beds became patchier and showed a large decline in areal cover (Table 1, Figure 13). The TERFS plot retained the highest areal cover (44.0%), followed by DT (14.9%) and the BuDS plot with very little area remaining (4.3%). Eelgrass area, however, was not excluded to just within the original planting boundaries; since restoration began, eelgrass expanded shoreward and seaward of original plots, perhaps aided by the close proximity of the control bed. At the time of the last area survey in February 2015, the total area of eelgrass within the original plots was 0.02 acres, while the total eelgrass area within the 2012 restoration sites, including area shoreward and seaward of original plots, totaled 0.20 acres, a substantial increase compared to eelgrass area prior to restoration.

Table 1. Eelgrass area within each restoration plot through 2.5 years after restoration. Eelgrass area (m^2) within each plot and percentage remaining of the original planting area calculated for each time period. Values in bold did not meet success criteria.

Method	Initial Area (m^2)	0.5 year (m^2)	1 yr (m^2)	1.5 yr (m^2)	2.5 yr (m^2)
DT	64	55.0 (*86.0%*)	47.3 (*73.9%*)	54.8 (*85.7%*)	**9.5 (*14.9%*)**
TERFS	64	**0.6 (*1.0%*)**	57.9 (*90.5%*)	62.1 (97.*0%*)	**28.2 (*44.0%*)**
BuDS	108	**22.2 (20.*5%*)**	62.9 (*58.3%*)	75.6 (*70.0%*)	**4.6 (*4.3%*)**

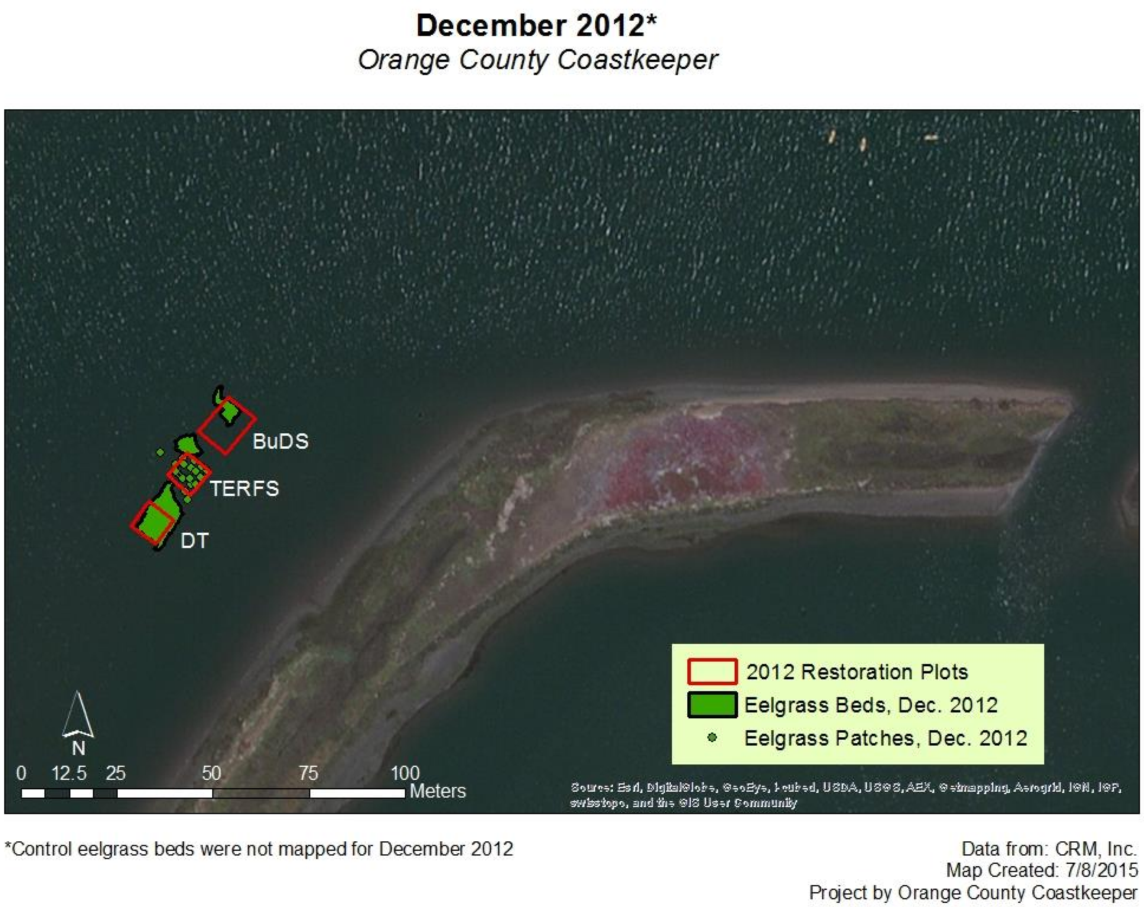

Figure 8. Eelgrass bed area along De Anza Peninsula in December 2012, 7 months after restoration. The areas of 2012 restoration plots are outlined in red boxes.

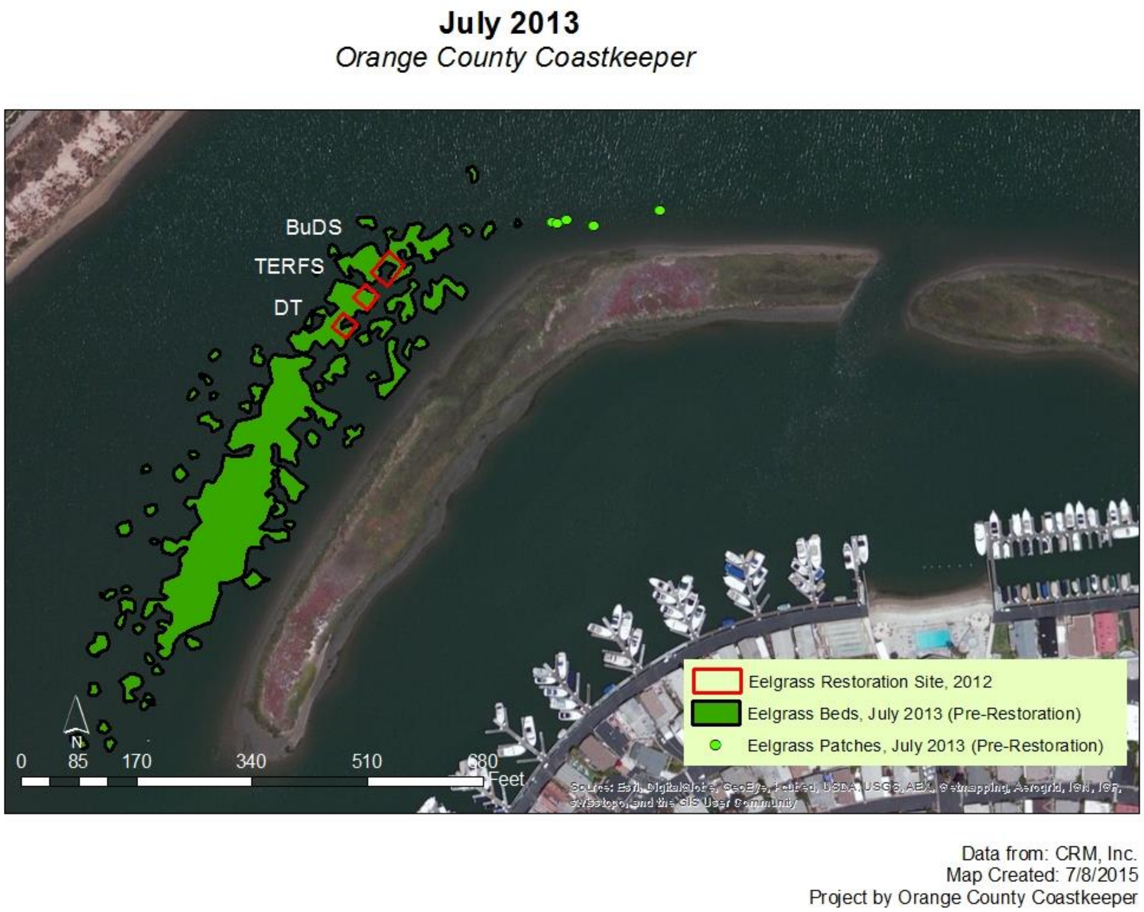

Figure 9. Eelgrass bed area along De Anza Peninsula in July 2013 restoration, 1 year after 2012 restoration (red squares) and prior to 2013 restoration.

