Malibu Lagoon Restoration and Enhancement Project

Comprehensive Monitoring Report (Year 2)

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Photo: Malibu Lagoon Restoration Project at sunrise (I. Medel; 25 October 2014).

Executive Summary

The Malibu Lagoon Restoration and Enhancement Project was complete on 31 March 2013. An evaluation of post-restoration conditions, through detailed physical, chemical, and biological monitoring components have resulted in several overarching trends. A clear pattern in the water quality data, for example, indicates that lowering the lagoon elevation, creating a wider single channel directed more towards the incoming tide, orienting channel configurations in line with prevailing wind patterns, and removing the pinch points (i.e. bridges) have led to an increase in circulation both in an open and closed berm lagoon condition. Vertical profile mixing and increased dissolved oxygen are additional water quality indicators of a more well-functioning post-restoration system, in addition to meeting several of the project goals. While some biological communities, such as vegetation and subsequently birds, will continue to establish over time, several aspects of the restoration are already well ahead of the goals outlined in the Monitoring Plan (SMBRF 2012). Components of the post-restoration monitoring program that meet or exceed project success criteria are summarized, below.

California Rapid Assessment Method: Condition scores already exceed pre-restoration conditions, and data indicate improving condition scores with each successive survey. The overall CRAM score increased from 50 pre-restoration to 66 for the most recent survey, and each of the attribute averages are higher in the most recent post-restoration survey than the pre-restoration attribute averages.

Physical Monitoring – Channel Cross-sections: Overall, channel cross sections remained stable and did not exhibit any large scale changes between survey dates. However, each cross section displayed general smoothing patterns or micro-topographical changes as sediment was shifted or deposited in microhabitat indentations, and as small rises were scoured away or created by the movement of tidal waters. The largest sediment deposition area was found along Transect 5 (Figure 10) and exhibited a change of +0.595 ft (7.2 inches) between 2013 and 2014. The largest sediment scour area was found along Transect 4 (Figure 9) and exhibited a change of -0.815 ft (9.78 inches).

Water Quality – Automated Water Quality Monitoring: A high proportion of dissolved oxygen samples were recorded above success criteria thresholds and pre-restoration conditions. Notably, more than 95% of closed condition dissolved oxygen readings were above 1 mg/L for both back channel monitoring stations compared with a maximum of 88% being recorded during pre-restoration conditions. Additionally, post restoration data showed a marked increase in the percent time dissolved oxygen readings were above success criteria thresholds.

Water Quality – Vertical Profiles: Minimal to no haloclines observed during closed conditions indicated good mixing. Post-restoration improvements in circulation in both open and closed berm conditions were indicated by the presence of high levels of dissolved oxygen throughout the site, especially in the back channels, which were previously severely impacted by extremely low dissolved oxygen and anoxic conditions. Dissolved oxygen was well above the success criteria threshold (i.e. > 1 mg/L) for all samples and never fell below 6 mg/L at any of the stations during all post-restoration sampling events; the levels during the closed berm condition sampling event never fell below 11 mg/L. These data contrast the pre-restoration closed berm sampling event, where the dissolved oxygen vertical profile data dropped below the 1 mg/L threshold multiple times, especially at increased depths. Data indicate post-restoration mixing during closed conditions, meeting the project goal tied specifically to increased circulation.

Water Quality – Surface and Bottom Water Constituent Sampling: The post-restoration nutrient concentrations remained relatively constant, with the exception of the 30 December 2014 surveys, which showed consistently higher nutrient concentrations across multiple parameters. The higher concentrations were possibly due to nutrient-laden water discharges from the Tapia Water Reclamation Facility located outside the project area upstream in Malibu Creek. Additionally, based on the Heal the Bay Beach Report Card data, the post-restoration trend appears to be declining numbers of TMDL exceedances

Sediment Quality – Sediment Constituent Sampling: Sediment grain size distributions identified thalweg sampling locations to exhibit lower proportions of gravel than the channel plain and channel bank composite samples. Sediment nutrients remained fairly consistent between pre- and post-restoration surveys. However, multiple large spikes for all nutrients are present in the pre-restoration September 2006 and April 2007 data which double the highest concentrations identified in post-restoration surveys, specifically, maximum Total Phosphorous and Total Nitrogen concentrations. Post-restoration sediment nutrient data also displayed more uniform distributions and smaller total ranges. For example, the post-restoration total phosphorous sample range was 56 – 704 mg/kg, compared to 0.09 – 1420 mg/kg during pre-restoration conditions.

Biological Monitoring – Benthic Invertebrates: The invertebrate survey data results establish a shift from a depauperate, pollution-tolerant invertebrate community, to a healthier, diverse invertebrate community that also includes a higher percentage abundance of sensitive species. Additionally, a slight increase of the number of taxa of sensitive species was recorded, as compared to pre-restoration conditions. Summary data include 25 taxa represented in the 2014 post-restoration surveys, including the small benthic cores (22 taxa) and the net sweep (10 taxa) invertebrate data

Biological Monitoring – Fish Community Surveys: As fish are highly mobile, each fish survey event represented a snapshot in time and fluctuated across the site locations. The data also showed a high level of seasonal variability, especially when comparing open and closed berm conditions. Based on the semi-annual surveys representing single-sampling events, the post-restoration fish community has returned to the area, with the added function of serving as a nursery habitat as exhibited by the abundance of captured larva and juvenile individuals (e.g. staghorn sculpin, goby, and topsmelt) in the May 2014 survey data.

Biological Monitoring – Avian Community Surveys: The avian community, including special status species like the California Brown Pelican (California Fully Protected) and Western Snowy Plover (Federally Threatened), have continued to heavily use the site throughout the restoration and post-restoration phases. An increase (20%) was observed in the quantity of individuals within the fish-eating guild species and a decrease (87%) in urban species.

Vegetation – SAV / Algae Percent Cover Monitoring: There was significant and excessive algal growth in the Lagoon pre-restoration; algae cover was one of the key indicators of eutrophication to the system. An apparent reduction in floating mat algae was observed during survey periods when compared to pre-restoration conditions. The post-restoration cover data were dominated by 'wrack', or floating, detached marine kelp species, and after two years, still remained below a 10% total cover range and well within the success criteria recommendations. Additionally, wind-driven circulation in the post-restoration channels tended to disperse the algal blooms, thereby reducing any potential impacts from the algae becoming trapped in one location. Eutrophication was also evaluated based on an increase in number of days where the dissolved oxygen levels were above the recommended thresholds (i.e. 5, 3, and 1 mg/L).

Vegetation – Plant Cover Transects: Data demonstrate an increase in vegetation cover for all transects over time; also, non-native cover on all transects was well below success criteria. One transect already meets third year success criteria for absolute native cover. Thirteen to 41 native plant species were identified immediately adjacent to the transects, compared to an average of six dominant species pre-restoration.

Vegetation – Photo-Point Monitoring: Photos correspond with plant cover transect data demonstrating continued maturation and development of vegetation assemblages over time.

While the majority of monitoring components have met or exceeded established success criteria and none require the implementation of adaptive management measures, a few criteria require an extended establishment period to stabilize under post-restoration conditions. For example, more time is needed to evaluate sediment grain size across multiple sampling years, as the current shift towards smaller grain size did not correspond with the lack of sediment deposition in the channel cross-section surveys. The grain size results were likely due in part to use of courser-grained sediments in the restoration process to reduce scour. Additionally, continuing surveys of avifauna will further describe the shift in bird guild use of the site from one of urban- and freshwater-guilds, to one of fish-eating waterbirds. Further establishment of the vegetation community assemblages will likely facilitate increased used of the site by shorebird and scrub/woodland guilds. All five years of data will be imperative to establish long-term trends for all parameters.

Overall, post-restoration monitoring surveys thus far have identified the distinct recovery and establishment of many important chemical and biological wetland functions. The site will continue to be closely monitored for hydrology and biological resources for a minimum of five years following restoration.

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Introduction

Malibu Lagoon is a 31-acre shallow water estuarine embayment occurring at the terminus of the Malibu Creek Watershed, the second largest watershed draining into Santa Monica Bay. It receives year-round freshwater from sources upstream and is periodically open to the ocean via a breach across a sandbar at the mouth of the estuary. Malibu Creek and Lagoon empties into the Pacific Ocean at world renowned surfing and recreational destination, Malibu Surfrider Beach, which receives approximately 1.5 million visitors every year.

The California State Coastal Conservancy (SCC), in partnership with the Resource Conservation District of the Santa Monica Mountains (RCDSMM), Heal the Bay, and California State Department of Parks and Recreation (CDPR) developed the Malibu Lagoon Restoration and Enhancement Project (Project) to enhance water quality and restore habitat conditions at Malibu Lagoon. The restoration plan for Malibu Lagoon evolved over a nearly 20-year time frame with extensive input from the public, coastal wetland experts, biologists, and responsible agencies. The Project involved excavation of 12 acres in the western half of the Lagoon and the subsequent planting of native wetland vegetation. Construction began on 1 June 2012 and was completed on 31 March 2013. A ribbon cutting ceremony was held on 5 May 2013.

Post-construction monitoring was conducted as described in the "Malibu Lagoon Restoration and Enhancement Plan, Hydrologic and Biological Monitoring Plan" and the "Malibu Lagoon Plant Communities Restoration, Monitoring, and Reporting Plan" which each specify hydrologic and biological monitoring protocols and procedures for conducting monitoring before, during, and after the Project. The post-restoration monitoring and data collection time period covered by this report is from 14 February 2013 to 30 December 2014. An aerial overview of Malibu Lagoon highlighting the restoration and monitoring areas in relation to the main lagoon and Surfrider Beach are displayed in Figure 1.

Figure 1. Map of project location site (Western Channels) and the surrounding Malibu Lagoon.

Comprehensive Monitoring Report Goals

This Comprehensive Monitoring Report outlines methods, but focuses on providing data accumulated since the completion of the restoration. When applicable, it displays trends over time and compares to pre-restoration data. The goal of this document is to report the post-restoration conditions of the Malibu Lagoon Restoration and Enhancement Project using hydrologic, chemical, and biological data.

Methods and sampling dates/times are included in each subsection of the report. There are two primary components of the report: hydrologic and biologic. The hydrology component includes both physical monitoring parameters and water and sediment quality. Hydrologic chapters that are included in this report are as follows: California Rapid Assessment Method surveys, physical channel cross sections, automated water quality sondes, vertical water quality station profiles, and laboratory analyses for top and bottom water nutrients and sediment quality data. Biological chapters included in this report are as follows: fish, birds, benthic invertebrates, submerged vegetation and algae, vegetation cover, and photo point surveys. Detailed fish and bird reports are also included as appendices.

This document was assembled using various studies and work products that were developed over the course of the Malibu Lagoon restoration planning effort as well as the addition of new, post-restoration data. Summary details on the restoration, monitoring protocols, and prior results are compiled from the documents listed in the literature cited, as well as post-restoration baseline data from Abramson et al. 2013. For detailed methods, refer to the referenced monitoring literature for each section.

Hydrologic Monitoring

The monitoring program includes semi-annual physical condition and water and sediment quality assessments, once during tidally dominated conditions (spring) and once during closed conditions (early fall), as well as annual biological sampling for multiple parameters during the spring and fall. The monitoring will occur for five years following the completion of the Lagoon restoration plan as documented in the 2012 Malibu Lagoon Restoration and Enhancement Plan, Hydrologic and Biological Project Monitoring Plan (Monitoring Plan).

Water quality and physical monitoring of Malibu Lagoon post-restoration seek to evaluate the specific habitat improvements made to the lagoon as a result of increased water circulation, increased tidal inundation and flushing, and increased storage capacity. Long-term monitoring assess post-restoration water quality and habitat conditions over time. The overarching goal of the hydrological section of this report is to detect observable improvements in the chemical conditions that facilitate biological stability by the reestablishment and persistence of species diversity and native organisms well beyond the first five years following construction.

Specific objectives of the physical and water quality monitoring of the Malibu Lagoon are to:

- Assess the habitat and water quality improvements towards the restoration goals.
- Document changes in the water quality of the lagoon environment over time following restoration.
- Provide timely identification of any problems with the physical or chemical development of the lagoon.

Specific water quality and physical parameters that are assessed in this report include: channel cross-section and elevation transects, automated water quality sampling at three locations using permanent data sondes, vertical water quality profiles at set stations within the Lagoon, and laboratory analyses for top and bottom water nutrients and sediment quality data. Additionally, Level-2 (broad-scale, rapid assessment monitoring) California Rapid Assessment Method (CRAM) surveys were conducted to assess the overall condition of the site.

California Rapid Assessment Method

Introduction

The following description of the summary and objectives of California Rapid Assessment Method (CRAM) surveys are directly cited from the CRAM User Manual (CWMW 2012):

> "The overall goal of CRAM is to provide rapid, scientifically defensible, standardized, cost-effective assessments of the status and trends in the condition of wetlands and the performance of related policies, programs and projects throughout California...
>
> In essence, CRAM enables two or more trained practitioners working together in the field for one half day or less to assess the overall health of a wetland by choosing the best-fit set of narrative descriptions of observable conditions ranging from the worst commonly observed to the best achievable for the type of wetland being assessed. Metrics are organized into four main attributes: (landscape context and buffer, hydrology, physical structure, and biotic structure) for each of six major types of wetlands recognized by CRAM (riverine wetlands, lacustrine wetlands, depressional wetlands, slope wetlands, playas, and estuarine wetlands)."

Methods

Four post-restoration surveys were completed within the wetland habitats on 14 February 2013, 4 October 2013, 7 May 2014, and 23 December 2014 (Figure 2); the May 2014 sampling event was an extra survey implemented during a closed-berm condition. According to module requirements, bar-built CRAM assessments should be conducted during an open berm condition and low tide; therefore, the May data may be skewed towards slightly lower condition scores. The pre-restoration survey was conducted on 1 June 2012 and is evaluated alongside the post-restoration data. CRAM attributes and final score data are evaluated on a 30-100 scale, with 30 being the poorest possible condition score, and 100 being the highest possible "reference" score for the state of California.

CRAM data were collected using the estuarine CRAM module during low tide on 1 June 2012 and are compared to the bar-built CRAM module assessments on the post-restoration survey dates. A quality control check / crosswalk survey was conducted to compare the two CRAM module scores (i.e. estuarine and bar-built) at the same Assessment Area (Figure 3), and the error between the two modules was within 1-2 points for the final scores. Therefore, pre- and post-restoration data can be evaluated together, assuming an error of ±2 final score points. Detailed field methods followed protocols described in the User Manual (CWMW 2012) and the CRAM Field Books (CWMW 2012a, CWMW 2013).

CRAM metrics are organized into four main attributes: landscape and buffer context, hydrology, physical structure, and biotic structure for each type of wetlands (i.e. depressional and estuarine wetlands) with multiple metrics and sub-metric assessments (Table 1). The attributes are all averaged to quantify a final assessment score for each wetland module and AA analyzed.

Table 1. Summary table of CRAM attributes; descriptions modified from the CRAM User Manual (CWMW 2013).

Attribute	Metric	Sub-metric	Description	Assessment Location
Landscape and Buffer Context	Aquatic Area Abundance	---	Spatial association to adjacent areas with aquatic resources	Office
	Buffer	Percent of AA with Buffer	Relationship between the extent of buffer and the functions it provides	Office
		Average Buffer Width	Extent of buffer width assesses area of adjacent functions provided	Office
		Buffer Condition	Assessment of extent and quality of vegetation, soil condition, and human disturbance of adjacent areas	Field
Hydrology	Water Source	---	Water source directly affects the extent, duration, and frequency of hydrological dynamics	Office / Field
	Hydroperiod	---	Characteristic frequency and duration of inundation or saturation	Office / Field
	Hydrologic Connectivity	---	Ability of water to flow into or out of a wetland, or accommodate flood waters	Office / Field
Physical Structure	Structural Patch Richness	---	Number of different obvious physical surfaces or features that may provide habitat for species	Field
	Topographic Complexity	---	Micro- and macro-topographic relief and variety of elevations	Field
Biotic Structure	Plant Community Composition	Number of Plant Layers	Number of vegetation stratum indicated by a discreet canopy at a specific height	Field
Biotic Structure	Plant Community Composition	Number of Co-dominant Species	For each plant layer, the number of species represented by living vegetation	Field
		Percent Invasion	Number of invasive co-dominant species based on Cal-IPC status	Field
	Horizontal Interspersion	---	Variety and interspersion of different plant "zones": monoculture or multi-species associations arranged along gradients	Field
	Vertical Biotic Structure	---	Interspersion and complexity of plant canopy layers and the space beneath	Field

Figure 3 displays the Assessment Area (AA) and buffer lines for the post-restoration CRAM survey. The AA is approximately one hectare, or two and a half acres of wetland habitats, following guidelines described in the User Manual. The AA location is approximately the same as the pre-restoration survey.