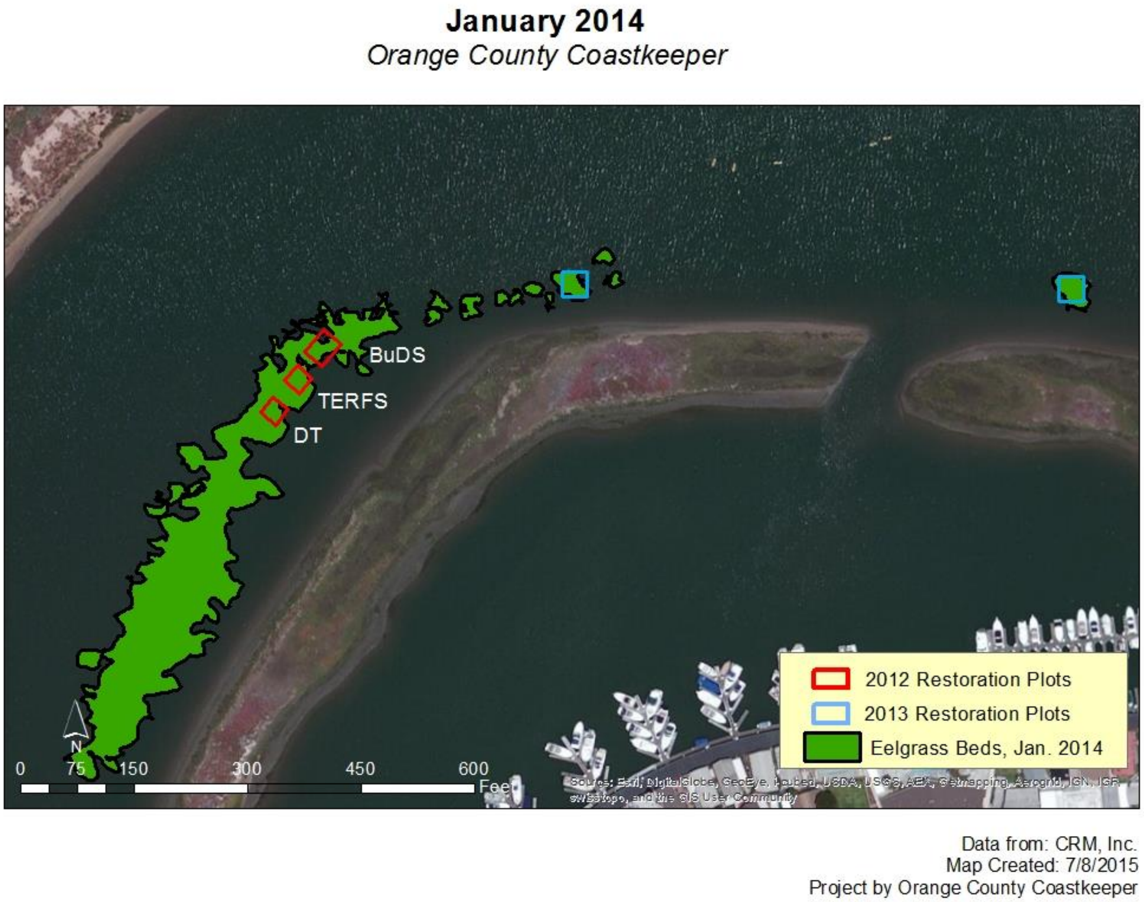

Figure 10. Eelgrass bed area along De Anza Peninsula in January 2014, 1.5 years after 2012 restoration (red squares), 0.5 years after 2013 restoration (blue squares), and prior to 2014 restoration.

Eelgrass turion density

Eelgrass turion density differed between each restoration method planted in 2012. Six months after planting, the density within the Diver Transplant plot was higher than the TERFS plot, but not significantly different from control density (Figure 11, Appendix A). In each successive survey, the TERFS and BuDS plots showed a higher density than the Diver Transplant plots, though none were significantly different from the control density. Each restoration method tested in 2012 restoration surpassed turion density success criteria within the first year following restoration (Table 2), achieving over 20% of the control density. During the second year in January 2014, the TERFS and BuDS plots surpassed success criteria, but the diver transplant plot was slightly below the minimum of 70% of control density.

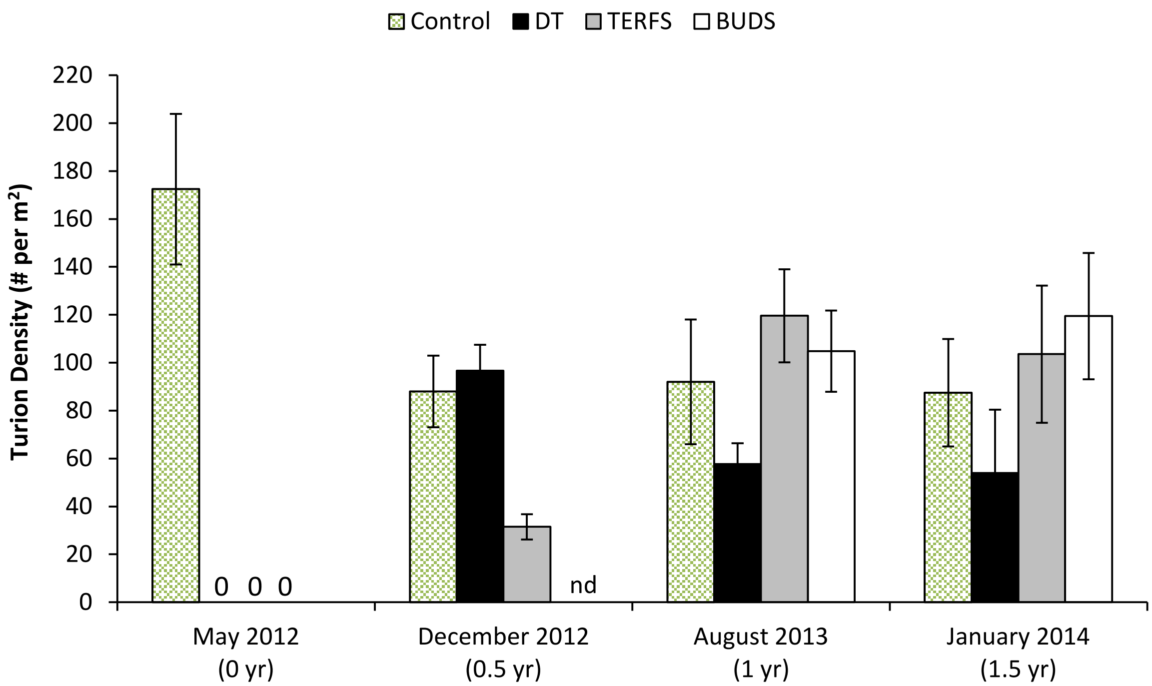

Figure 11. Mean turion density (± 95% confidence intervals) in 2012 restoration sites and De Anza control eelgrass bed from June 2012 (before restoration) to January 2014 (1.5 years after restoration). Three methods were tested (DT, TERFS, and BuDS), and planted in plots 10 meters apart from one another.

Table 2. Percentage of control density following restoration in each restoration bed. Values not meeting success criteria in bold. Dashes used when data not available.

	0.5 yr	1 yr	1.5 yr
Success Criteria	20%	20%	70%
2012 Sites	35.8%	102.2%	105.5%
DT	109.9%	62.7%	**61.7%**
TERFS	35.8%	130.0%	118.4%
BuDS	-	114.0%	136.6%

Discussion:

While all three methods tested were successful in retaining eelgrass, some methods were more successful than others. Though the Diver Transplant (DT) plot retained the greatest area and turion density 6 months after restoration, the TERFS plot retained the greatest area and higher turion densities in each successive survey. The BuDS plot showed the least success out of each of the methods.

This pilot study was not intended to be an exhaustive test of each method, nor does it suggest the effectiveness of each method at other locations in Newport Bay. Only a single plot of each method was compared, which does not capture the possible range of variability in effectiveness of each method. In addition, these results are likely context dependent and the same results may not be achieved in different locations with different environmental conditions. More research with greater replication of each method in different areas of the bay is necessary to better understand the appropriate use for each restoration method in Newport Bay.

However, from our pilot study we can draw some comparisons between the methods from our own experience. A benefit of the TERFS method is less effort required by divers, who are, in theory, eliminated from the planting process as the TERFS units can be lowered into place from the surface. However, in the compacted sediments along De Anza Peninsula, the frames in our project required extra time by divers to ensure they were buried correctly in the sediment. In softer sediments, this method might be more appropriate. The greatest disadvantages of this method are the increased cost of supplies (metal frames) and additional requirement to correctly time removal of the frames. Divers must carefully remove the metal frames before the roots and rhizomes have taken hold. Removing the frames too late will rip up the transplanted eelgrass and counteract planting efforts. The TERFS frames were never removed in the study because the roots and rhizomes had already taken hold over the frames into the sediment. In a larger scale restoration effort, leaving TERF frames in the water is not a viable option and will increase trash and boater hazards in our waterways. This project is the first to use the TERFS method in southern California, and elsewhere in California, in San Francisco Bay, the TERFS method has shown only partial success (NOAA Fisheries, 2014). We recommend additional testing of the TERFS technique to perfect methods of use and better understand the appropriate conditions of its use.

While the diver transplant method showed intermediate success, there are several benefits of this method including low costs of supplies, and well-documented success in southern California bays (87% project success rate, NOAA Fisheries, 2014). There are some disadvantages of this method, including a greater requirement for skilled divers to plant the eelgrass, which limits the scale of restoration.

The BuDS method showed the least retention of eelgrass area within the original planted plot, though likely the eelgrass dispersed outside of the BuDS planting area. This method is especially difficult to track the success of, especially in a high current area like De Anza Peninsula in Upper Newport Bay. The benefit of the method is less diver use in planting time, though this time is likely made up in collection time in targeting the correct individual plants. To complete this effort on a large scale also requires a substantial time input to collect plants at the right stage of development and time out of water by biologists verifying readiness of plants for use. In addition, particularly in the high traffic area along De Anza Peninsula, many of the buoys and bags were damaged by boaters, which require greater signage, communication and compliance with the community for this method to work.

Based on the 6 month results we had comparing each method, and logistical, cost and labor factors, we decided the Diver Transplant restoration method was the most appealing method of restoration in Upper Newport Bay along De Anza Peninsula. We proceeded in Years Two and Three with this method only.

Years 2 and 3 – Restoration

Project objective: The goal of the second and third years of restoration was to increase areal coverage of eelgrass in Upper Newport Bay through restoration by implementing the most effective technique determined from small pilot scale study.

Methods:

Restoration Methods:

After determining the most successful and cost effective restoration method to be Diver transplant from preliminary pilot study results, eelgrass was transplanted using this method only in Years 2 and 3 in the same methods as described in Chapter 2. In Year 2 (June 2013), two 10 m by 10 m plots were planted (200 m^2), one on each half of De Anza Peninsula (DP1 and DP2) using diver transplanted bundles spaced every 0. 5 meters. In Year 3 (July 2014), 3 plots of diver transplanted eelgrass were planted, two - 10 m by 10 m plots and one - 2 m by 20 m plot. The two 10 m by 10 m plots were planted along DP1 and the 20 m by 2 m plot was planted along DP2 (Figure 3 in Chapter 2). In each plot, eelgrass bundles were prepared as in the year before and were planted in a grid approximately every 0.5 meters from each other.

Monitoring Methods:

Each plot monitored biannually starting before restoration through June 2015 following methods described in Chapter 2.

Results:

Areal Cover

At the time of the last area survey in February 2015, the areas remaining in each plot differed substantially (Figure 12, Table 3). The greatest area remained in the one year old plots planted in 2014 (plot 2: 70.5% and plot 3: 60.2%, Table 3), though one 2014 plot did not retain any eelgrass after 1 year (plot 5). Plots planted in 2013 experienced varied success: plot 4 retained nearly 50% of the original planted area (though still below success criteria), while plot 1 retained 5.5% of original planted area. Eelgrass area, however, was not limited to just within the original planting boundaries. Since restoration began, eelgrass expanded outside the boundaries of the original plots and several new eelgrass patches also showed up on the northern side of De Anza Peninsula (Figure 12). At the time of the last area survey in February 2015, the total area of eelgrass within the original plots was 0.05 acres, while the total eelgrass along the northern side of the peninsula totaled 0.12 acres, which is a substantial increase from before restoration when no eelgrass area existed on the northern side of the peninsula.

Eelgrass area along De Anza Peninsula has continued to increase since the project initiation in 2012. Before restoration initiation, a 0.42 acre eelgrass bed existed on the western side of the peninsula (Figure 13). Each successive year, eelgrass was planted farther upstream on the northern side of the peninsula to expand eelgrass acreage in the area. At the latest survey in February 2015, the total area on De Anza Peninsula was 0.89 acres (Figure 12), which is over 2 times the area present before the restoration project. However, at times, the area along the peninsula was 3-4 times the amount present before restoration (July 2013: 1.595 acres and January 2014: 1.417 acres). This expansion is likely due to the combined effects of expansion of the pre-existing eelgrass bed and restoration efforts.

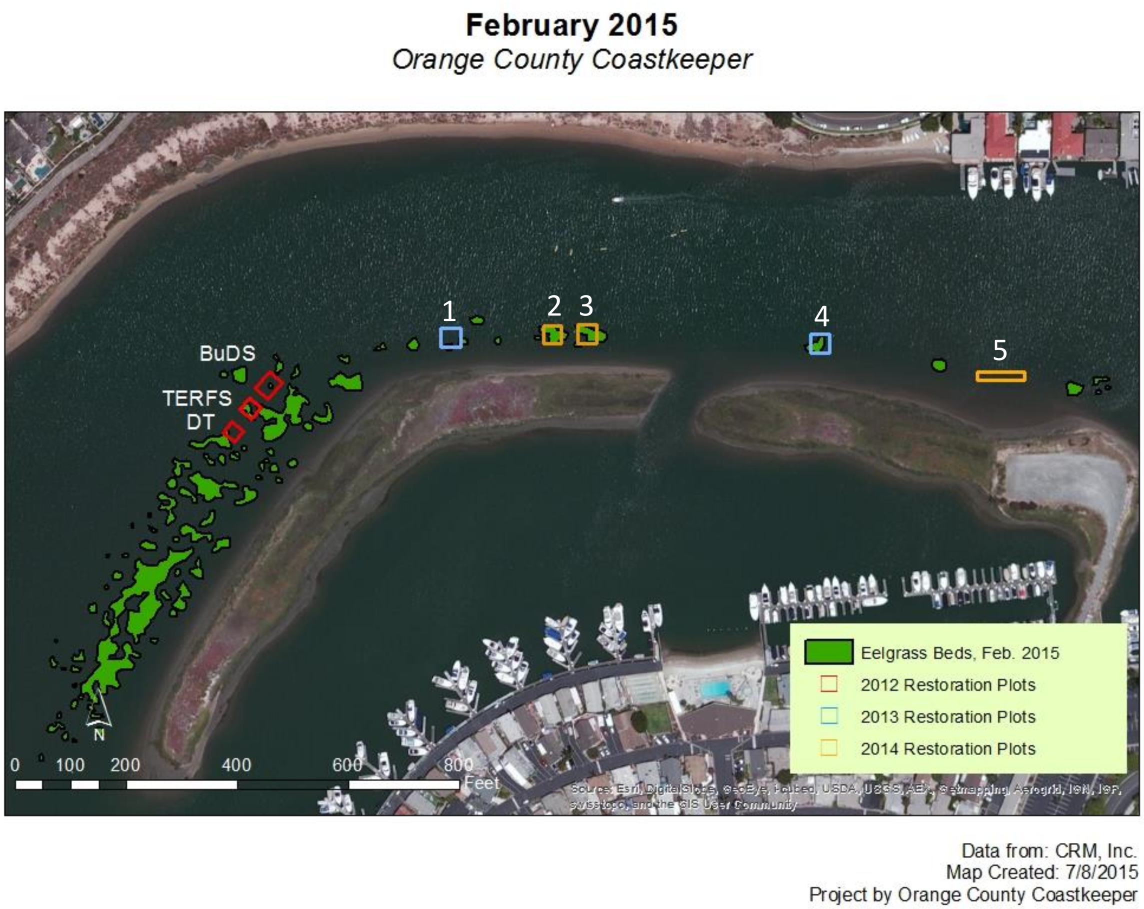

Figure 12. Eelgrass bed area along De Anza Peninsula in February 2015, 2.5 years after 2012 restoration (red squares), 1.5 years after 2013 restoration (blue squares), and 0.5 years after 2014 restoration (yellow squares). Plot numbers listed above each plot.

Table 3. Eelgrass areal cover remaining at the final area survey in February 2015. Plot numbers correspond to the numbers shown in Figure 12. Plots not meeting success criteria highlighted in bold.

Plot #	Initial Planting	Initial (m^2)	Final (m^2)	Percent Cover
1	2013	100	5.50	**5.5%**
2	2014	100	70.47	70.5%
3	2014	100	60.18	60.2%
4	2013	100	49.71	**49.7%**
5	2014	40	0.00	**0.0%**

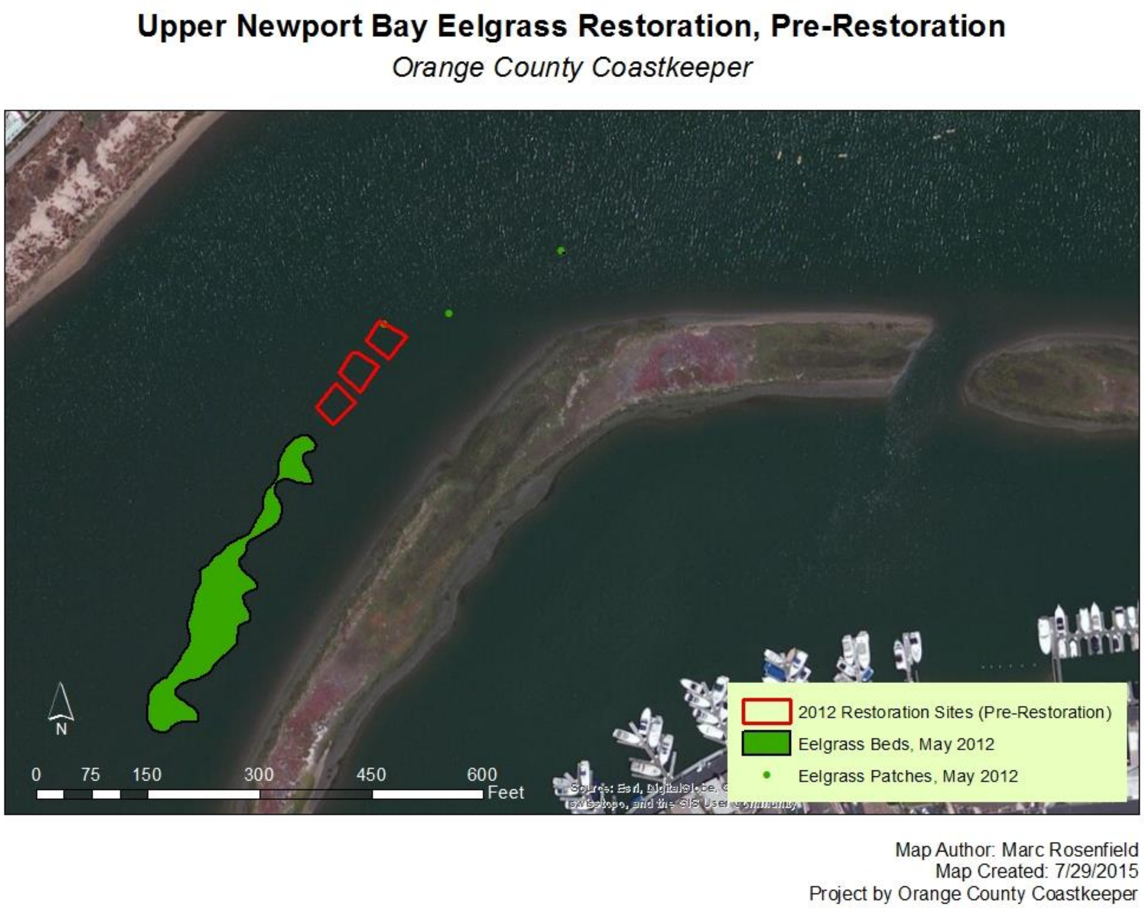

Figure 13. Eelgrass bed area along De Anza Peninsula in May 2012, prior to initial restoration. The areas of 2012 restoration plots are outlined in red boxes.

Eelgrass Turion Density

Eelgrass planted on the northern side of the De Anza Peninsula in 2013 took approximately 1 year to equal control bed density on the western side of the peninsula, though beds planted in 2014 still were lower than control bed densities after 1 year (Figure 14, Appendix A). At the 2 year mark though, the 2013 beds were lower than control density, though all restored beds showed evidence of a decline.