Figure 2. Landscape photo of a portion of the CRAM AA for Malibu Lagoon on the most recent survey, 23 December 2014.

Figure 3. Post-restoration CRAM Assessment Area (blue polygon) at Malibu Lagoon. Red lines indicate radiating (potential) buffer lines.

Results

The results of all post-restoration CRAM assessment surveys are shown in Table 2, with the pre-restoration data also included for comparison. While the overall CRAM score (i.e. 50 pre-restoration to 66 based on the latest survey) and each of the attribute averages are higher in the most recent post-restoration survey, the biotic structure and buffer attributes still have the potential to increase over time, due to increasing complexity and continued maturation in defined vegetation structure.

Table 2. CRAM data from AA pre- and post-restoration using the Estuarine CRAM Module. Attribute values were rounded to the nearest whole number. Asterisk indicates closed berm condition.

Attribute	**Pre-restoration**	**02/14/13**	**10/04/13**	**05/07/14 ***	**12/23/14**
Attribute 1: Buffer and Landscape Context	38	38	38	38	53
Attribute 2: Hydrology Attribute	50	58	58	58	58
Attribute 3: Physical Structure Attribute	50	88	75	75	88
Attribute 4: Biotic Structure Attribute	61	39	56	53	64
Overall AA Score	**50**	**56**	**57**	**56**	**66**

Performance Evaluation

Post-restoration surveys show a consistent increase in final CRAM scores over time, with the exception of the May 2014 survey during the closed berm condition, which likely falsely depressed the final score slightly, due to inundation and reduction in visibility of the AA channel and habitat areas. Even without a fully developed vegetation community, the biotic characteristic is already higher than the pre-restoration CRAM attribute score. It is likely that this score will continue to increase with increasing vegetation complexity over time, and the continued removal of invasive plant species. The overall CRAM final score is also likely to increase slightly over time, remaining consistently above the pre-restoration assessment final score. CRAM surveys will continue annually throughout the duration of the monitoring program.

Physical Monitoring – Channel Cross-Sections

Introduction

Many of the biological and chemical processes that occur in wetlands are driven by the physical and hydrologic characteristics of the site (Nordby and Zedler 1991, Williams and Zedler 1999, Zedler 2001). Physical surveys of hydrology, topography, and tidal inundation regimes (Zedler 2001, PWA 2006) can be used to assess temporal changes to a site, including erosion and sedimentation over time. The goal of the cross-section surveys for this report was to provide a set of channel widths, depths, and cross-section data to assess sediment movement (i.e. erosion, accretion) over time.

Methods

Five permanent and repeatable cross-section locations were monitored twice post-restoration on 14 February 2013 and 18 December 2014 (Figures 4 and 5). Horizontal and vertical locations of cross-section end-points were fixed by monuments. Sediment scour or deposition depths were calculated from the data.

Figure 4. Cross channel elevation surveys at Malibu Lagoon, 18 December 2014.

Figure 5. Map of cross-channel elevation transect locations.

Results

Results were calculated for all five post-restoration cross-section transects comparatively across both survey dates (Figures 6-10). Cross-sections started between eight and twelve feet elevation on the near shore channel banks and ended at approximately the same elevation on the foreshore. Transect lengths ranged between 104 and 232 ft (Figures 6-10). All elevation data were surveyed using the North American Vertical Datum of 1988 (NAVD 88). The largest sediment deposition area was found along Transect 5 (Figure 10) and exhibited a change of +0.595 ft (7.2 inches) between 2013 and 2014. The largest sediment scour area was found along Transect 4 (Figure 9) and exhibited a change of -0.815 ft (9.78 inches).

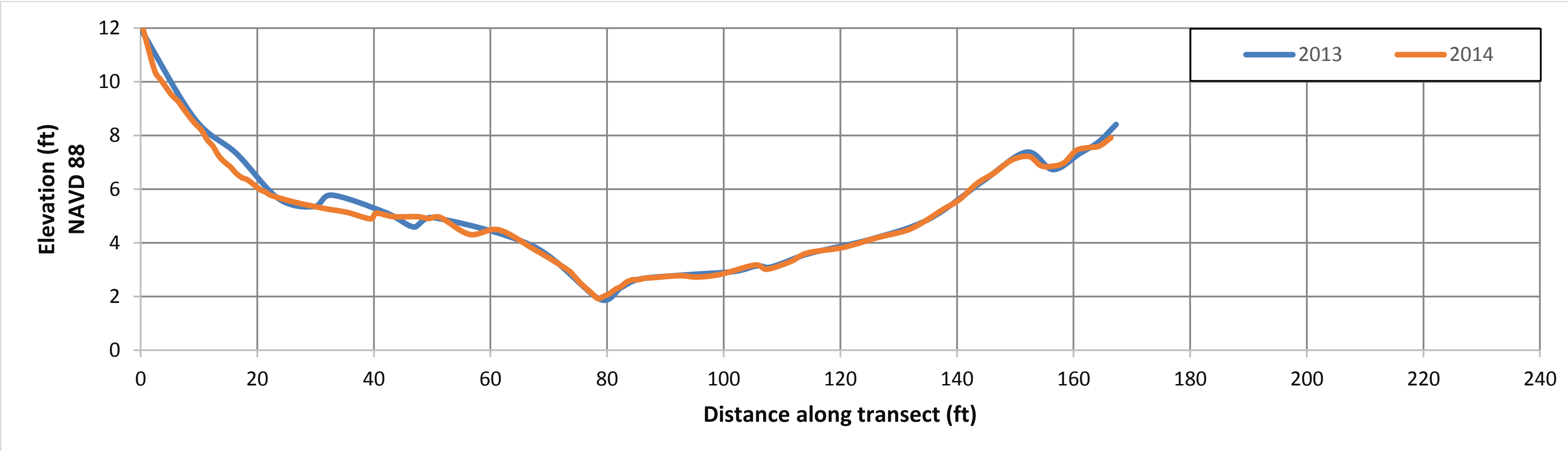

Figure 6. Channel Cross-section Transect 1.

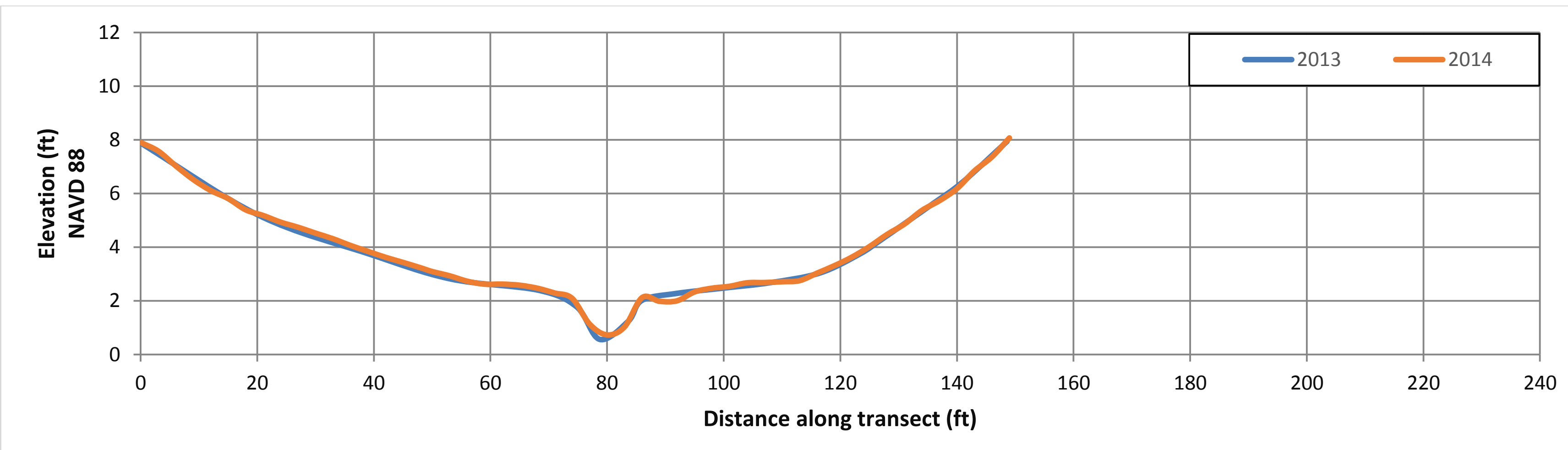

Figure 7. Channel Cross-section Transect 2.

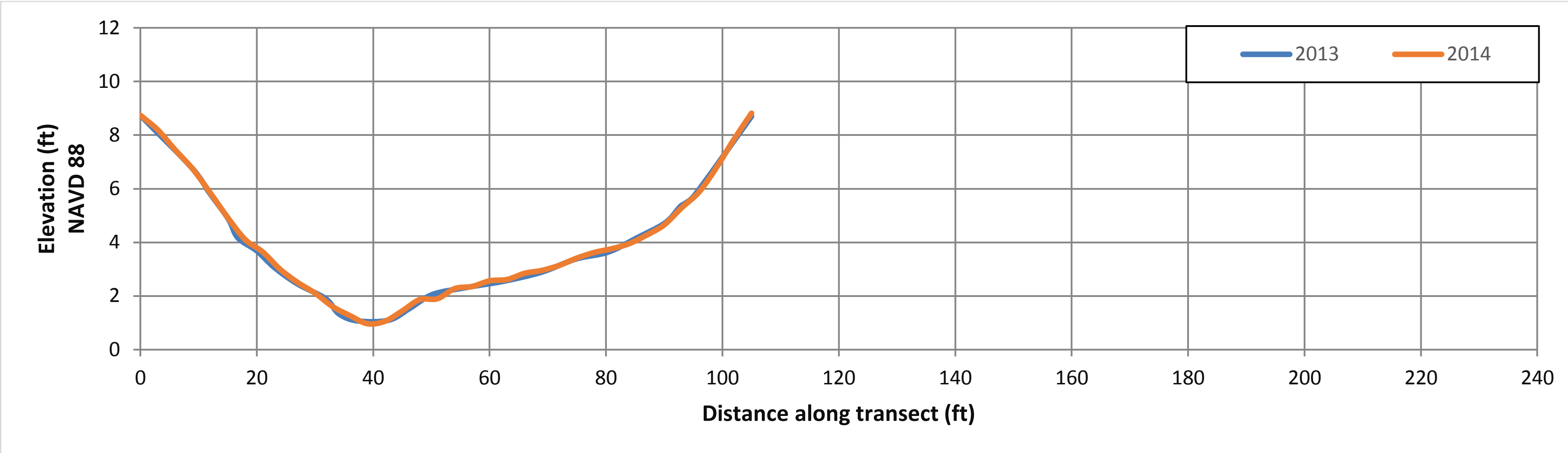

Figure 8. Channel Cross-section Transect 3.

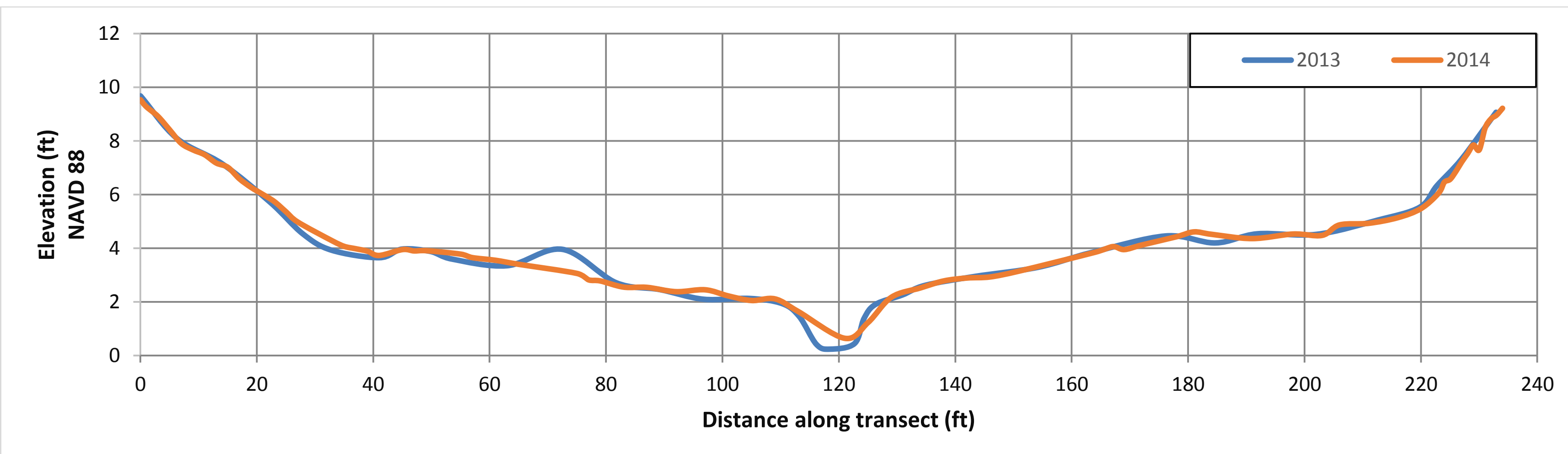

Figure 9. Channel Cross-section Transect 4.

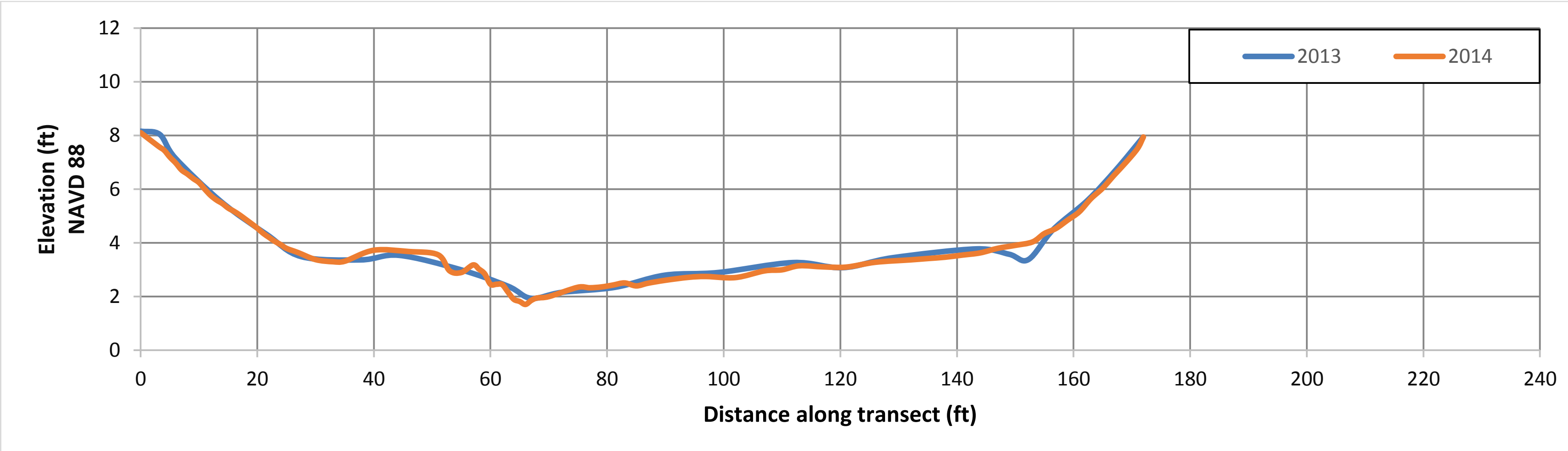

Figure 10. Channel Cross-section Transect 5.