The restoration beds in 2013 and 2014 both met success criteria within the first year after restoration; however the 2013 beds were slightly below success criteria at the 2 year mark in June 2015 (Table 4).

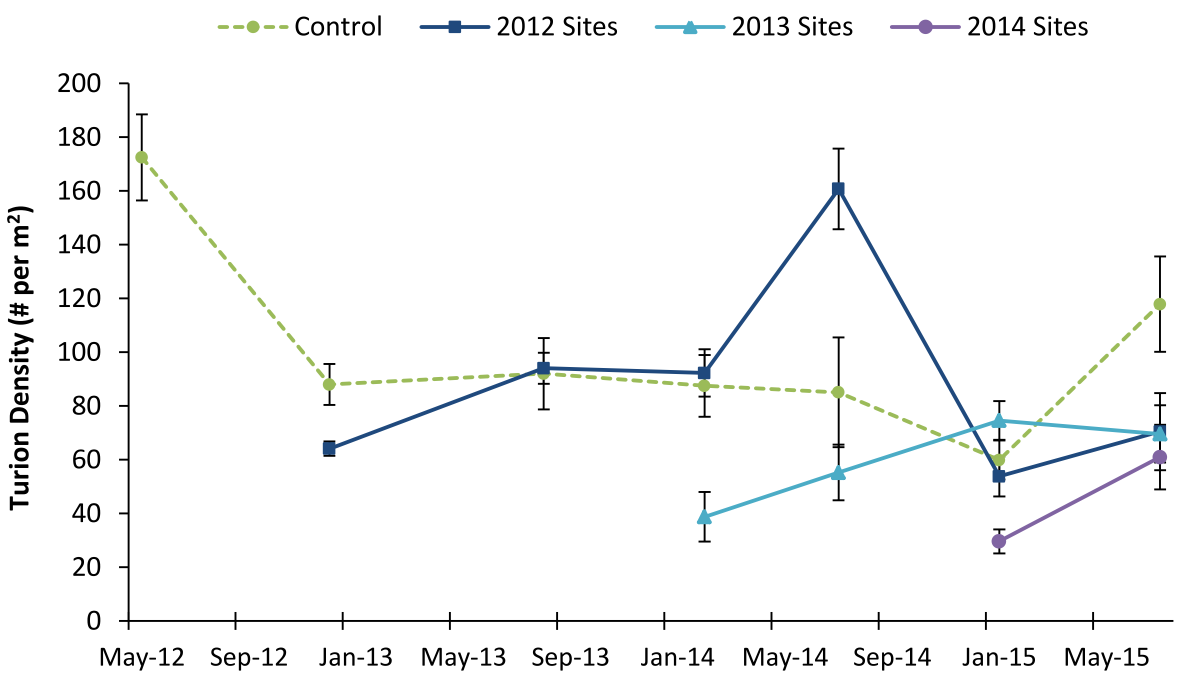

Figure 14. Mean turion density (± SE) for restoration plots planted the summer of each year (2012, 2013, and 2014).

Table 4. Percentage of control density following restoration over each restoration plot per year. Values not meeting success criteria highlighted in bold. Dashes used when data not available.

	0.5 yr	1 yr	1.5 yr	2 yr	2.5 yr	3 yr
Success Criteria	20%	20%	70%	70%	85%	85%
2012 Sites	72.8%	102.2%	105.5%	189.0%	89.8%	**59.8%**
2013 Sites	44.3%	64.9%	124.6%	**59.0%**	-	-
2014 Sites	49.5%	51.7%	-	-	-	-

Discussion:

The northern side of De Anza peninsula is a slightly less hospitable area for eelgrass than the site of year one restoration on the western side of the peninsula, particularly due to stronger water currents and more compacted, larger grain size sediments. Our efforts tested whether eelgrass restoration could succeed in these conditions. We found mixed success in this area. Retention of planted eelgrass area along the northern side of De Anza Peninsula in years two and three was extremely variable and ranged from 70% cover to 0% percent cover and turion densities took slightly longer to reach control bed densities than restoration efforts on the western side of the peninsula. We saw substantially less expansion of eelgrass in this location than in the year one site, though this may also have to do with the proximity of the pre-existing eelgrass bed on the western side. In general, it looks as though the year 2 and 3 restoration efforts closest to the western side of the peninsula showed the greatest eelgrass area coverage. However, these most successful beds are only a year old and should continue to be monitored, as the 2 year old beds in this location did not meet year 2 success criteria. Longer term monitoring will also reveal if the presence of eelgrass enables future eelgrass proliferation, since eelgrass, as a foundation species, is expected to modify the environment to improve conditions for future eelgrass growth.

Water Quality and Light Irradiance

Project objective: To determine if water quality and light values in the restored site along De Anza Peninsula (RS) fall within the ranges for long term eelgrass survival and growth in comparison to reference beds.

Methods

Water Quality

Temperature, dissolved oxygen, pH, and salinity were measured 1-2 days each quarter using an YSI 556 Multi-Probe System. Five stations were monitored: Shellmaker Island (SMI), the De Anza Peninsula restoration site (RS) in Upper Newport Bay, donor bed Inner Linda Isle (ILI), and potential donor beds, Outer Linda Isle (OLI) and Harbor Island (HI) (Figure 15). Shellmaker Island was included as an un-vegetated reference site that is also a potential eelgrass habitat site. Water quality measures were taken at three depths: 1 foot below the surface, mid-depth, and 1 foot above the seafloor. Mean water column values for each parameter were obtained by averaging across the three depths.

Light irradiance

Instantaneous light measurements were collected 1-2 days each quarter during water quality monitoring surveys at each water quality site (Figure 15). Photosynthetic Photon Flux (PPF) (mmol/m^{-2}/s^{-1}) was measured using an Apogee Quantum Meter MQ200 attached to a Secchi disk to measure the amount of light energy present at several depths. Instantaneous readings were made in air, one foot below the surface of the water, at mid-depth, and one foot above the seafloor. Methods followed those of CRM, 2010. The percent of surface irradiance hitting the eelgrass canopy was calculated as the percentage of light energy (PPF) measured one foot above the seafloor from one foot below the surface. A Secchi extinction depth was also recorded to measure water transparency of the upper portion of the water column.

The following relationships were examined for light energy at all survey sites form June – December 2012: 1) Light energy (PPF) and depth relationships; 2) mean surface PPF irradiance (for all depth levels measured); 3) the ratio of PPF light one foot above the bottom to light energy “in air” (prior to being absorbed by water); and 4) the ration of PPF one foot above the bottom and one foot below the surface of the water. The data represent average values of replicate data collected at three depth levels at each station using the Quantum meter.

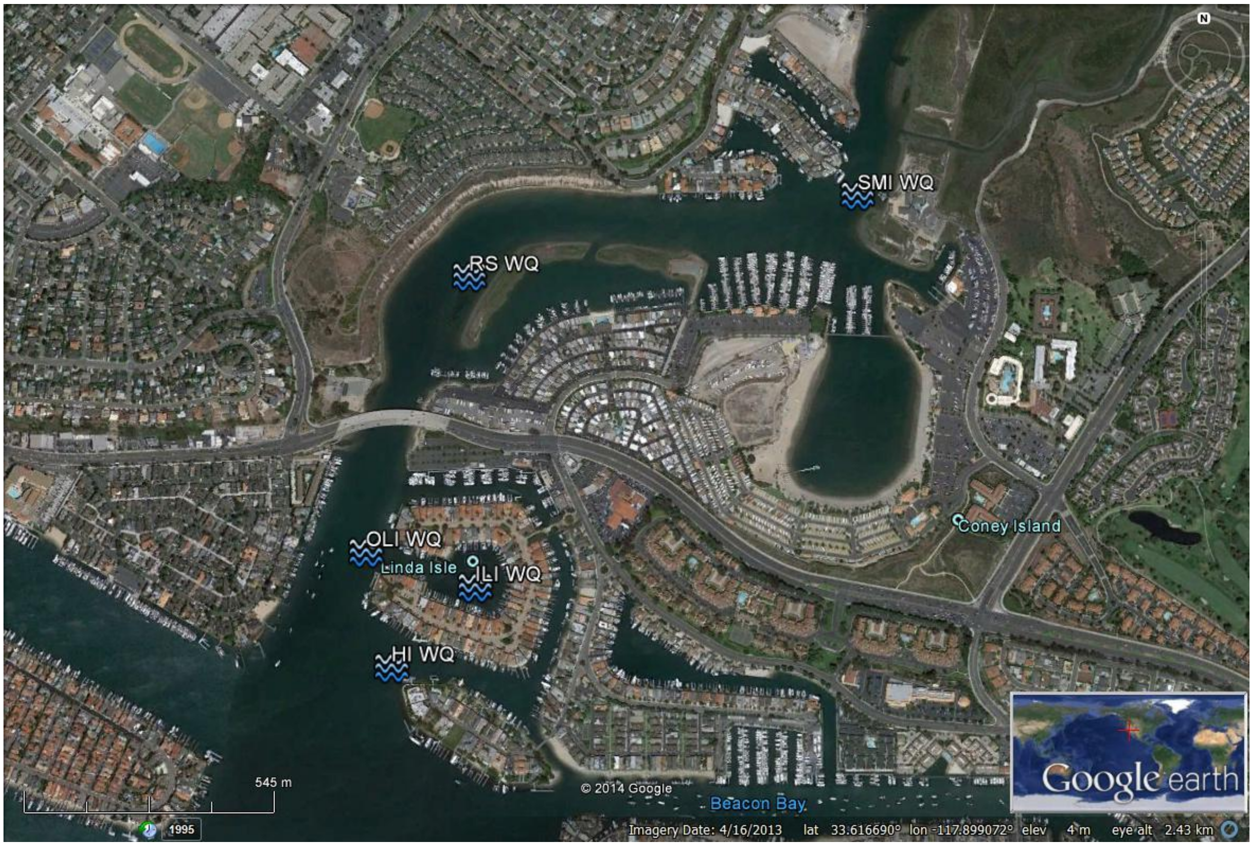

Figure 15. Water Quality and Light Monitoring Stations. 1) Shellmaker Island (SMI); 2) Restoration Site (RS); 3) Harbor Island (HI), 4) Inner Linda Isle (ILI) and 5) Outer Linda Isle (OLI).

Results:

Water quality

Temperature

Eelgrass can tolerate a wide range of temperatures with optimal temperature distributions between 10°C and 20°C. The yearly mean temperature ranged from 18.6°C to 20.6°C in each site, approaching the upper limits of optimal temperature. Temperatures did not substantially differ between sites; however there was a trend for higher mean temperatures as distance from the mouth of the bay increased, with Harbor Island being the closest to the mouth and Shellmaker Island farthest away (Figure 16, Appendix D). Warmer temperatures were present in 2012 and 2013, with 2014 showing a slightly lower yearly average.

Dissolved Oxygen

While eelgrass requires oxygen to drive aerobic metabolism, it is not necessarily a limiting factor as eelgrass obtains oxygen through internal production as well as passive diffusion from the water. Through photosynthesis, eelgrass beds deliver oxygen to the soil, water, and air; however, during periods of high turbidity or increased biofouling that reduces light levels, there is a decrease in photosynthesis and thus oxygen production. Additionally, eelgrass may experience periods of hypoxia and anoxia, and may negatively affect eelgrass growth and survival. The concentration of dissolved oxygen (DO) may be affected by many factors, including water temperature, sunlight, salinity, tidal flushing, biological activity, and depth (CRM, 2009) and normal ranges occur from 7 – 10 mg/L. A minimum of 5 mg/L is required to sustain most life. Yearly mean dissolved oxygen values generally fell within normal range, fluctuating from 6.7 to 8.7 mg/L, with an overall average of 7.6 mg/L (Figure 17, Appendix D). Generally, there was a trend for higher dissolved oxygen values in vegetated sites compared with the un-vegetated Shellmaker Island site.

Hydrogen Ion Concentration (pH)

Seawater in southern California is typically slightly basic, ranging from about 7.5 to 8.6 (State Water Quality Control Board, 1965). Freshwater inputs tend to lower pH, while biological activity, such as photosynthesis, tends to raise pH. Low oxygen conditions will also lower pH. Mean pH values per year showed very little variation, with mean values ranging from 7.8 to 7.9, within the normal range of growth conditions (Figure 18, Appendix D).

Salinity

Eelgrass tolerates a wide range of water salinities, including the ranges that are observed in Newport Bay, which ranges from 30-34 ppt (parts per thousand) on average. However, during wet periods, surface salinity may decrease to below 25 ppt at times (County of Orange, 2005, cited in CRM, 2009). During this three year time period, however, with few large rain events, salinities remained closer to the higher end of their normal range. Mean salinity across all the sites and years was 33.5 ppt, and ranged from 32 to 34.2 ppt (Figure 19, Appendix D). Few differences were observed between sites, however the Shellmaker Island site, which was farthest from the mouth of the bay, showed a trend for lower salinities. Mean salinities each year varied slightly, with 2015 showing a slightly lower average than 2013 or 2014.

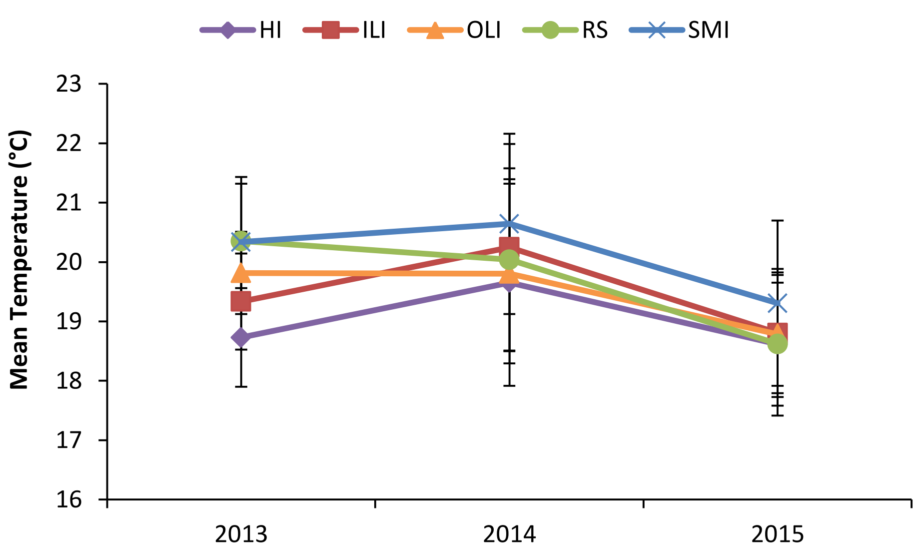

Figure 16. Mean yearly temperature (± SE) in each site from May 2013 – June 2015.

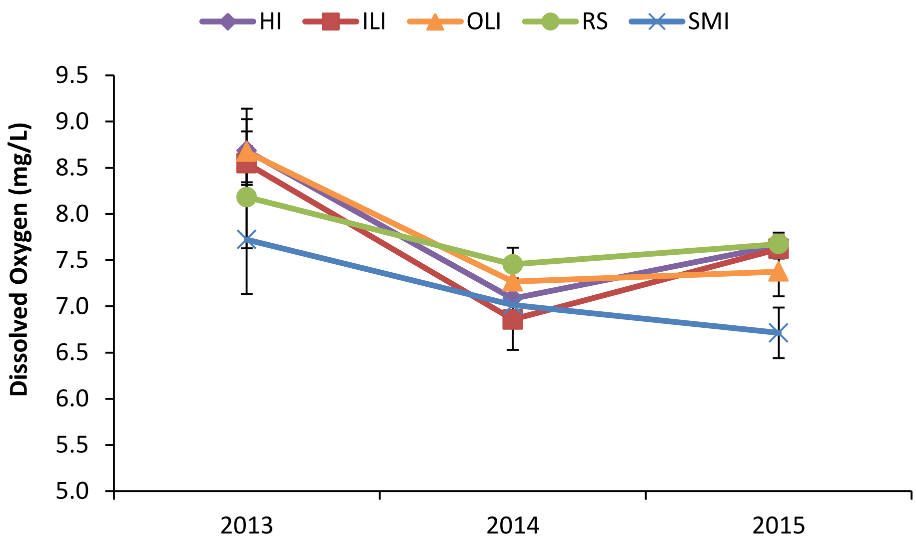

Figure 17. Mean dissolved oxygen per year (± SE) in each site from May 2013 – June 2015.

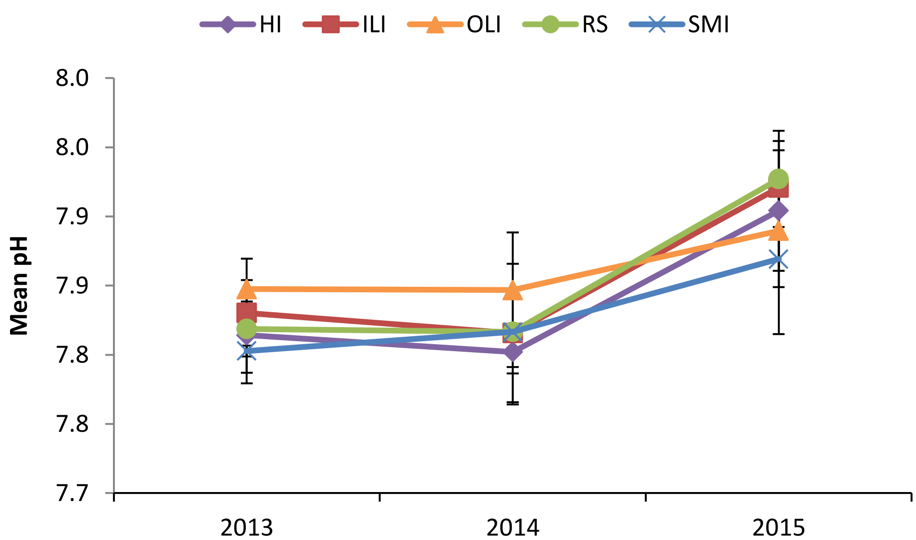

Figure 18. Mean pH level per year (± SE) in each site from May 2013 – June 2015.

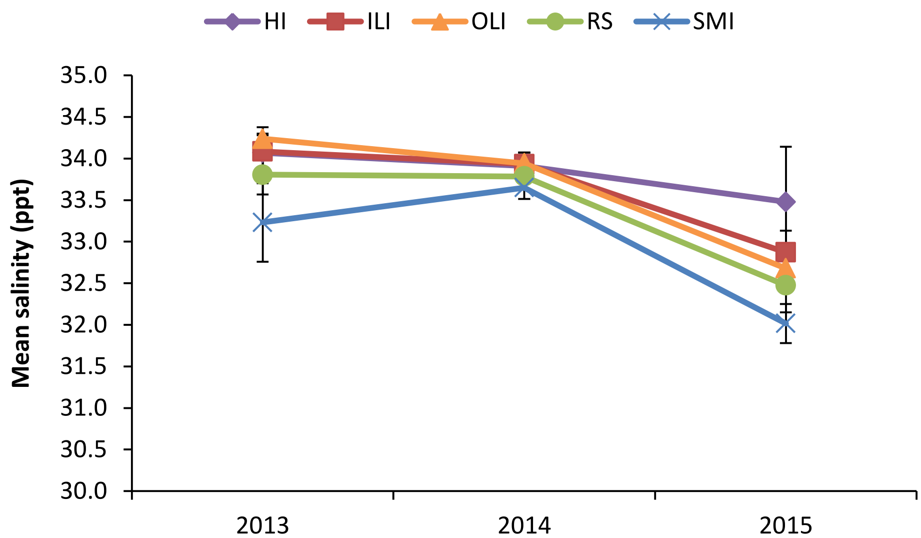

Figure 19. Mean salinity per year (± SE) in each site from May 2013 – June 2015.