Performance Evaluation

A primary restoration target involved increasing tidal energy to suspend and scour fine grain sediments to limit sedimentation during open lagoon conditions. Overall, channel cross sections remained stable and did not exhibit any large scale changes between survey dates. However, each cross section displayed general smoothing patterns or micro-topographical changes as sediment was shifted or deposited in microhabitat indentations, and as small rises were scoured away or created by the movement of tidal waters. The small scale changes are indicative of channel cross sections equilibrating to open lagoon tidal conditions.

Water Quality – Automated Water Quality Monitoring

Introduction

Water quality probes are used to measure water parameters in continuous monitoring mode by collecting data at user-defined intervals and storing those data until download. Water quality multi-probes can be deployed continuously at monitoring stations to characterize parameters over multiple tidal cycles, during open and closed conditions, through freshwater-input events, or over longer periods of time. One goal of the automated monitoring was to evaluate dissolved oxygen patterns over open and closed berm conditions in the Lagoon.

Methods

Three Yellow Springs Instruments (YSI) 600XLM or equivalent multi-parameter data loggers were deployed in the Lagoon approximately 0.5 ft above the bottom sediments to measure water depth, dissolved oxygen (mg/L), temperature, salinity, conductivity, pH, and oxygen reduction potential (ORP) at 30-minute intervals. Detailed user manuals were used for calibration and maintenance; in-depth descriptions of the specifications and operations of these instruments can be found at www.ysi.com.

Data were collected between May 2013 and December 2014 at three permanent post-restoration stations. Dates of deployment varied by station due to probe malfunctions, servicing, or calibration glitches (Table 3). Post-restoration monitoring stations were located within the western Lagoon's main channel (Station 2) and within the western Lagoon's back channels (Stations 5 and 8) (Figure 11). When possible, data were compared to pre-restoration data collected from hydrologically similar back channels (ML2 and ML6) (Figure 12). Pre-restoration data were collected between October 2006 and June 2012.

Data were downloaded, and the sondes were calibrated, cleaned, and redeployed approximately once monthly (Figure 13). YSI calibration instructions (www.ysi.com) were followed for each calibration and each probe. Data output from the sondes were exported into a spreadsheet and QA/QC procedures were performed by removing inaccurate data from the analyses, including: data from probes not meeting full calibration or operating standards, data that were acquired when the sonde was not submerged, data that were outside of user manual range specifications, and data that were collected when the battery readings were insufficient. Malfunctioning probes and sondes were sent back to the manufacturer for maintenance.

Table 3. Reasons for data gaps due to malfunction, servicing, or calibration issues with the sondes.

Station	Start Gap	End Gap	Parameter	Reason
2	8/3/2013	7/26/2014	All	Sonde malfunction, sent to manufacturer for repairs
5	N/A	N/A	N/A	No data gaps
8	8/28/2014	11/26/2014	Dissolved Oxygen	Probe malfunction

Figure 11. Map of post-restoration vertical profile, SAV/algae, surface and bottom water nutrient, and sediment survey stations. Stations 2, 5, and 8 are the locations of the three permanently-deployed YSI data sondes.

Figure 12. Map of pre-restoration water quality monitoring stations. ML2 and ML6 are the locations of the pre-restoration permanently-deployed YSI data sondes.

Figure 13. Deploying a YSI sonde post-restoration at Station 8; 5 March 2014.

Results

Graphs displaying data from post-construction monitoring at Stations 2, 5, and 8 are presented in Figures 14-16. Figures 14a, 15a, and 16a demonstrate the relationship between water salinity (ppt) and water depth (NAVD 88 ft). During closed conditions across the mouth of the main Lagoon, salinity levels were lower as freshwater inputs from Malibu Creek raised the water elevations. Figures 14b, 15b, and 16b demonstrate the relationship between temperature (^{o}C) and dissolved oxygen (mg/L). In general, as temperature increased in a closed lagoon scenario, levels of dissolved oxygen decreased as the primary producer communities (algae) consumed the available oxygen. However, a high proportion of dissolved oxygen samples were recorded above success criteria thresholds. Notably, more than 95% of closed condition dissolved oxygen readings were above 1 mg/L for both back channel monitoring stations (stations 5 and 8). Table 4 summarizes the overall percentage of dissolved oxygen readings above each specified threshold. Due to sonde malfunctions, data were not collected from Station 2 during closed conditions and were subsequently not included in Table 4. Figures 14c, 15c, and 16c illustrate the relationship between pH and oxidation reduction potential.

Table 4. Proportion of readings during closed conditions above thresholds identified in SMBRF 2012. *Note: Figures 14-16 follow the 'Performance Evaluation' subsection for formatting purposes.*

	Dissolved Oxygen Threshold (mg/ L)			
Station	1	1.5	3	5
5	96.97%	94.71%	85.24%	66.61%
8	95.76%	94.30%	88.23%	75.25%

Data were also analyzed to identify the number of consecutive 24-hour periods (i.e. 1200 – 1159) that dissolved readings were below 1 mg/L for more than 25% of the time (i.e. 6 total hours) and below 1.5 mg/L for more than 50% of the time (i.e. 12 total hours) during closed conditions. Results of the analyses displayed four and nine consecutive 24-hour periods below 1 mg/L (25% time) for Station 5 and Station 8, respectively. Additionally, results displayed two and six consecutive 24-hour periods below 1.5 mg/L (50% time) for Station 5 and Station 8, respectively.

Data from the back channel sonde displayed a marked increase in the percentage of readings above dissolved oxygen thresholds, when compared to pre-restoration data from the back channel. The post-restoration back channel sondes were above 1 mg/L dissolved oxygen during closed conditions approximately 97% (Station 5) and 96% (Station 8) of the time compared to only approximately 83% (ML2) and 89% (ML6) during pre-restoration deployment. The percentage of post-restoration closed condition readings above 1.5 mg/L dissolved oxygen were approximately 95% (Station 5) and 94% (Station 8), compared to 81% (ML2) and 86% (Station 6) during pre-restoration conditions.

Performance Evaluation

A primary goal of the restoration and indicator of the Project's success was to increase levels of dissolved oxygen within the Lagoon's back channels, specifically in areas that were developing 'dead zones' of anoxia in pre-restoration conditions. Post-restoration improvements to circulation, specifically within closed berm conditions, were indicated by the consistently higher levels of dissolved oxygen throughout the site and for longer periods of time, when compared to the pre-restoration conditions.

Additionally, post-restoration dissolved oxygen data exceeded success criteria for sustained time periods during closed conditions. Dissolved oxygen success criteria allowed readings to be below 1.0 mg/L for more than six hours in a 24 hour period for no more than 30 consecutive days and below 1.5 mg/L for more than 12 hours for no more than 45 consecutive days. Results of the analyses displayed only four and nine consecutive 24-hour periods below 1 mg/L (25% time) for Station 5 and Station 8, respectively. Additionally, results displayed only two and six consecutive 24-hour periods below 1.5 mg/L (50% time) for Station 5 and Station 8, respectively. These are significantly below or better than the threshold levels described in the success criteria. These data indicate a post-restoration decrease in the impacts caused by eutrophication as evaluated by the number of days above the thresholds.

Observationally, post-restoration data sonde housings have experienced high levels of biofouling and large accretions of biological organisms (primarily barnacles) which were not present in pre-restoration back channels. Biofouling has the potential to decrease the oxygen levels being measured by the data sondes based on reduced circulation reaching the actual probe.

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Water Quality – Vertical Profiles

Introduction

Vertical water quality profiles are discreet water quality measurements taken at predefined depths within a water column. Vertical profile sampling data may be used to identify stratification within the water column and to provide a better understanding of internal water column mixing dynamics and circulation patterns during both open and closed lagoon conditions.

Methods

Semi-annual vertical profile sampling (at 0.5 foot intervals) of water quality parameters [dissolved oxygen (DO), temperature, salinity and pH] were performed at eight stations during a high tide (N = 2) or closed condition (N = 1) using a YSI 600 XLM hand-held water quality instrument or equivalent (Table 5). The vertical profiles provide a spatial expansion of the continuous data sonde loggers to the whole water column in addition to providing quality control checks for the continuous datasets. In-depth descriptions of the specifications and operation manual of this instrument can be found at www.ysi.com.

Three post-restoration vertical water quality profile surveys were conducted during the dates and tides listed in Table 5 at all eight water quality stations (Figure 11).

Table 5. Dates and lagoon conditions for vertical profile surveys. Tide heights are reported as Mean Sea Level.

Date	Lagoon Condition	Tide
14 February 2013	Open	high neap; 3.9 ft MSL
5 May 2014	Closed	N/A
23 December 2014	Open	high spring; 6.6 ft MSL

Vertical Profile Field Collection Protocols:

1. Before beginning, all probes were calibrated according to the instrument's manual.
2. Probes were lowered underwater and allowed to equilibrate to the surrounding water.
3. The total water column was divided into approximately 0.5 ft intervals, with an extra sample taken just above the bottom, if that did not correspond with a factor of the 0.5 ft depth interval. At each depth, water temperature, dissolved oxygen (mg/L), salinity, and pH were measured.
4. All water quality parameters were recorded for each depth interval.

Results

Results suggest fairly consistent temperature data throughout the water column; the warmest temperatures occurred during the spring sampling event (5 May 2014), and cooler temperatures occurred during the two winter sampling events (14 February 2013 and 23 December 2014) (Figures 17a and 17b). Salinity data displayed some stratification during the open lagoon condition survey events, with a brackish water lens of lower salinity water occurring on the surface of the water column and more saline, oceanic water occurring towards the bottom of the water column (Figures 18a and 18b). During these times, the survey area was exposed to tidal influence. During the closed lagoon condition sampling event (5 May 2014), little to no salinity stratification occurred, indicating good mixing. The mixing is in direct contrast to the pre-restoration conditions, where the dissolved oxygen exhibited stratification in the form of oxyclines (or sharp gradients in oxygen concentration, substantial reductions) at multiple stations, especially during the closed berm condition sampling event (26 September 2007; 2nd Nature 2010).

Dissolved oxygen (DO) data showed consistently high values at all stations; all DO data points greatly exceeded the 1 mg/L threshold (dotted red line on graphs) during both open and closed lagoon conditions (Figures 19a and 19b). The vertical profile dissolved oxygen levels never fell below 6 mg/L at any of the stations during all post-restoration sampling events, and the levels during the closed berm condition sampling event (May 2014) never fell below 11 mg/L. This is in contrast to the pre-restoration closed berm sampling event (26 September 2007), where the dissolved oxygen vertical profile data dropped below the 1 mg/L threshold multiple times, especially at increased depths (2nd Nature 2010).

Average, maximum, and minimum values for each of the parameters measured (i.e. salinity, water temperature, and pH) were all consistent with water quality parameter goals of the restoration project (Tables 5 and 6).

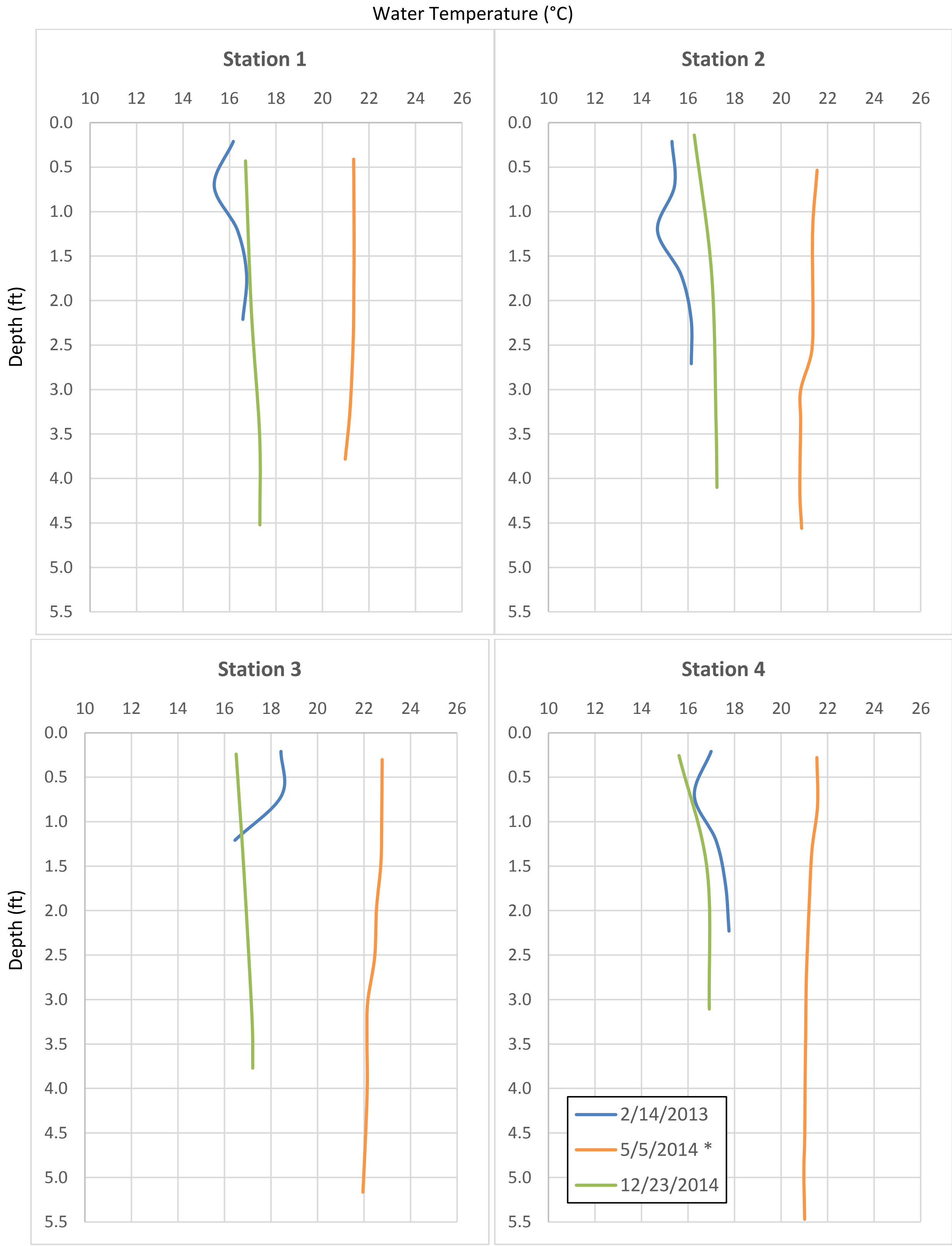


Figure 17a. Post-restoration temperature vertical water quality profiles at Stations 1-4. Asterisk indicates a closed berm condition.