Light

Algae and seagrasses utilize light energy within the visible light spectrum (400-700 nanometer wavelengths) for photosynthesis. The light energy in these wavelengths was measured in order to compare light energy at different depths in both vegetated and unvegetated areas and between restored and natural beds in order to determine if success criteria have been met for restored eelgrass areas. Light is a key factor affecting the distribution, density, and growth of eelgrass and may be affected by many factors in Newport Bay, including turbidity, depth, tidal condition, time of day and year, winter storms, plankton blooms, shading from boats and docks, and dredging and boating activities (CRM, 2009). A higher Secchi depth is indicative of less turbid surface waters. Secchi depth varied slightly between the sites and years, though generally, Harbor Island and Inner Linda Isle had the highest Secchi depth (Figure 20, Appendix C).

Optimal eelgrass growth occurs above 20% surface irradiance (Abal et al. 1994), which was achieved each year in the restoration site (Figure 21, Appendix C). The un-vegetated site, Shellmaker Island, was consistently below this minimum and so may not be suitable for eelgrass restoration at this time. Additionally, Harbor Island and Inner Linda Isle approached this minimum, or was lower than the minimum, for several years.

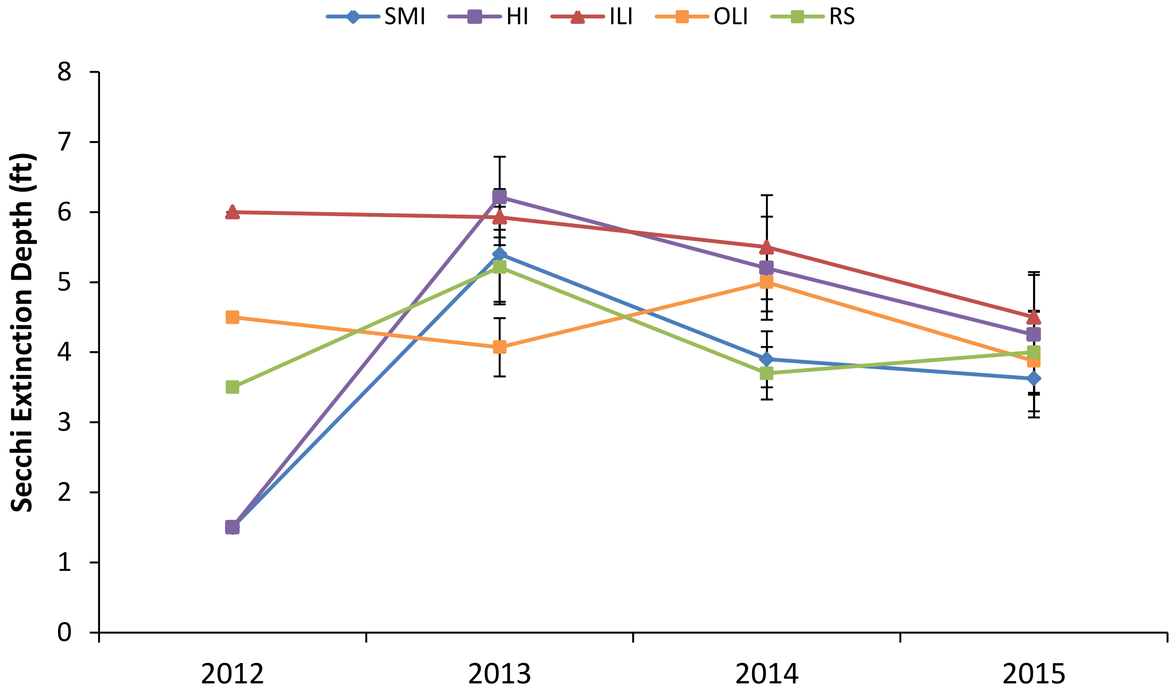

Figure 20. Mean Secchi extinction depth (± SE) over all survey periods each year.

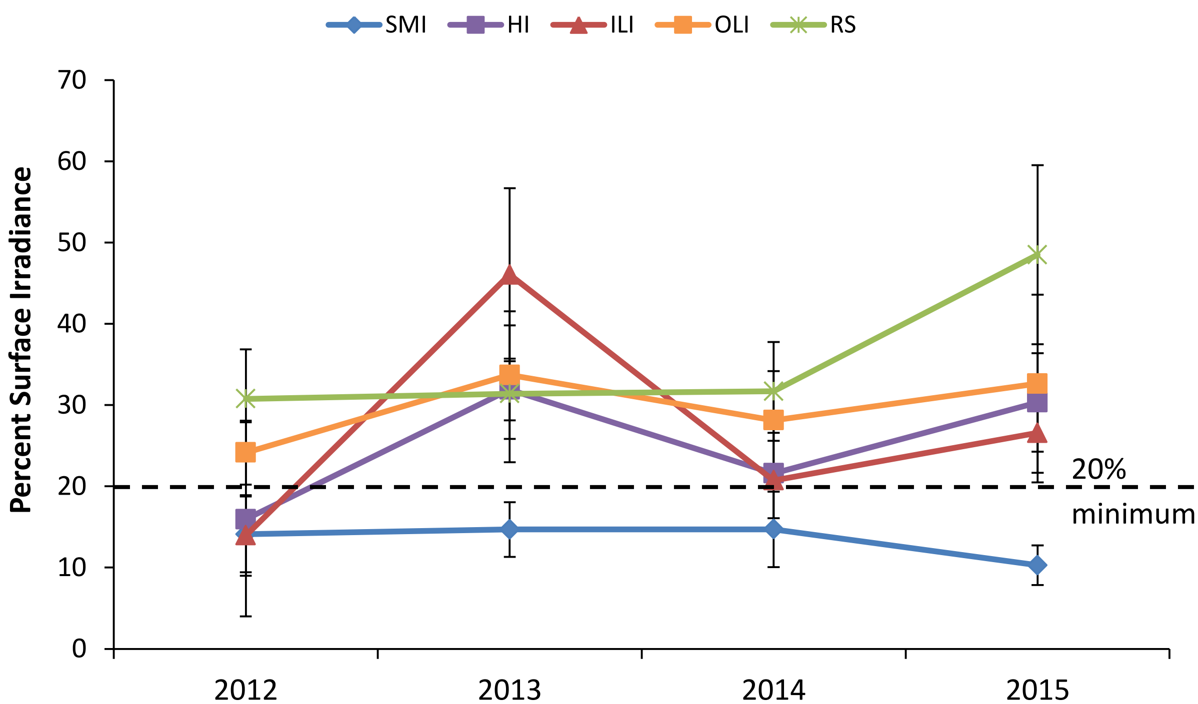

Figure 21. Mean percent surface irradiance (± SE) over all survey periods each year.

Acknowledgements

We would like to thank the hardworking volunteers and interns who made this project a reality. Thanks also to the California Coastal Commission, California Dept. of Fish and Wildlife at the Back Bay Science Center, US Fish and Wildlife Service, County of Orange, the City of Newport Beach and Mike Josselyn, Wetlands Research Associates, Inc. Major funds were provided by NOAA Restoration Center, the CA State Coastal Conservancy (Project No. 11-068), and Wells Fargo. Additional local funding for community based restoration activities was provided by Beach Cities SCUBA, Sam's Club, Vons, Ralphs, Trader Joe's, and Peet's Coffee.

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Appendix A
Mean Turion Density Data

Table 1. Mean turion density at each site for each survey period.

	Mean Turions/m^2	Std Dev	N	95% CI
May 2012				
Control	172.5	80.2	25	31.4
Harbor Island	77.6	52.9	125	9.3
Inner Linda Isle	128.6	29.8	30	10.7
Outer Linda Isle	119.5	31.5	30	11.3
December 2012				
2012 sites				
DT	96.7	44.4	65	10.8
TERFS	31.53	11.72	19	5.3
Control	88.00	63.83	70	15.0
August 2013				
2012 sites	94.04	43.43	57	11.3
DT	57.68	19.34	19	8.7
TERFS	119.58	43.28	19	19.5
BuDS	104.84	37.61	19	16.9
Control	92.00	59.33	20	26.0
Harbor Island	58.40	34.15	20	15.0
Inner Linda Isle	105.60	54.17	20	23.7
Outer Linda Isle	92.80	46.17	20	20.2
January 2014				
2012 sites	92.24	61.80	49	17.3
DT	54.00	53.75	16	26.3
TERFS	103.56	61.87	18	28.6
BuDS	119.47	52.15	15	26.4
2013 sites	38.75	52.21	32	18.1
DP1	53.78	62.62	18	28.9
DP2	19.43	25.63	14	13.4
Control	87.47	44.38	15	22.5
Harbor Island	92.86	57.60	30	20.6
Inner Linda Isle	130.00	73.26	30	26.2
Outer Linda Isle	96.67	52.75	30	18.9

July 2014				
2012 sites	160.77	83.48	31	29.4
2013 sites	55.23	81.67	62	20.3
DP1	65.29	91.54	31	32.2
DP2	45.16	70.52	31	24.8
Control	85.07	112.01	30	40.1
Harbor Island	107.56	87.36	27	33.0
Inner Linda Isle	184.00	95.10	30	34.0
Outer Linda Isle	86.93	63.33	30	22.7
January 2015				
2012 sites	53.78	44.38	36	14.5
2013 sites	74.59	60.59	71	14.1
DP1	63.48	65.63	46	19.0
DP2	95.04	44.26	25	17.4
2014 sites	29.61	33.50	57	8.7
DP1 A	19.29	25.15	17	12.0
DP1 B	40.40	38.63	20	16.9
Control	59.89	42.88	35	14.2
Harbor Island	33.33	27.72	30	9.9
Inner Linda Isle	85.87	28.57	30	10.2
Outer Linda Isle	57.60	54.19	30	19.4
June 2015				
2012 sites	70.45	79.93	31	28.1
2013 sites	69.60	67.33	40	20.9
DP1	41.52	63.18	21	27.0
DP2	100.63	58.75	19	26.4
2014 sites	60.94	70.16	34	23.6
DP1 A	92.80	72.11	15	36.5
Control	117.87	97.10	30	34.7
Harbor Island	80.80	55.44	30	19.8
Inner Linda Isle	115.73	44.75	30	16.0
Outer Linda Isle	53.60	49.86	30	17.8

Appendix B: Impact to Donor Eelgrass Beds

Densities were monitored in all the potential donor eelgrass beds and compared to control site densities to monitor impact of collection activities (Figure 1). The majority of eelgrass collections came from the Inner Linda Isle site, though Outer Linda Isle and Harbor Island were monitored as future potential donor sites. Despite the collection pressure, Inner Linda Isle site densities were consistently the highest out of all the eelgrass beds monitored. In addition, any declines observed over time in each of the donor and potential donor beds were similar to declines observed in the control site at the same times. We found no evidence that the donor beds were negatively impacted by our collection activities.

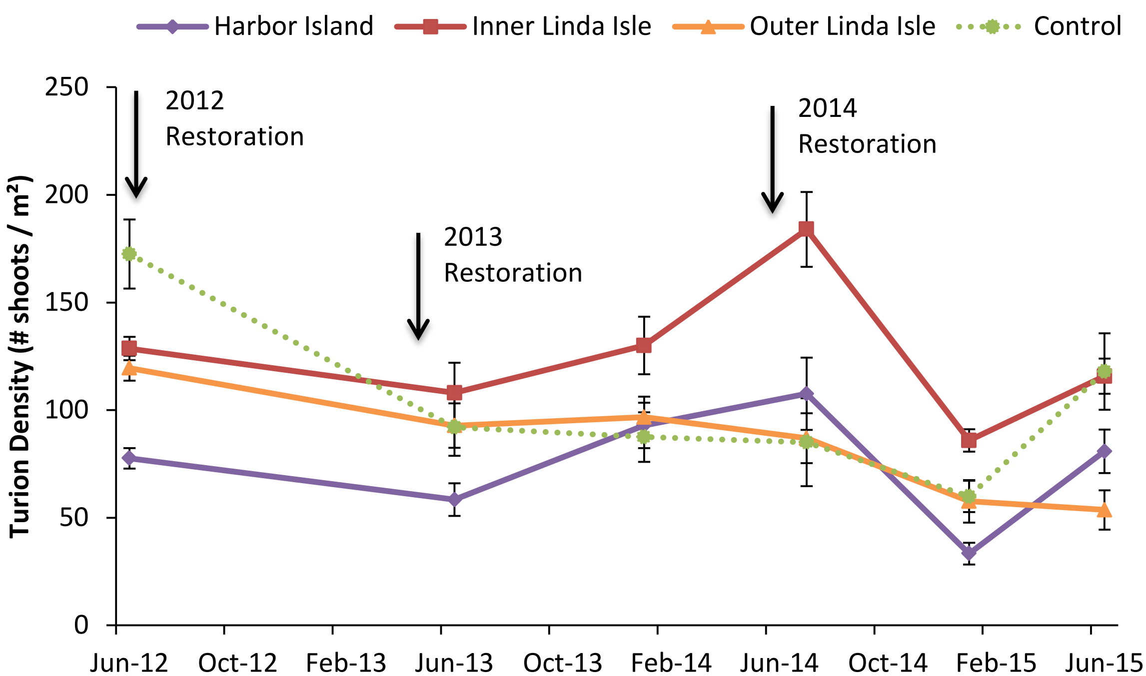

Figure 1. Mean turion density (± SE) for donor eelgrass beds (Harbor Island, Inner Linda Isle and Outer Linda Isle) and control eelgrass bed along De Anza Peninsula from June 2012 (before all restoration activities) to June 2015 (after 3 collections in June 2012, July 2013 and July 2014).

APPENDIX C Light Data

Restored Site

Date	Time	% cloud cover	Maximum Depth (ft)	Secchi extinction (ft)	In-air light (PPF)	Water surface light (PPF)	Mid-depth light (PPF)	Bottom light (PPF)	% Surface Irradiance
8/1/2012		0	5	-	2000	1363	1020	640	46.96
9/19/2012	12:21 PM	0	9	-	1750	1058	540	240	22.68
10/24/2012	10:00 AM	0	5	-	1130	870	340	175	20.11
12/19/2012	11:05 AM	0	4	3.5	1170	690	430	230	33.33
1/21/2013	1:15 PM	75	5	5	1123	990	890	580	58.59
3/11/2013	2:27 PM	0	7	5	1543	1230	300	240	19.51
5/22/2013	12:15 PM	0	6	3	1810	960	640	220	22.92
8/22/2013	4:11 PM	0	4.5	4.5	1443	800	790	500	62.50
9/24/2013	11:23 AM	50	5	5	2000	1300	900	500	38.46
11/24/2013	12:30 PM	0	9	7	1300	673	267	60	8.92
1/16/2014	1:26 PM	0	3	3	1296	972	808	534	54.94
3/27/2014	11:04 AM	0	8.5	3.5	1550	920	630	180	19.57
7/2/2014	2:04 PM	0	8	5	2048	1250	590	350	28.00
9/18/2014	1:00 PM	0	5	3	1900	1034	393	266	25.73
10/23/2014	10:10 AM	0	7	4	1108	799	406	242	30.29
1/29/2015	1:30 PM	100	5	3	435	180	112	62	34.44
3/8/2015	12:50 PM	0	7	5	1820	1255	602	396	31.55
4/9/2015	10:26 AM	60	3	3	1401	903	-	720	79.73
6/8/2015	2:51 PM	92	6	5	947	451	307	218	48.34

Harbor Island

Date	Time	% cloud cover	Maximum Depth (ft)	Secchi extinction (ft)	In-air light (PPF)	Water surface light (PPF)	Mid-depth light (PPF)	Bottom light (PPF)	% Surface Irradiance
10/24/2012	10:48 AM	0	8	-	1050	860	440	240	27.91
12/19/2012	10:33 AM	0	7	1.5	1080	350	50	14	4.00
1/21/2013	12:30 PM	0	6	6	1340	1140	670	450	39.47
3/11/2013	2:00 PM	0	7.5	7.5	1719	1080	846	500	46.30
5/22/2013	10:30 AM	100	5	3	770	350	180	100	28.57
8/22/2013	2:07 PM	0	10	7	1800	1200	530	400	33.33
9/24/2013	10:26 AM	75	10	6	860	360	220	50	13.89
11/24/2013	11:26 AM	0	7	7	1300	730	550	226	30.96
1/16/2014	10:13 AM	0	6	6	1000	760	530	280	36.84
3/27/2014	9:55 AM	0	10	6	1250	1030	315	140	13.59
7/2/2014	10:23 AM	0	7	7	1748	1380	750	450	32.61
9/11/2014	10:15 AM	0	10	3	1351	545	230	48	8.81
10/23/2014	9:40 AM	0	9	4	750	630	188	102	16.19
1/29/2015	10:00 AM	100	6	6	225	110	83	50	45.45
3/8/2015	12:00 PM	0	5	5	1750	1140	765	396	34.74
4/9/2015	9:50 AM	55	6	2	920	430	251	95	22.09
6/8/2015	2:13 PM	95	8	4	692	420	243	80	19.05

Outer Linda Isle

Date	Time	% cloud cover	Maximum Depth (ft)	Secchi extinction (ft)	In-air light (PPF)	Water surface light (PPF)	Mid-depth light (PPF)	Bottom light (PPF)	% Surface Irradiance
8/1/2012		0	9	-	2000	1370	583	278	20.29
9/19/2012	12:45 PM	0	10.5	-	1529	1133	752	196	17.30
10/24/2012	10:38 AM	0	4	-	1200	850	430	300	35.29
12/19/2012	10:55 AM	0	6	4.5	1150	925	340	220	23.78
1/21/2013	12:00 PM	0	3	3	1390	1100	890	700	63.64
3/11/2013	2:14 PM	0	4	4	1620	1200	927	589	49.08
5/22/2013	11:17 AM	35	5	3	1760	1220	525	125	10.25

8/22/2013	3:54 PM	0	4	3	1470	540	490	170	31.48
9/24/2013	11:06 AM	70	6	5.5	2000	1100	230	50	4.55
11/24/2013	12:18 PM	0	5	5	1360	650	500	250	38.46
1/16/2014	12:52 PM	0	6	6	1224	967	717	302	31.23
3/27/2014	10:30 AM	0	6	4.5	1340	580	390	289	49.83
7/2/2014	12:54 PM	0	9	6	2075	1300	720	330	25.38
9/11/2014	10:38 AM	0	7	4	1373	785	438	143	18.22
10/23/2014	10:00 AM	0	8	4.5	1219	592	220	95	16.05
1/29/2015	10:15 AM	100	3.5	3.5	400	215	165	130	60.47
3/8/2015	12:20 PM	0	6	5	1730	1030	555	352	34.17
4/9/2015	10:00 AM	60	3	2	958	685	n/a	197	28.76
6/8/2015	2:37 PM	95	8	5	791	378	115	27	7.14