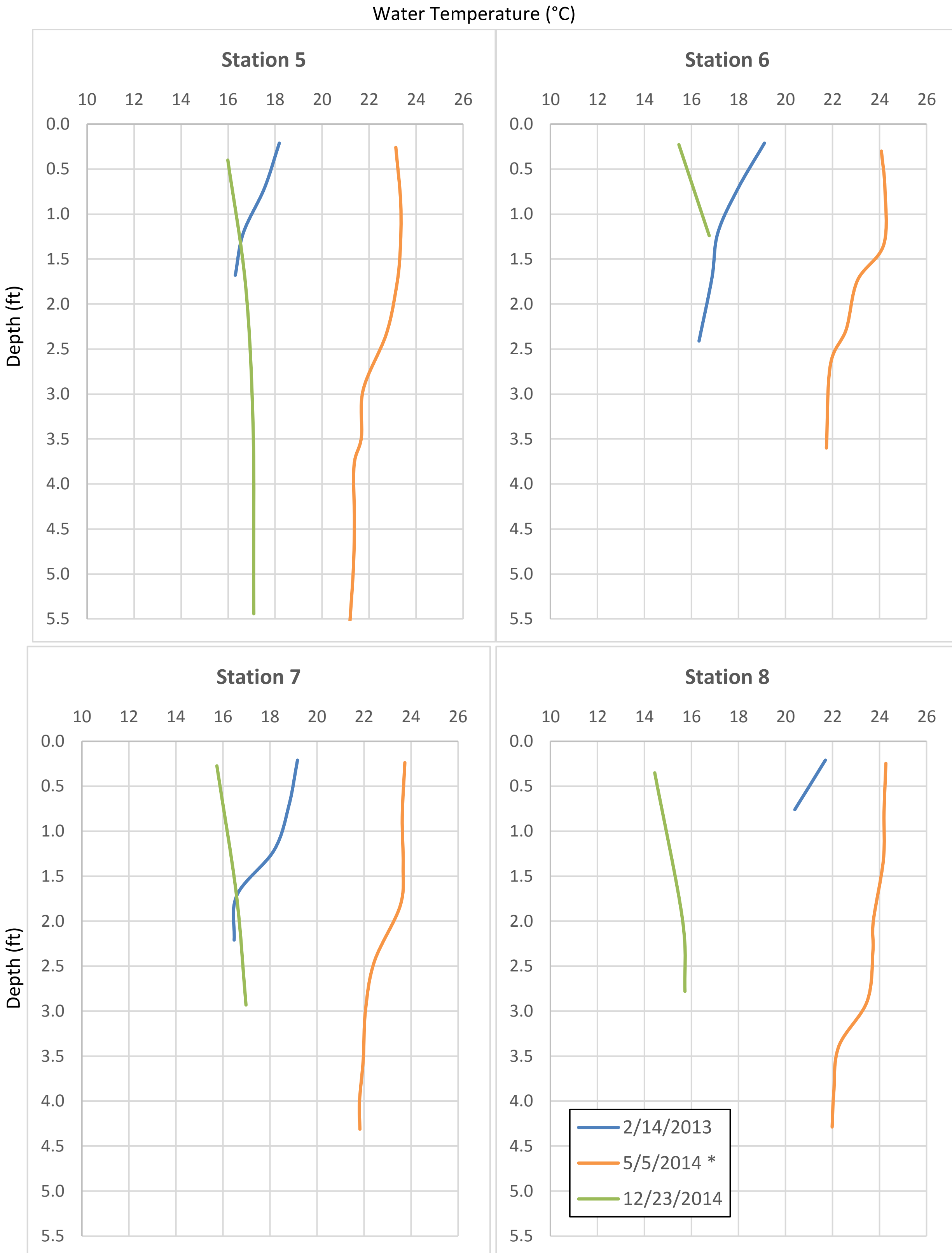


Figure 17b. Post-restoration temperature vertical water quality profiles at Stations 5-8. Asterisk indicates a closed berm condition.

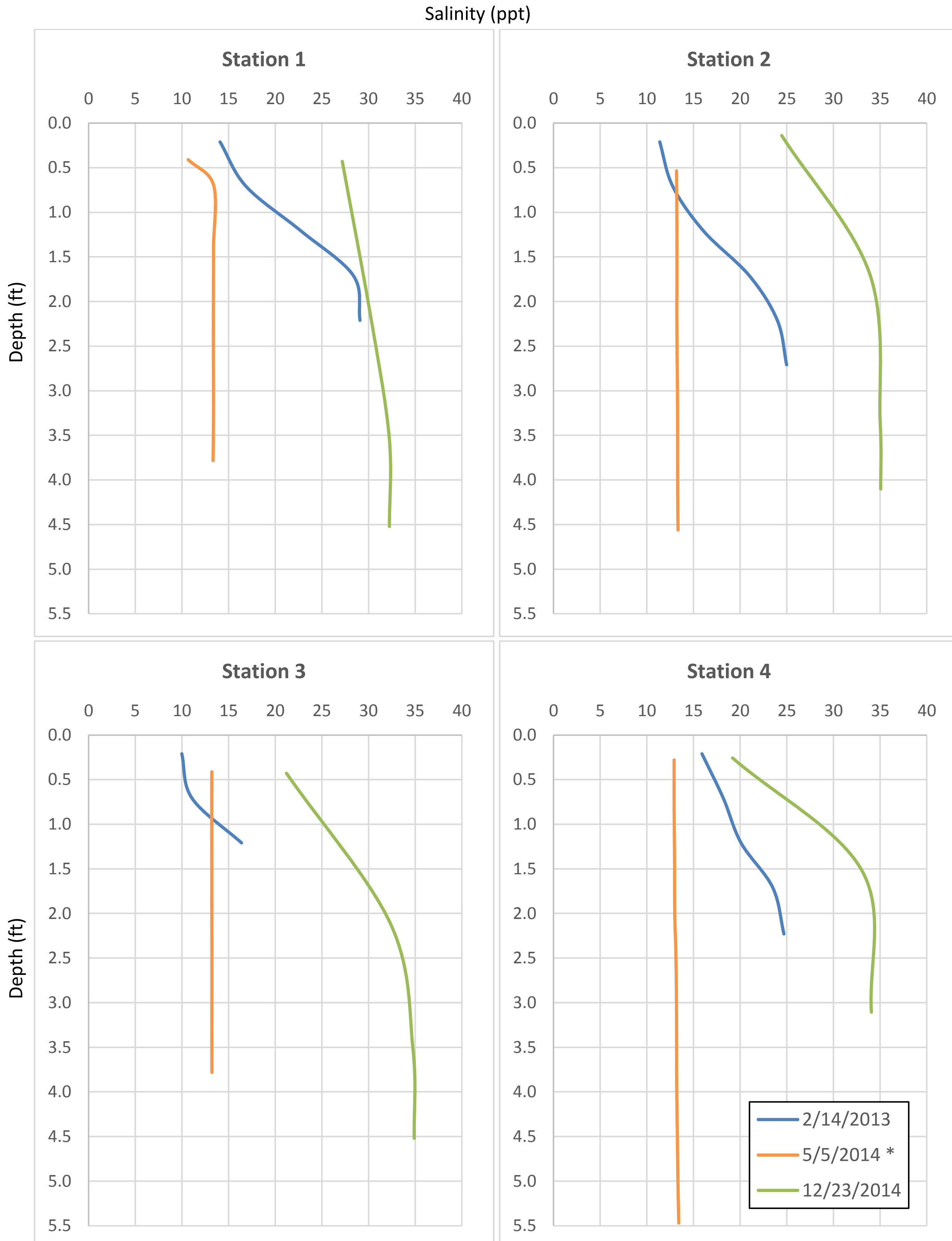


Figure 18a. Post-restoration salinity vertical water quality profiles at Stations 1-4. Asterisk indicates a closed berm condition.

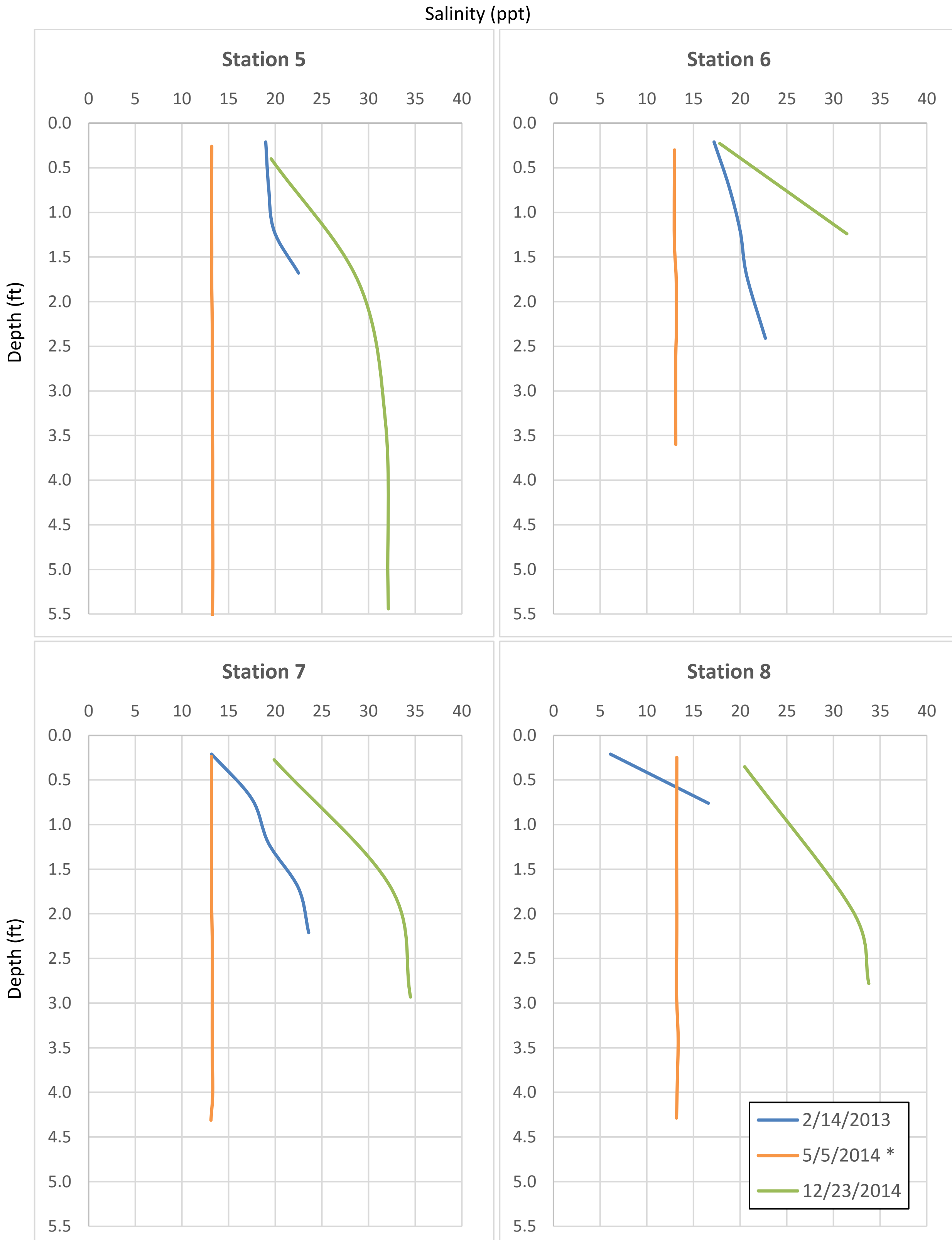


Figure 18b. Post-restoration salinity vertical water quality profiles at Stations 5-8. Asterisk indicates a closed berm condition.

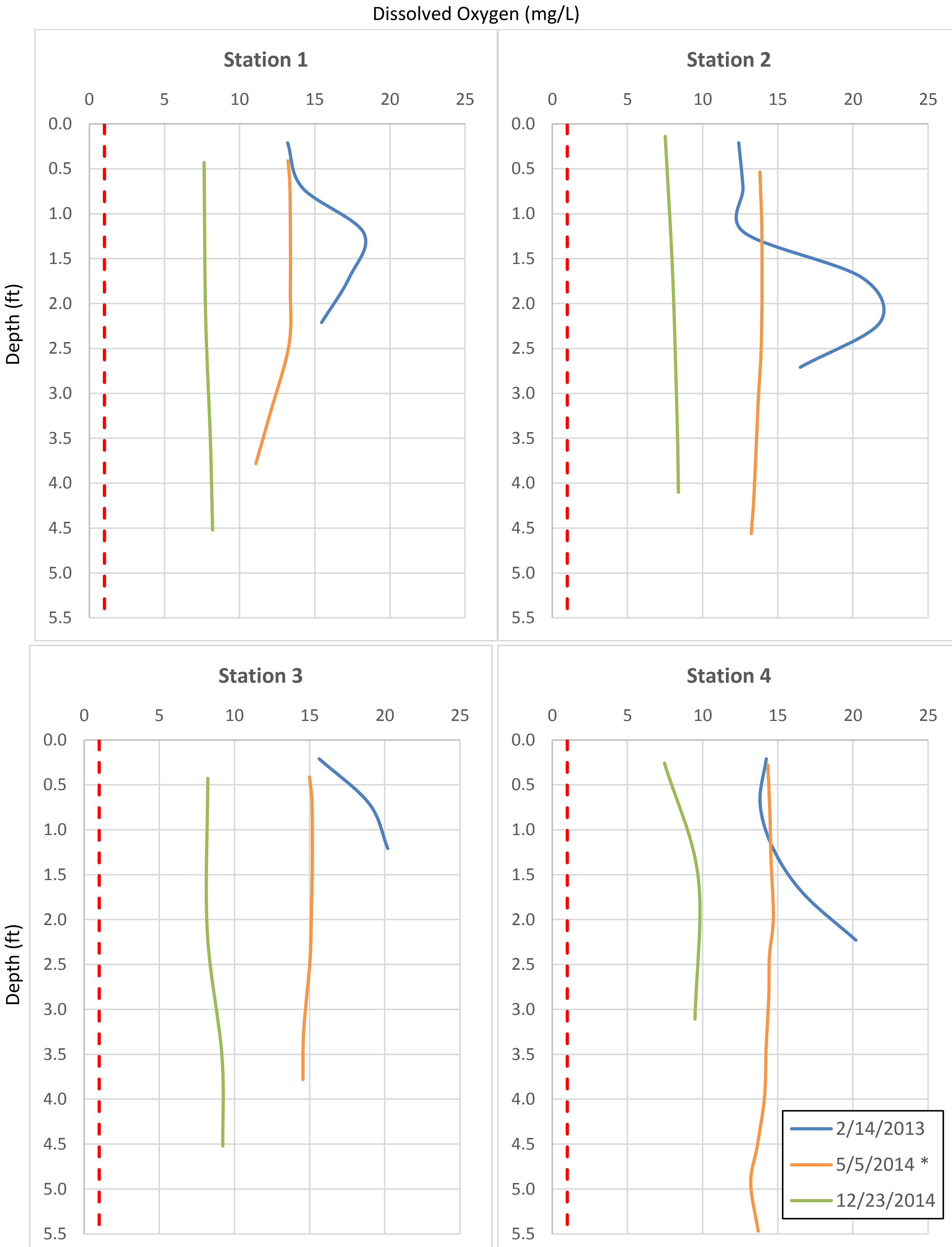


Figure 19a. Post-restoration dissolved oxygen vertical water quality profiles at Stations 1-4 (red line represents 1 mg/L threshold). Asterisk indicates a closed berm condition.

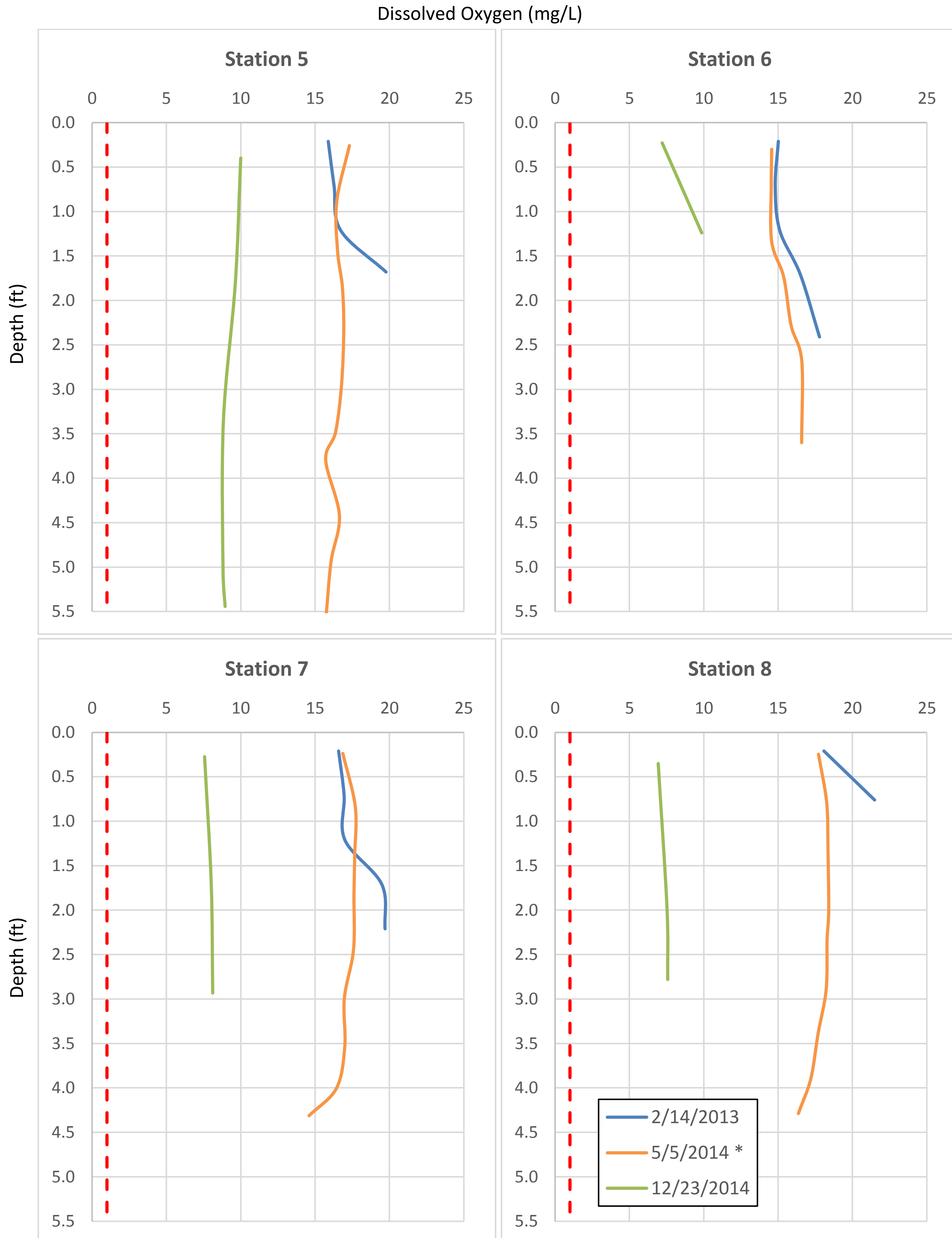


Figure 19b. Post-restoration dissolved oxygen vertical water quality profiles at Stations 5-8 (red line represents 1 mg/L threshold). Asterisk indicates a closed berm condition.

Table 6. Minimum and maximum values for each parameter measured across each survey date. Asterisk indicates a closed berm condition.

Survey Date	Temperature (°C)		Salinity (ppt)		Dissolved Oxygen (mg/L)		pH	
	Min	Max	Min	Max	Min	Max	Min	Max
2/14/2013	14.69	21.70	6.10	29.10	12.41	21.80	8.00	8.55
5/5/2014 *	20.81	24.27	10.68	13.42	11.08	18.41	9.03	9.33
12/23/2014	14.44	17.30	17.82	35.08	6.93	10.00	7.24	8.06

Table 7. Average parameter values and standard error (SE) by date and station. Asterisk indicates a closed berm condition.

Date	Station	Average Temperature (°C)	SE Temp	Average Salinity (ppt)	SE Salinity	Average DO (mg/L)	SE DO	Average pH	SE pH
2/14/2013	1	16.23	0.24	22.26	3.00	15.68	0.94	8.28	0.05
	2	15.57	0.23	18.38	2.36	16.13	1.72	8.28	0.08
	3	17.78	0.66	12.50	1.98	18.26	1.36	8.41	0.03
	4	17.17	0.26	20.48	1.63	15.93	1.18	8.16	0.02
	5	17.17	0.43	20.18	0.80	17.17	0.89	8.26	0.06
	6	17.48	0.49	19.88	0.92	15.84	0.57	8.12	0.05
	7	17.85	0.56	19.22	1.86	17.94	0.68	8.26	0.04
	8	21.05	0.65	11.35	5.25	19.79	1.71	8.10	0.08
5/5/2014 *	1	21.27	0.05	13.00	0.39	12.82	0.34	9.13	0.03
	2	21.15	0.10	13.26	0.02	13.72	0.09	9.18	0.01
	3	22.37	0.10	13.21	0.01	14.69	0.20	9.25	0.01
	4	21.18	0.06	13.14	0.05	14.17	0.14	9.16	0.00
	5	22.21	0.27	13.25	0.01	16.48	0.15	9.27	0.01
	6	23.11	0.41	13.05	0.04	15.44	0.35	9.16	0.02
	7	22.74	0.29	13.21	0.02	16.94	0.33	9.28	0.02
	8	23.32	0.32	13.22	0.02	17.84	0.23	9.30	0.01
12/23/2014	1	17.06	0.15	30.46	1.19	7.90	0.13	8.00	0.03
	2	16.93	0.23	32.12	2.57	8.06	0.20	7.87	0.04
	3	16.94	0.17	30.81	3.25	8.70	0.29	7.89	0.04
	4	16.44	0.42	28.77	4.81	8.89	0.71	7.75	0.05
	5	16.80	0.21	28.91	2.41	9.25	0.24	7.93	0.06
	6	16.11	0.65	24.64	6.82	8.54	1.33	7.77	0.02
	7	16.43	0.36	28.92	4.56	7.90	0.17	7.66	0.04
	8	15.26	0.41	28.80	4.18	7.34	0.21	7.29	0.05

Performance Evaluation

Post-restoration improvements in circulation in both open and closed berm conditions were indicated by the presence of high levels of dissolved oxygen throughout the site, especially in the back channels, which were previously severely impacted by extremely low dissolved oxygen and anoxic conditions. Dissolved oxygen was well above the success criteria threshold (i.e. > 1 mg/L) for all samples and never fell below 6 mg/L at any of the stations during all post-restoration sampling events; the levels during the closed berm condition sampling event (May 2014) never fell below 11 mg/L. These data contrast the *pre-restoration* closed berm sampling event (26 September 2007), where the dissolved oxygen vertical profile data dropped below the 1 mg/L threshold multiple times, especially at increased depths (2nd Nature 2010). Data indicate post-restoration mixing during closed conditions, meeting the project goal tied specifically to increased circulation.

The other water quality parameters exhibited expected trends, which included warmer, well circulated (i.e. mixed, or non-stratified) water in the spring sampling closed berm condition event and stratified, cooler tidal water in the winter, open berm sampling events. The stratification was most noticeable for the salinity data, with fresher, brackish water on the surface, and more saline, oceanic water closer to the bottom of the channels.

Water Quality – Surface and Bottom Water Constituent Sampling

Introduction

Water quality measurements may be used as indicators of both human health concerns and the overall chemical and physical conditions of a site. Reduced wetland water quality suggests poor circulation, lack of tidal flushing, or increased sediment transport in wetlands (Zedler 2001). Improvements to water quality and circulation were several of the goals of the restoration of Malibu Lagoon. As such, water quality sampling was conducted post-restoration with the principal objective of determining if there were any exceedances of the water quality maximum thresholds post-construction.

Methods

Semi-annual surface water and bottom water samples were collected at the eight vertical profile stations (Figure 11) on 5 May 2014 and 30 December 2014, as described in the Monitoring Plan. May 2014 samples were processed by Associated Labs and December 2014 samples were processed by Eurofins Calscience, Inc., including: nitrate plus nitrite as N, total kjeldahl nitrogen, total phosphorous, orthophosphate, ammonia, and chlorophyll a (surface samples only). Annual summary Beach Report Card bacteria score data from Heal the Bay are also reported for Surfrider Beach (at the breach location) for pre- and post-restoration years from 2008-2014 (data were downloaded from http://brc.healthebay.org/ on 2 April 2015).

Results

Graphs displaying data from pre- and post-construction monitoring at all stations are presented in Figures 20 (bottom) and 21 (surface). Figures 20a, 21a and 20b, 21b display the values of nitrate plus nitrite as N concentrations for pre- and post-restoration surveys. Figures 20c, 21c and 20d, 21d display the values of total kjeldahl nitrogen concentrations for pre- and post-restoration surveys. Figures 20e, 21e and 20f, 21f display the values of total phosphorous concentrations for pre- and post-restoration surveys. Figures 20g, 21g and 20h, 21h display the values for orthophosphate concentrations for pre- and post-restoration surveys. Figures 20i, 21i and 20j, 21j display the values for ammonia concentrations for pre- and post-restoration surveys. Figures 21k and 21l display the values for chlorophyll *a* concentrations for pre- and post-restoration surveys. While pre- and post-restoration data were not directly comparable on a station-by-station basis due to physical grading differences in the site, data in graphs were presented to closely match pre- and post-restoration monitoring locations based on their geographic orientation within the lagoon (e.g. north, southwest).

The post-restoration nutrient concentrations remained relatively constant, with the exception of the 30 December 2014 surveys, which showed consistently higher nutrient concentrations across multiple parameters [i.e. total kjeldahl nitrogen (in bottom samples only), total phosphorous, and chlorophyll *a*]. The higher concentrations were likely due to nutrient-laden water discharges from adjacent onsite wastewater treatment facilities or the Tapia Water Reclamation Facility located outside the project area upstream in Malibu Creek.

Summary bacteria data from Heal the Bay suggest a decrease in Total Maximum Daily Load (TMDL) exceedances, post-restoration (Table 7), as well as a higher “grade” post-restoration than immediately preceding the restoration (B and F, respectively).

Table 8. Summary annual grade from the bacteria Beach Report Card Heal the Bay data (downloaded 2 April 2015). Note: the grey cells display pre-restoration data and the light green cells display post-restoration data.

Year	Grade (AB 411)	TMDL Exceedances
2008	A	79
2009	D	64
2010	C	31
2011	B	102
2012	F	37
2013	B	33
2014	B	8

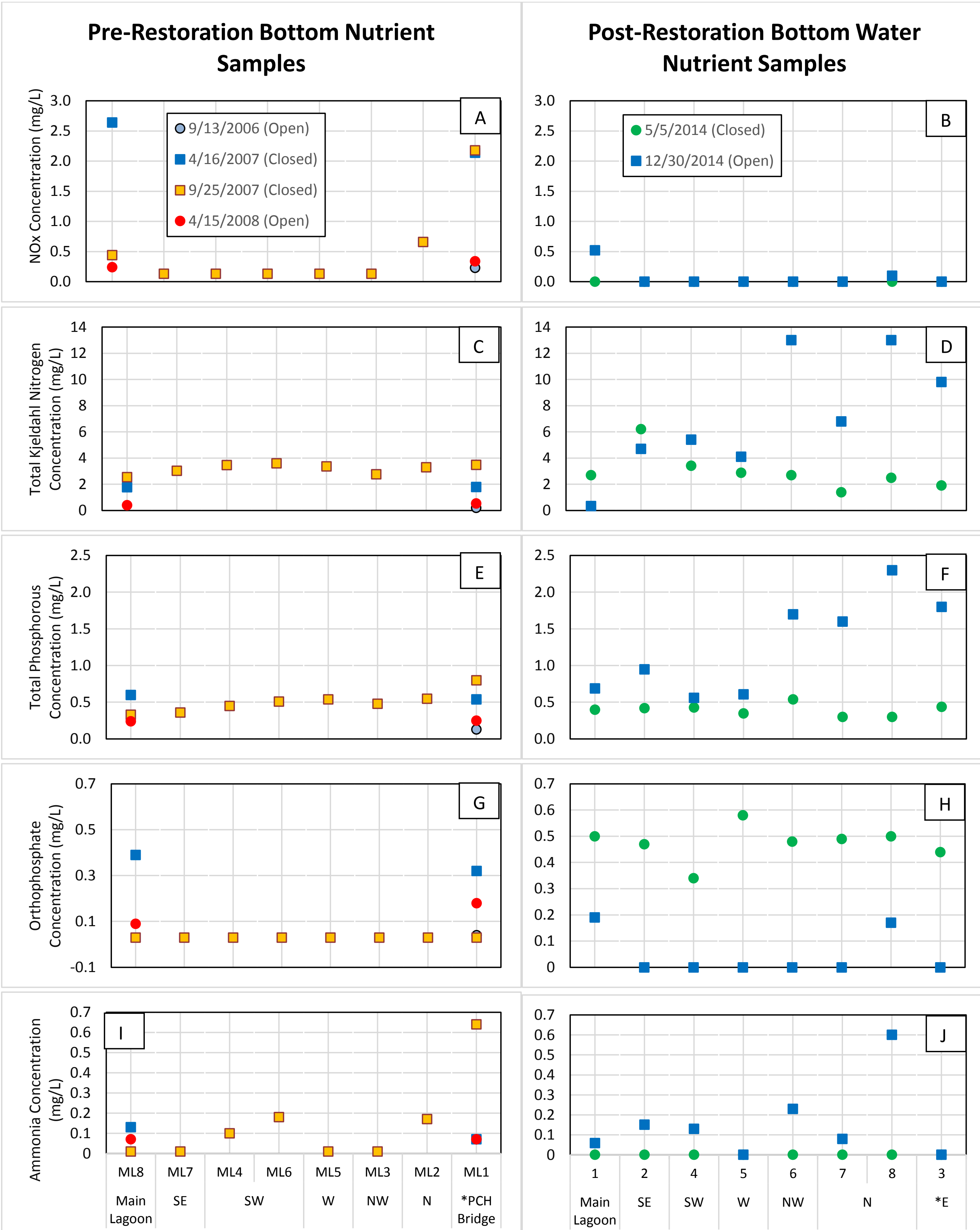
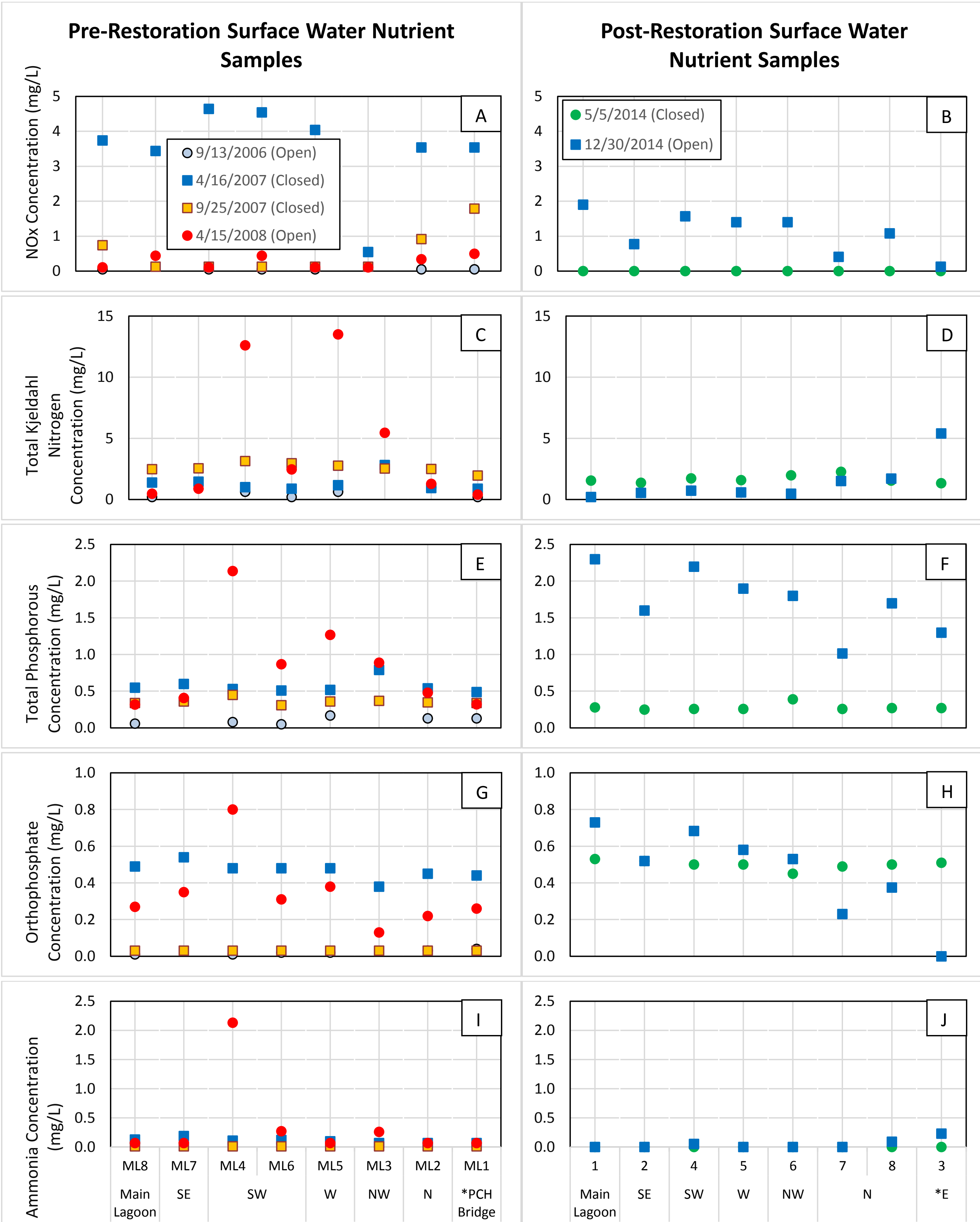


Figure 20. Graphs displaying bottom water nutrients concentrations from pre- and post-construction surveys.