Inner Linda Isle

Date	Time	% cloud cover	Maximum Depth (ft)	Secchi extinction (ft)	In-air light (PPF)	Water surface light (PPF)	Mid-depth light (PPF)	Bottom light (PPF)	% Surface Irradiance
8/1/2012		0	10	-	1888	1369	830	56	4.09
10/24/2012	10:25 AM	0	8	-	1320	770	370	140	18.18
12/19/2012	10:45 AM	0	7	6	1030	1020	440	200	19.61
1/21/2013	11:50 AM	0	6	6	1390	1000	730	600	60.00
3/11/2013	2:04 PM	0	6.5	6.5	1355	1100	590	400	36.36
5/22/2013	10:56 AM	95	8	4	810	550	730	52	9.45
8/22/2013	3:06 PM	0	8	7	1690	975	900	350	35.90
9/24/2013	10:50 AM	75	9	5	435	250	170	50	20.00
11/24/2013	12:00 PM	0	6.5	6.5	1240	535	500	430	80.37
1/16/2014	12:11 PM	0	7	5.5	1420	822	345	164	19.95
3/27/2014	10:23 AM	0	10	4	1470	1060	508	195	18.40
7/2/2014	12:31 PM	0	8	8	2030	1300	846	555	42.69
9/11/2014	10:20 AM	0	9	6	1150	746	503	107	14.34
10/23/2014	9:53 AM	0	10	4	1280	593	137	49	8.26
1/29/2015	10:10 AM	100	6	6	335	194	121	72	37.11

3/8/2015	12:15 PM	0	5	5	1470	747	520	110	14.73
4/9/2015	10:10 AM	60	5	3	1350	805	520	140	17.39
6/8/2015	2:28 PM	95	6	4	645	431	315	160	37.12

Shellmaker Island

Date	Time	% cloud cover	Maximum Depth (ft)	Secchi extinction (ft)	In-air light (PPF)	Water surface light (PPF)	Mid-depth light (PPF)	Bottom light (PPF)	% Surface Irradiance
8/1/2012	-	75	9	-	1450	1200	760	150	12.50
9/19/2012	1:30 PM	0	12	-	1851	1290	350	50	3.88
10/24/2012	2:30 PM	0	7.5	-	1108	464	182	123	26.51
12/19/2012	11:30 AM	0	8	1.5	1140	170	60	23	13.53
1/21/2013	2:00 PM	75	7	7	600	400	230	108	27.00
3/11/2013	3:06 PM	0	6.5	5	1428	1140	520	218	19.12
5/22/2013	12:34 PM	0	8	3	1840	1130	450	115	10.18
8/22/2013	-	-	-	-	-	-	-	-	-
9/24/2013	11:53 AM	30	9	7	1860	1670	200	40	2.40
11/24/2013	1:00 PM	0	8	6	1280	680	300	100	14.71
12/24/2013	1:00 PM	0	8	6	1280	680	300	100	14.71
1/16/2014	2:27 PM	0	6	5	1037	705	430	194	27.52
3/27/2014	11:25 AM	0	8	3	1680	450	215	110	24.44
7/2/2014	5:06 PM	0	9	4.5	1130	780	165	54	6.92
9/11/2014	11:17 AM	0	11	3	1650	910	210	56	6.15
10/23/2014	11:10 AM	0	9	4	1322	731	213	62	8.48
1/29/2015	1:45 AM	100	6	3	514	205	116	35	17.07
3/8/2015	1:05 AM	0	10	5	1845	1309	528	98	7.49
4/9/2015	10:45 AM	40	5	2.5	1540	877	181	92	10.49
6/8/2015	1:35 AM	100	10.5	4	728	361	96	22	6.09

APPENDIX D: Water Quality Data

Restored Site

Date	Temperature (°C)	DO Concentration	pH	Salinity (ppt)
5/23/2013	21.46	7.67	7.78	33.69
7/19/2013	22.55	6.54	7.77	34.02
8/23/2013	22.53	7.04	7.80	34.06
9/25/2013	20.67	10.11	7.89	34.59
10/30/2013	17.94	9.22	7.87	33.64
11/25/2013	16.97	8.52	7.81	32.84
1/17/2014	15.82	8.10	7.85	33.64
3/28/2014	17.03	6.97	7.78	33.95
7/3/2014	23.50	7.45	7.90	33.76
9/12/2014	22.80	7.39	7.82	33.88
10/24/2014	21.04	7.36	7.73	33.69
1/30/2015	15.38	7.57	7.97	32.57
3/9/2015	18.24	7.82	8.00	31.81
4/10/2015	20.04	7.46	7.87	32.19
6/9/2015	20.82	7.85	7.87	33.33

Harbor Island

Date	Temperature (°C)	DO Concentration	pH	Salinity (ppt)
5/23/2013	20.82	8.02	7.83	34.09
7/19/2013	-	-	-	-
8/23/2013	18.27	8.21	7.77	34.12
9/25/2013	20.51	9.39	7.86	34.60
10/30/2013	17.35	9.64	7.88	34.33
11/25/2013	16.70	8.17	7.73	33.21
1/17/2014	15.17	7.92	7.90	34.38
3/28/2014	15.75	6.99	7.78	34.20
7/3/2014	23.23	6.68	7.86	33.80
9/12/2014	22.72	6.79	7.79	33.54
10/24/2014	21.40	7.05	7.68	33.64
1/30/2015	16.34	7.95	7.88	35.25
3/9/2015	17.97	7.82	8.03	32.04
4/10/2015	18.85	7.32	7.85	33.33
6/9/2015	21.30	7.55	7.85	33.29

Outer Linda Isle

Date	Temperature (°C)	DO Concentration	pH	Salinity (ppt)
5/23/2013	21.01	7.81	7.81	33.99
7/19/2013	-	-	-	-
8/23/2013	20.09	7.94	7.81	34.07
9/25/2013	20.34	9.64	7.89	34.61
10/30/2013	17.82	9.31	7.89	34.28
11/25/2013	-	-	-	-
1/17/2014	15.70	8.19	7.91	34.09
3/28/2014	16.70	6.96	7.80	34.17
7/3/2014	23.04	7.12	7.92	33.93
9/12/2014	22.45	7.00	7.91	33.78
10/24/2014	21.13	7.07	7.70	33.74
1/30/2015	16.59	7.48	7.88	32.77
3/9/2015	17.85	8.03	8.01	32.05
4/10/2015	19.58	6.74	7.84	32.62
6/9/2015	21.13	7.26	7.83	33.28

Inner Linda Isle

Date	Temperature (°C)	DO Concentration	pH	Salinity (ppt)
5/23/2013	21.03	7.61	7.81	34.05
7/19/2013	-	-	-	-
8/23/2013	19.60	8.63	7.85	34.12
9/25/2013	21.08	9.59	7.87	34.53
10/30/2013	17.81	8.90	7.88	34.36
11/25/2013	17.16	8.01	7.75	33.37
1/17/2014	15.50	8.15	7.91	34.18
3/28/2014	16.74	6.59	7.79	34.13
7/3/2014	23.64	6.72	7.90	34.17
9/12/2014	23.74	6.39	7.85	33.55
10/24/2014	21.62	6.45	7.64	33.64
1/30/2015	16.53	7.85	7.93	32.80
3/9/2015	17.90	7.59	8.01	32.17
4/10/2015	19.19	7.55	7.90	33.30
6/9/2015	21.60	7.50	7.85	33.22

Shellmaker Island

Date	Temperature (°C)	DO Concentration	pH	Salinity (ppt)
5/23/2013	21.79	7.33	7.77	33.54
7/19/2013	23.04	5.74	7.75	33.89
8/23/2013	-	-	-	-

9/25/2013	21.17	9.13	7.85	34.46
10/30/2013	18.69	8.67	7.87	32.28
11/25/2013	16.98	7.75	7.78	32.00
1/17/2014	16.28	7.90	7.85	33.40
3/28/2014	17.92	6.48	7.76	33.57
7/3/2014	24.29	6.68	7.85	34.17
9/12/2014	22.79	6.98	7.87	33.64
10/24/2014	21.92	7.04	7.75	33.47
1/30/2015	15.93	6.50	7.92	31.80
3/9/2015	18.50	7.50	7.99	31.54
4/10/2015	20.27	6.62	7.84	32.09
6/9/2015	22.52	6.23	7.73	32.63

APPENDIX E

Species List of Organisms Observed During the Eelgrass Habitat Mapping Surveys

Common Name	**Scientific Name**
Algae	
green algae	*Enteromorpha* sp.
green algae	*Ulva lactuca*
brown algae	*Cystoseira osmundacea*
brown algae	*Colpomenia sinuosa*
red algae	*Acrosorium uncinatum*
red algae	*Gracilariopsis sjoestedti*
red algae	*unid. red leafy algae*
Sponges	
yellow sponge	*Haliclona sp.*
Red sponge	*Ophlitaspongia pennata*
Tunicates	
Colonial tunicates	*Botryllus*
Stalked tunicate	*Styela montereyensis*
Pleated sea squirt	*Styela plicata*
Mollusks-Gastropods	
Orange-peel doris	*Acanthodoris lutea*
California sea hare (juvenile)	*Aplysia californica*
Gould's bubble snail	*Bulla gouldiana*
Predatory sea slug	*Navanax inermis*
California cone snail	*Conus californicus*
Limpet	*Lottia limatula*
Two-spotted octopus	*Octopus bimaculatus*

Eelgrass nudibranch	*Phyllaplysia taylori*
Mollusks-Pelecypods	
Speckled scallop	*Argopecten aequisulcatus*
Wavy chione	*Chione undatella*
Oyster	*Crassostrea gigas*
Bay mussel	*Mytilus galloprovincialis*
California Jack Knife clam	*Tagelus californianus*
Arthropods	
Swimming crab	*Portunus xantusii*
Ectoprocts	
stoloniferan ectoproct	*Zoobotryon verticillatum*
Fish	
Top smelt	*Atherinops affinis*
Goby	*Gobiidae, unid.*
Surfperch (juvenile)	*Embiotocidae, unid.*
Barred sand bass (juvenile)	*Paralabrax nebulifer*
California halibut (juvenile)	*Paralichthys californicus*
Turbot	*Pleuronichthys, unid*
round stingray	*Urolophus halleri*