Pre-Restoration Surface Water Nutrient Samples
Post-Restoration Surface Water Nutrient Samples
NOx Concentration (mg/L)
Total Kjeldahl Nitrogen Concentration (mg/L)
Total Phosphorous Concentration (mg/L)
Orthophosphate Concentration (mg/L)
Ammonia Concentration (mg/L)
A
B
C
D
E
F
G
H
I
J
9/13/2006 (Open)
4/16/2007 (Closed)
9/25/2007 (Closed)
4/15/2008 (Open)
5/5/2014 (Closed)
12/30/2014 (Open)
ML8
ML7
ML4
ML6
ML5
ML3
ML2
ML1
Main Lagoon
SE
SW
W
NW
N
*PCH Bridge
1
2
4
5
6
7
8
3
Main Lagoon
SE
SW
W
NW
N
*E

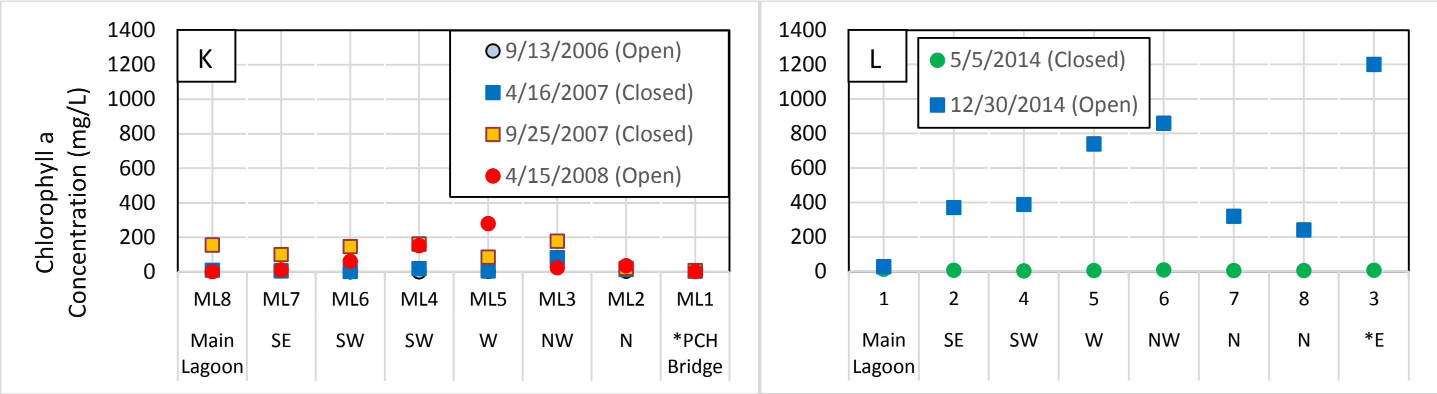


Figure 21. Graphs displaying surface water nutrients concentrations from pre- and post-construction surveys.

Performance Evaluation

Nutrient inputs to the system have remained consistent before and after the restoration process, and the inputs to the restoration area are from adjacent to or upstream, not within the project site. This was well-represented in the data results. Anomalous data collected during the December 2014 surveys are possibly the result of non-project area discharges, as the December 2014 data were collected during the only surveys, pre- or post-restoration, to be implemented during the Tapia Facility's permitted discharge dates into Malibu Creek (November 15 – April 15).

Additionally, based on the Heal the Bay Beach Report Card data, the post-restoration trend appears to be declining numbers of TMDL exceedances; however, more data points (years) are needed to evaluate a long-term trend as 2013 and 2014 had reduced rainfall, compared to the average for the area.

Sediment Quality – Sediment Constituent Sampling

Introduction

Urban wetlands can be contaminated by a wide variety of constituents and sources (Comeleo et al. 1996, Bay et al. 2010). Identification and assessment of sediment toxicity levels are essential to understanding wetland systems, as sediment contamination can result in significant impacts to wetland ecological processes (Lau and Chu 2000, Greaney 2005). Principal goals of the sediment constituent sampling was to determine the trajectory of sediment grain sizes and compare nutrient sequestering conditions to baseline conditions.

Methods

Semi-annual post-restoration sediment samples were collected from the five channel cross section stations (Stations 2, 3, 4, 5, and 8) on 5 May 2014 and the eight vertical profile stations (Stations 1-8; Figure 11) on 30 December 2014. May 2014 samples were processed by Associated Labs and December 2014 samples were processed by Eurofins Calscience, Inc., including: grain size, total organic carbon, percent moisture, nitrate plus nitrite as Nitrogen, total phosphorus, total kjeldahl nitrogen (ammonia, organic, and reduced nitrogen), and total nitrogen (includes total kjeldahl nitrogen).

Five sediment samples were collected at each station during both sampling periods at the left and right channel banks, the thalweg, and within the channel plain (Figure 22). Channel plain samples are collected from approximately halfway between the channel bank and thalweg during closed conditions and along the wetted perimeter of tidal waters in open conditions. Samples from the May 2014 surveys were composited for the channel banks and composited for the channel plain. All samples for the channel banks and channel plain were composited into a single sample during the December 2014 survey.

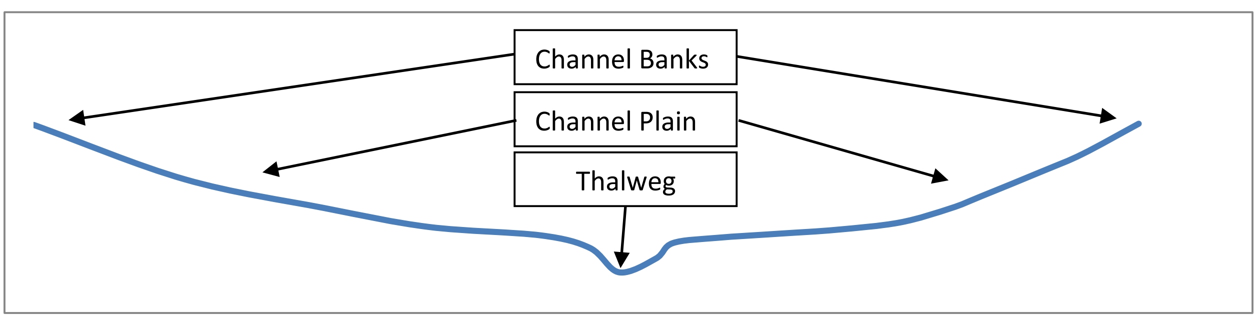


Figure 22. Representative channel cross section displaying the locations of sediment quality collection zones.

Sediment data were collected during pre-restoration conditions at four sampling locations (Figure 23) during four sampling events in September 2006, April 2007, September 2007, and April 2008. Pre-restoration sediment samples were processed for nitrates, total phosphorus, total kjeldahl nitrogen, and total nitrogen. Whenever possible, site-wide data trends are compared for pre- and post-restoration sediment nutrient data.

Figure 23. Map showing the location of pre-restoration sediment monitoring stations.

Results

Grain Size Analysis

Sediment grain size analysis percentages integrated to include silt and clay (< 0.0625 mm), sand (between 0.0625 mm and 2 mm), and gravel (> 2 mm) for both May 2014 and December 2014 surveys were summarized in Table 8. Overall, the thalweg sampling locations exhibited lower proportions of gravel than the channel plain and channel bank composite samples. Of the five stations surveyed during both sampling periods, a slight to moderate increase in fine grained sediments (i.e. silt and clay) was identified for three of the five stations. The largest increase occurred at station 8 which experienced an increased percentage of fine grain sediments from 1.2% in April 2014 to 44% in December 2014.

Table 9. Sediment grain size analysis for all cross sections. 'Channel Bank' and 'Within Channel' categories for May 2014 are composited from the left and right sides of the channel. 'Channel' category for December 2014 is a composite of the channel bank and within channel locations for both the left and right banks.

	Station	Location	Total Silt and Clay % (0 to 0.0625 mm)	Sand % (0.0625 mm to 2 mm)	Gravel % (>2 mm)	Median Grain Size
May 2014	2	Channel Bank	65.2	34.8	0.0	Silt
		Thalweg	55.1	44.9	0.0	Silt
		Within Channel	14.1	56.3	29.6	Medium Sand
	3	Channel Bank	15.5	69.0	15.6	Fine Sand
		Thalweg	69.8	30.2	0.0	Silt
		Within Channel	6.5	81.0	12.5	Medium Sand
	4	Channel Bank	2.4	74.3	23.3	Medium Sand
		Thalweg	22.9	77.1	0.0	Fine Sand
		Within Channel	16.4	76.5	7.1	Fine Sand
	5	Channel Bank	13.3	74.9	11.8	Medium Sand
		Thalweg	64.5	35.5	0.0	Silt
		Within Channel	11.1	83.4	5.5	Medium Sand
	8	Channel Bank	33.3	66.7	0.0	Fine Sand
		Thalweg	1.2	41.6	57.2	Gravel
		Within Channel	5.3	67.8	26.9	Medium Sand
December 2014	1	Channel	13.9	82.7	3.4	Fine Sand
		Thalweg	4.6	80.4	15.0	Coarse Sand
	2	Channel	68.1	31.9	0.0	Silt
		Thalweg	75.2	24.8	0.0	Silt
	3	Channel	45.2	54.8	0.0	Very Fine Sand
		Thalweg	69.4	30.6	0.0	Silt
	4	Channel	41.6	57.3	1.1	Very Fine Sand
		Thalweg	42.7	56.2	1.1	Fine Sand
	5	Channel	66.6	32.0	1.4	Silt
		Thalweg	63.0	37.0	0.0	Silt
	6	Channel	85.0	15.0	0.0	Silt
		Thalweg	13.3	56.7	30.0	Coarse Sand
	7	Channel	71.6	28.4	0.0	Silt
		Thalweg	81.5	14.2	4.3	Silt
	8	Channel	14.4	64.2	21.4	Medium Sand
		Thalweg	44.0	56.0	0.0	Very Fine Sand

Sediment Nutrients

Table 9 displays sediment nutrient values from all stations for pre-restoration surveys; Table 10 displays post-restoration sediment nutrient values. Overall, nutrient concentrations, specifically nitrate plus nitrite as N and total phosphorous, were lower during the December 2014 surveys when compared to May 2014 surveys. However, one sample was identified as an outlier from the December 2014 surveys at Station 1: nitrate plus nitrite as N a channel composite concentration (96 mg/kg). Total kjeldahl nitrogen and total nitrogen concentrations remained relatively consistent across survey dates with the exception of spikes for the thalweg data collected at Stations 2 and 3 with values of 1,921 and 1,340 mg/kg, respectively. However, those spikes were several times smaller than thalweg spikes at several of the pre-restoration stations (Table 9).

Table 10. Pre-restoration sediment nutrient data for all cross sections.

	Station	Location	Nitrate (mg/kg)	TN (mg/kg)	TKN (mg/kg)	TP (mg/kg)
September 2006	A	Channel Bank	2.10	61.80	59.80	325.00
		Channel Plain	1.00	107.00	107.00	327.00
		Thalweg	1.00	192.00	192.00	345.00
	B	Channel Bank	1.00	1600.00	1600.00	637.00
		Channel Plain	1.00	3450.00	3450.00	1160.00
		Thalweg	1.00	3040.00	3040.00	1020.00
	C	Channel Bank	1.00	2850.00	2850.00	839.00
		Channel Plain	1.00	2630.00	2630.00	1420.00
		Thalweg	1.00	3520.00	3520.00	965.00
	D	Channel Bank	1.76	439.00	438.00	385.00
		Channel Plain	1.00	1010.00	1010.00	640.00
		Thalweg	1.00	2233.33	2233.33	957.00
April 2007	A	Channel Bank	1.00	169.00	169.00	420.00
		Channel Plain	1.00	157.00	157.00	366.00
		Thalweg	1.00	314.00	314.00	457.00
	B	Channel Bank	1.00	1260.00	1260.00	565.00
		Channel Plain	1.00	2500.00	2500.00	776.00
		Thalweg	1.00	3300.00	3300.00	917.00
	C	Thalweg	1.00	3500.00	3500.00	1290.00
		Channel Bank	14.00	3260.00	3230.00	1180.00
		Channel Plain	1.00	2050.00	2050.00	651.00
	D	Thalweg	1.00	3610.00	3610.00	0.09
		Channel Bank	1.00	592.00	592.00	296.00
		Channel Plain	1.00	1220.00	1220.00	505.00
Sept 2007	A	Thalweg	1.00	319.00	319.00	259.00
		Channel Plain	1.00	812.00	812.00	316.00
		Channel Bank	1.00	385.00	385.00	331.00

	Station	Location	Nitrate (mg/kg)	TN (mg/kg)	TKN (mg/kg)	TP (mg/kg)
September 2007	B	Thalweg	1.00	1210.00	1210.00	328.00
		Channel Plain	1.00	1640.00	1640.00	511.00
		Channel Bank	1.00	612.00	612.00	402.00
	C	Thalweg	1.00	1450.00	1450.00	253.00
		Channel Plain	1.80	655.00	653.00	535.00
		Channel Bank	1.43	2466.00	2466.00	474.00
	D	Thalweg	1.00	997.00	997.00	344.00
		Channel Plain	1.00	296.00	296.00	332.00
		Channel Bank	1.00	466.00	466.00	289.00
April 2008	A	Channel Bank	4.80	255.00	250.00	331.00
		Channel Plain	0.00	260.00	260.00	357.00
		Thalweg	0.00	280.00	280.00	263.00
	B	Channel Bank	0.00	730.00	730.00	386.00
		Channel Plain	0.00	980.00	980.00	376.00
		Thalweg	0.00	1110.00	1110.00	360.00
	C	Channel Bank	1.20	1321.00	1320.00	458.00
		Channel Plain	1.40	971.00	970.00	367.00
		Thalweg	0.00	1480.00	1480.00	385.00
	D	Channel Bank	5.40	560.00	555.00	398.00
		Channel Plain	1.10	1441.00	1440.00	383.00
		Thalweg	1.00	1600.00	1600.00	324.00

Table 11. Post-restoration sediment nutrient data for all cross sections.

	Station	Location	Nitrate + Nitrite, as N (mg/kg)	TN (mg/kg)	TKN (mg/kg)	TP (mg/kg)
May 2014	2	Channel Bank	2.11	630.00	628.00	704.00
		Thalweg	3.28	1921.00	1920.00	631.00
		Channel Plain	2.22	754.00	752.00	588.00
	3	Channel Bank	0.72	572.00	571.00	608.00
		Thalweg	0.66	1340.70	1340.00	575.00
		Channel Plain	1.03	401.00	400.00	391.00
	4	Channel Plain	2.47	788.50	786.00	678.00
		Channel Bank	0.51	276.00	276.00	245.00
		Thalweg	1.41	533.00	532.00	501.00
	5	Channel Bank	1.39	385.00	384.00	625.00
		Thalweg	1.41	595.00	594.00	428.00
		Channel Plain	3.23	453.20	450.00	526.00
	8	Channel Bank	1.10	388.00	387.00	646.00

	Station	Location	Nitrate + Nitrite, as N (mg/kg)	TN (mg/kg)	TKN (mg/kg)	TP (mg/kg)
		Thalweg	0.52	553.00	553.00	348.90
		Channel Plain	1.28	366.00	365.00	406.00
December 2014	1	Channel Composite	96.00	810.00	800.00	130.67
		Thalweg	0.00	98.00	98.00	250.00
	2	Channel Composite	0.00	840.00	840.00	200.00
		Thalweg	0.62	850.00	850.00	180.00
	3	Channel Composite	0.00	630.00	630.00	230.00
		Thalweg	0.00	390.00	390.00	180.00
	4	Channel Composite	0.00	430.00	430.00	245.00
		Thalweg	0.00	330.00	335.00	210.00
	5	Channel Composite	0.00	420.00	420.00	200.00
		Thalweg	0.00	690.00	690.00	110.00
	6	Channel Composite	0.93	800.00	800.00	56.00
		Thalweg	0.00	220.00	220.00	250.00
	7	Channel Composite	1.40	550.00	550.00	270.00
		Thalweg	0.00	390.00	390.00	190.00
	8	Channel Composite	5.20	520.00	510.00	210.00
		Thalweg	0.00	720.00	720.00	120.00

Performance Evaluation

Sediment grain size distributions experienced an increase in the percentage of fine grain sediments between May 2014 and December 2014 for multiple stations. As the deposition of some fine-grained sediments is a predictable occurrence during closed, low water energy conditions and the channel construction focused on using coarse-grained sediments to minimize the potential impacts of scouring following reconnection with tidal waters, this is not an unexpected trend. Since channel cross-section data (Figures 6 – 10) did not demonstrate any large scale increases in elevation, sediment grain size distributions are likely still progressing towards a balance with the current hydrologic and sediment input regimes. The trajectory of current grain size distributions are still within project success criteria which specifies that a single station must decrease in median grain size for six consecutive sampling events or show an increase in nutrient sequestering.

Sediment nutrients remained fairly consistent between pre- and post-restoration surveys. However, multiple large spikes for all nutrients are present in the pre-restoration September 2006 and April 2007 data which double the highest concentrations identified in post-restoration surveys. Post-restoration sediment nutrient data also displayed more uniform distributions and smaller total ranges. For example, the post-restoration total phosphorous sample range was 56 – 704 mg/kg, compared to 0.09 – 1420 mg/kg during pre-restoration conditions. As another example, the post-restoration total nitrogen sample range was 98 – 1921 mg/kg compared to a pre-restoration range of 61.8 – 3610 mg/kg. The increased uniformity in the distribution patterns of the sediment nutrients across the site may be another indicator of better circulation patterns, especially during the closed berm May sampling period.

Sediment nutrient data are currently meeting success criteria, which includes reducing overall nutrient sequestering over time, based on lower TN and TP maximum values post-restoration. Sediment nutrient concentrations were also found to be generally lower from May 2014 to December 2014, yet results may indicate nutrient settling out of the water column within lower water energy environments during the closed conditions of the May 2014 surveys. Since no modifications were made to nutrient inputs, additional data will provide supplemental information regarding the rates of sediment nutrient sequestering and whether the data reflect natural fluctuations.

Biological Monitoring

An important component of the biological assessments of the Malibu Lagoon Restoration Project will be observable improvements in the establishment and persistence of species diversity and native organisms beyond the first five years following construction. Biological monitoring components will be monitored in the Lagoon to document any changes in the biological indicators as a result of restoration activities and to evaluate the Project's native flora and fauna reestablishment. The monitoring will include annual biological sampling for multiple parameters during the spring and fall and will occur for at least five years following the completion of the Lagoon restoration plan as documented in the 2012 Malibu Lagoon Restoration and Enhancement Plan, Hydrologic and Biological Project Monitoring Plan.

The objectives of the biological monitoring of the Malibu Lagoon are to:

- Assess the habitat and vegetation improvements towards the goals of restoration;
- Document the fish and bird communities' use of the site; and
- Provide timely identification of any problems with the biological development of the lagoon to allow for the implementation of adaptive management measures.

Specific biological parameters that were monitored and assessed in this report include: benthic invertebrate presence, abundance, and pollution tolerance values; fish presence and abundance; avifauna presence and abundance; SAV/algae cover; vegetation cover; and photo point assessments. Results are detailed below and in attached appendices.

Benthic Invertebrates

Introduction

Benthic invertebrate taxa are useful ecological indicators; the presence or absence of certain infauna (i.e. burrow into and live in bottom sediments) or epifauna (i.e. live on the surface of bottom sediments) within tidal channels can serve as indicators of water quality, anthropogenic stressors to the estuary, and the potential to support other trophic levels (WRP 2006); these benthic communities provide essential ecosystem services and support (Ramirez and McLean 1981). The goal of the benthic invertebrate surveys at Malibu Lagoon was to assess the types of taxa and the subsequent pollution tolerance values of those species (or taxa).

Methods

Post-restoration benthic invertebrate community sampling was conducted at eight stations (Figure 11) on 5 May 2014 and 30 December 2014 using two different methods: 1) bank net sweeps, and 2) benthic cores, as described in the Monitoring Plan. Post-restoration data are compared to pre-restoration data from 13 September 2006, 26 September 2007, and 9 November 2010. Benthic invert speciation was conducted by Dancing Coyote Environmental. See SMBRF 2012 for detailed benthic invertebrate collection and processing methods.

Invertebrate data were also analyzed as percent abundance by pollution tolerance value (TV), which is the List of Californian Macroinvertebrate Taxa and Standard Taxonomic Effort (CAMLnet) metric calculations in California. The 0-10 scale ranks individual species or taxa from highly intolerant (0-2) to highly tolerant of pollution (8-10).

Results

Summary data include 25 taxa represented in the 2014 post-restoration surveys, including the small benthic cores (22 taxa) and the net sweep (10 taxa) invertebrate data (Table 11). Figures 24 and 25 display data from the 2006 and 2007 pre-restoration surveys, and both of the 2014 post-restoration surveys. Post-restoration abundances were dominated by oligochaetes, polychaetes, and ostracods.

Data are reported using the pollution tolerance values established for freshwater invertebrate species (CAMLnet, CA Fish and Wildlife, 2003), and scores of 8-10 are considered to have high pollution tolerance. Both the benthic core and net sweep data indicate a rise in the percentage of sensitive taxa, or pollution-intolerant species, post-restoration (e.g. from 8.9% in 2007 to 99.9% in December of 2014 for benthic core invertebrates) (Figures 24a and 25a), and a decrease in the percent abundance of the pollution-tolerant taxa (e.g. from 93.6% and 91.7% pre-restoration to 57.0% and 1.1%, respectively, post-restoration for the net sweep data). Additionally, albeit less dramatically, a similar trend was expressed by the percentages of the numbers of taxa, which showed a slight increase in sensitive (pollution-intolerant) species use of the site and a decrease in the percent of number of pollution tolerant taxa (e.g. from 60% pre-restoration to 14.3% post-restoration, for benthic core invertebrates) (Figures 24b and 25b).

For additional incidental invertebrate data collected during the fish seining events, see the Fish Community Survey chapter (below). As an unusual ancillary note, during the December survey a California sea hare (*Aplysia californica*) was spotted in the main channel.

Table 12. Taxa presence list for all post-restoration surveys combined. Asterisks indicate a closed berm condition.

					Benthic Cores		Net Sweeps	
Phylum	**Class**	**Order**	**Family**	**Lowest Possible Taxon**	* May 2014	Dec 2014	* May 2014	Dec 2014
Annelida	Oligochaeta			Oligochaeta			X	X
Annelida	Oligochaeta	Haplotaxida	Tubicidae	Tubicidae	X			
Annelida	Oligochaeta	Haplotaxida	Tubificidae	Tubificidae		X		
Annelida	Polychaeta	Sedentaria	Capitellidae	*Capitella capitata* complex		X		
Annelida	Polychaeta	Sedentaria	Opheliidae	*Armandia brevis*		X		
Annelida	Polychaeta	Sedentaria	Spionidae	*Polydora cornuta*	X	X		X
Annelida	Polychaeta	Sedentaria	Spionidae	*Polydora nuchalis*	X			
Arthropoda	Insecta	Coleoptera	Dytiscidae	Hydroporinae	X			
Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Enochrus sp.*	X		X	
Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Hydrochus sp.*	X			
Arthropoda	Insecta	Diptera	Ceratopogonidae	Dasyhelea			X	
Arthropoda	Insecta	Diptera	Chironomidae	Chironomidae	X	X	X	X
Arthropoda	Insecta	Diptera	Diptera	*Dasyhelea sp.*		X		
Arthropoda	Insecta	Diptera	Dolichopodidae	Dolichopodidae	X	X	X	
Arthropoda	Insecta	Hemiptera	Corixidae	Corixidae	X		X	
Arthropoda	Insecta	Hemiptera	Corixidae	*Trichocorixa sp.*	X		X	
Arthropoda	Malacostraca	Amphipoda	Gammaridae	*Gammarus sp.*		X		
Arthropoda	Maxillopoda	Calanoida		Calanoida	X			
Arthropoda	Ostracoda			Ostracoda				X
Arthropoda	Ostracoda	Podocopida		Podocopida	X	X	X	
Chordata	Osteichthys			Fish egg/larva	X			
Mollusca	Gastropoda	Opisthobranchia	Hermaeidae	*Alderia willowi*	X			
Nematoda	Adenophorea	Mermithida	Mermithidae	Mermithidae	X	X		
Nemertea	Anopla	Paleonemertea		Paleonemertea	X			
Platyhelminthes	Turbellaria	Rhabdocoela		Rhabdocoela	X			

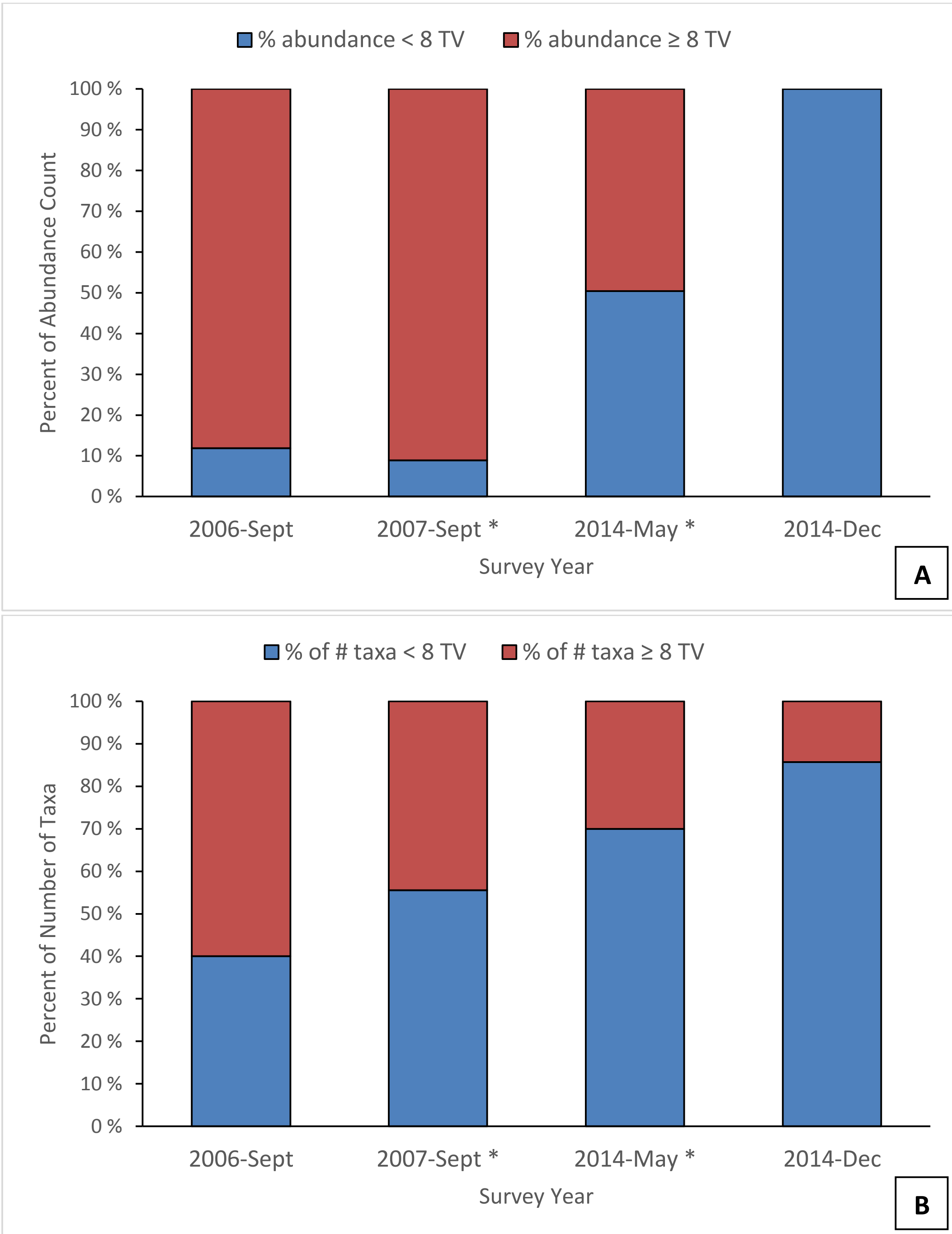


Figure 24. Benthic invertebrate core data results organized by (A) percent of abundance count data with pollution tolerance values (TV) below 8, and (B) percent of number of taxa with TV below 8. Asterisks indicate a closed berm condition.

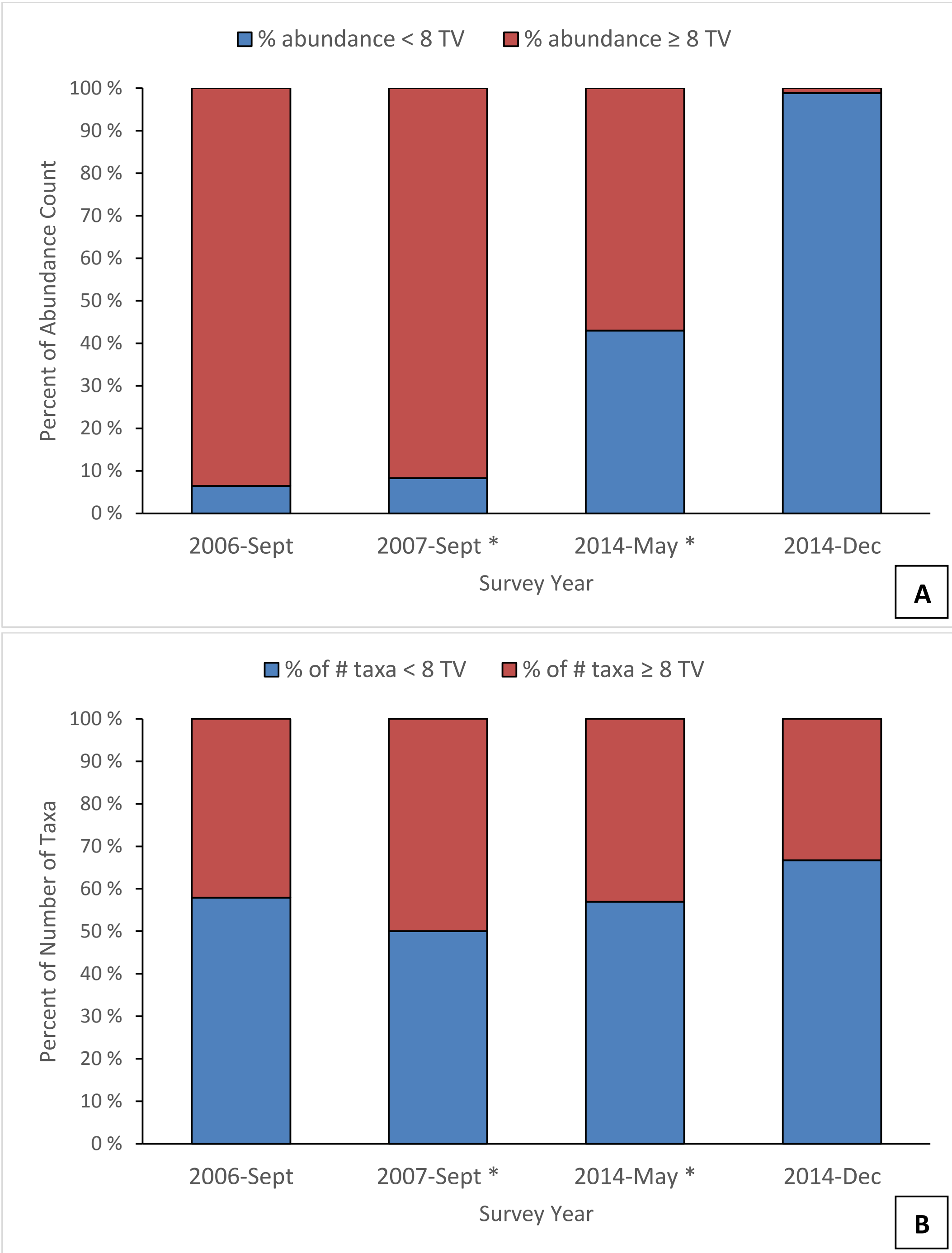


Figure 25. Net sweep invertebrate data results organized by (A) percent of abundance count data with pollution tolerance values (TV) below 8, and (B) percent of number of taxa with TV below 8. Asterisks indicate a closed berm condition.

Performance Evaluation

The invertebrate survey data results establish a shift from a depauperate, pollution-tolerant invertebrate community, to a healthier, diverse invertebrate community that also includes a higher percentage abundance of sensitive species and numbers of taxa. This trend is particularly evident in the community surveyed by the benthic cores and is less prominent in the net sweep survey data results. This trend is also strongest in the December data during an open lagoon condition, and is less obvious in May, when the closed berm, and lower salinity waters had fewer percentages of sensitive species. However, those data still showed higher percent abundances than either of the two pre-restoration survey results. The benthic invertebrate community will likely continue to develop over time as the vegetation community continues to develop and establish more complexity.

Fish Community Surveys

Introduction

Defining the fish assemblage of a wetland can be difficult due to the highly mobile nature of the fauna. However, it is this mobility that often allows them to rapidly colonize restored habitats (Zedler 2001). The goal of the fish community surveys at the Malibu Lagoon Restoration Project is to track changes in uses by different fish species within the restored habitat areas. The new channels are expected to provide more complex and diverse habitat throughout the western portion of the lagoon and additional areas with preferred sandier substrate for tidewater goby to spawn. Additionally, increased circulation and dissolved oxygen will also benefit the fish community. Summary information is included in the subsections below, with additional details and photographs included in Appendices 1 and 2 (May 2014 and December 2014).

Methods

Post-construction fish surveys of Malibu Lagoon were conducted on 8 January 2013, 15 May 2014 and 11 December 2014 by a team led by the Resource Conservation District of the Santa Monica Mountains with assistance from CDPR. Pre-restoration surveys were conducted on 20 June 2005. Due to the extremely deep unconsolidated fine grained sediment and anoxic conditions throughout the lagoon, pre-construction surveys were not conducted prior to the start of work in June 2012.

The lagoon was open for the January 2013 survey, but closed to the ocean on 12 April 2014, so water levels within the lagoon were up to 7.4 feet above mean high water for the May 2014 survey. The lagoon breached on 2 December 2014 at the west end near first point, then breached again in the mid-section a few days later. The initial breach closed and the mid-section breach remained open and passable for the December 2014 survey.

Six permanent sites (Figures 26 and 27) were seined to depletion and spot surveying was conducted at three places along the banks of the Main Lagoon. Site 2, which was established for monitoring in 2013, was inaccessible due to depth resulting from the closed condition of the lagoon. Therefore, Site 2a was added to comply with monitoring plan requirements.

For seine sites, two 10 x 2 m blocking nets were deployed perpendicular from the shore. The two nets were pulled together to form a triangle, trapping fish inside. Two teams with 3 m x 1 m seines walked to the apex of the triangle and pulled from the apex towards the shore. Seines were beached at the water edge and all contents examined. For spot surveys, three teams pulled 2 m x 1 m seines parallel to shoreline in three spots along the Main Lagoon beach bank from west to east.

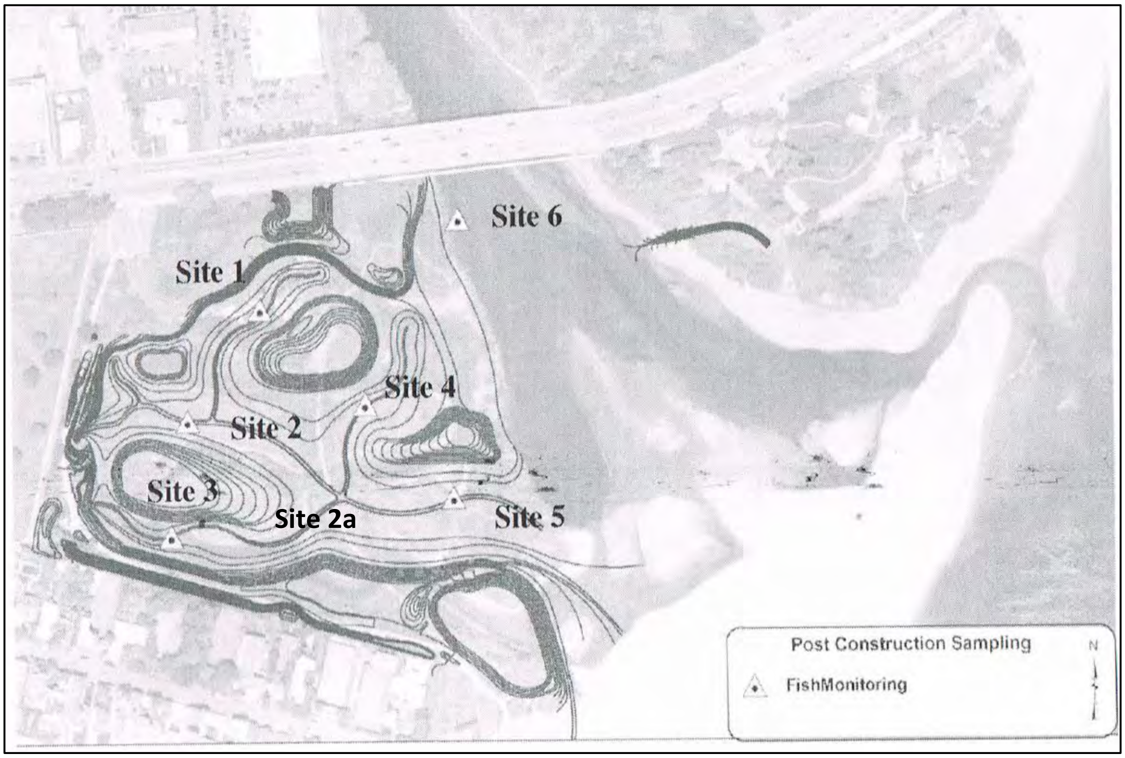


Figure 26. Map of the six permanent fish monitoring Sites.

Figure 27. Representative photograph of fish surveys being conducted at Site 5 on 15 May 2014 (photo: RCDSMM).

Results

For detailed water quality parameter measurements and fish species counts for each survey, see Appendices 1 and 2 and the first year post-restoration baseline report (Abramson et al. 2013). Table 12 displays presence data for each species captured or observed during each of the fishing survey dates. Pre-restoration spot sampling between 2005 and 2012 documented low numbers of native species and the increasing abundance of invasive exotic fishes.

Table 13. Species captured or observed during each of the fish survey events. Asterisk indicates closed berm condition. Note: 2005 survey is the pre-restoration baseline.

Native Fish (Common Names)	Scientific Name	Jun 2005	Jan 2013	May 2014 *	Dec 2014
Arrow goby	*Cleavlandia ios*			X	
Bay goby	*Lepidogobius lepidus*			X	
California killifish	*Fundulus parvipinnis*	X		X	
Diamond turbot	*Hypsopsetta guttulata*		X	X	
Long-jawed mudsucker	*Gillichthys mirabilis*	X		X	
Northern anchovy	*Engraulis mordax*		X		X
Opaleye	*Girella nigricans*	X			
Staghorn sculpin	*Leptocottus armatus*		X	X	
Striped mullet	*Mugil cephalus*			X	X
Tidewater goby	*Eucyclogobius newberryi*	X	X	X	
Topsmelt	*Atherinops sp.*	X	X	X	X
Topsmelt larva (< 5 cm)	*Atherinops sp.*			X	
Unidentified goby larva (< 5 cm)	----			X	
Unidentified smelt larva (< 5 cm)	*Atherinops sp.*			X	
Non-Native Fish					
Mississippi silversides	*Menidia berylina*		X	X	X
Mosquitofish	*Gambusia affinis*	X	X	X	X
Carp	*Cyprinus carpio*	X		X	
Invertebrates					
Oriental shrimp	----	X	X	X	X
Shore crab	*Hemigrapsus sp.*		X	X	X
Sea hare	*Aplysia californica*		X		
Ctenophore	----		X		
Salp	----		X		

January 2013 Survey

The five native fish species documented in the first post-construction survey (Table 12) reflect the winter, marine influenced conditions, as compared to the five native species observed in the June pre-construction survey of 2005. Tidewater gobies were observed in both the pre- and post-construction surveys. No opaleye or long-jawed mudsuckers were captured in January 2013, although numerous long-jawed mudsuckers were moved from the work area to the main lagoon in June 2012. Oriental shrimp and mosquitofish were observed in both the pre and post-construction surveys. Seining in the main body of the lagoon also documented juvenile staghorn sculpin and topsmelt, but additionally supported very small diamond turbot, northern anchovy and tidewater goby.

May 2014 Survey

Ten native fish species and one non-native species were captured in the May 2014 survey (Table 12). Additionally striped mullet and carp were observed jumping throughout the lagoon, but none were captured in the nets. A single, adult steelhead trout (*Onchorhynchus mykiss*) was observed swimming near Site 3 and estimated to be approximately 20 inches long (Figure 28). Only a single non-native mosquitofish was captured, compared to thousands of native fish larva, with topsmelt and gobies dominant in number.

Figure 28. Photograph of the adult steelhead trout swimming in the restoration area (May 2014; photo: RCDSMM).

December 2014 Survey

The dominant species found throughout the lagoon in the December 2014 survey were topsmelt and Mississippi silversides, with a few northern anchovy (Table 12). Additionally, striped mullet were observed throughout the lagoon, but only small juveniles (<5 cm) were captured in the nets. These identifications are based on review of voucher specimens by Dr. Rick Freeney at the Natural History Museum in February 2015.

Performance Evaluation

As fish are highly mobile, each fish survey event represented a snapshot in time and fluctuated across the site locations. The data also showed a high level of seasonal variability, especially when comparing open and closed berm conditions. Based on the semi-annual surveys representing single-sampling events, the post-restoration fish community has returned to the area, with the added function of serving as a nursery habitat as exhibited by the abundance of captured larva and juvenile individuals in the May 2014 survey data. The presence of staghorn sculpin, goby and topsmelt juveniles in the May 2014 survey indicated recent spawning and sufficient conditions to support rearing, despite the fact that vegetation was not yet fully re-established. Seining in the main body of the lagoon also documented juvenile staghorn sculpin and topsmelt, but additionally supported very small diamond turbot, CA killifish, long-jawed mudsucker, and tidewater goby. Presence of these juveniles indicates recent spawning and the potential for recruitment.

The native fish species documented in the January 2013 and December 2014 post-construction surveys reflect the winter, marine influenced conditions, as compared to the native fish species observed in May 2014. Tidewater gobies were observed in both the pre- and post-construction surveys.

Overall fish species richness was lower, relatively, in the December 2014 survey, possibly due to the breach of the sand berm prior to the survey as well as the low tide conditions during the start of the survey. Much of the lagoon habitat was exposed mudflats, and water levels in the sample locations were lower than for previous surveys.

Avian Community Surveys

Introduction

The presence and distribution of avifauna within an ecosystem is often used as an index of habitat quality because of their diet and vulnerability to environmental conditions (Conway 2008). Bird communities are in constant flux; therefore, regular, repeated surveys help maintain a clear picture of bird communities on a site. While the Malibu Lagoon Restoration and Enhancement project was not expected to increase the number of birds that utilize the Lagoon, it was anticipated that the creation of increased habitat diversity would allow for more roosting and foraging areas for various bird species. Summary information is included in the subsections below, with additional details and photographs included in Appendix 3.

Methods

From late 2005 through mid-2006, Cooper Ecological Monitoring, Inc. conducted quarterly bird surveys of the entire site, which involved two visits (morning and late afternoon) on two consecutive or near-consecutive days during October 2005, January 2006, April 2006 and July 2006.

Eight post-restoration surveys were conducted on the project site by Cooper Ecological Monitoring, Inc. on: 11-12 February 2013, 18-19 April 2013, 22-23 July 2013, 28-29 October 2013, 6-7 January 2014, 21-22 April 2014, 22-23 July 2014, and 28-29 October 2014. Surveyors at Cooper Ecological Monitoring, Inc. surveyed the entire site in the morning or afternoon of two consecutive or near-consecutive days to capture the variation due to tide and time of day. During site surveys, each bird species presence and quantity were recorded. Morning surveys began between 0615 and 0845, and afternoon surveys from 1445 and 1830, depending on the time of year and weather conditions. Each survey lasted between one and three hours, depending on the quantity of birds present.

Results

Bird community data were analyzed by categorizing species into ecological guilds based on foraging and habitat preference. Land bird species were grouped into three guilds including open country, scrub/woodland, and urban, while waterbird species were divided into six guilds which included freshwater marsh, marine/beach, shorebirds, waders, waterfowl, and fish-eaters. For the ecological guild analysis, only species that were recorded as more than one individual and aerial foragers were considered. Species that could not be reliably identified to species were omitted. Some species were classified into multiple guilds.

The presence of all landbird and waterbird guild species recorded on all pre- and post-restoration site-wide avifauna surveys are presented in Tables 13 and 14. Quantities and additional details for each identified species can be found in Appendix 3.

Table 14. Presence of landbird species recorded during all pre- and post-restoration surveys by guild.

		Pre-restoration	Post-restoration	
Guild	**Species**	**2005-06**	**2013 (Year 1)**	**2014 (Year 2)**
Open country	American Pipit	X	X	
	Cattle Egret	X		
	Killdeer	X	X	X
	Savannah Sparrow	X	X	X
	Say's Phoebe	X	X	X
	Western Kingbird	X		
	Western Meadowlark		X	X
Scrub/Woodland	Allen's Hummingbird	X	X	X
	American Robin		X	
	Anna's Hummingbird	X		X
	Bewick's Wren	X	X	X
	Bushtit	X	X	X
	California Towhee	X	X	X
	Cedar Waxwing	X		
	Hermit Thrush			X
	House Wren	X	X	X
	Lesser Goldfinch	X	X	X
	Lincoln's Sparrow	X		X
	Mourning Dove	X	X	X
	Orange-crowned Warbler	X		X
	Ruby-crowned Kinglet	X	X	X
	Song Sparrow	X	X	X
	Spotted Towhee	X		X
	Wilson's Warbler	X		
	Yellow Warbler	X		
Urban	American Crow	X	X	X
	Black Phoebe	X	X	X
	Brewer's Blackbird	X		
	Brown-headed Cowbird	X	X	X
	European Starling	X	X	X
	Hooded Oriole	X	X	
	House Finch	X	X	X
	Northern Mockingbird	X	X	X
	TOTAL	30	22	24

Table 15. Presence of waterbird species recorded during all pre- and post-construction surveys by guild.

Guild	Species	Pre-restoration 2005-06	Post-restoration 2013 (Year 1)	Post-restoration 2014 (Year 2)
Freshwater Marsh	Common Yellowthroat	X	X	X
	Great-tailed Grackle	X	X	X
	Marsh Wren	X		
	Red-winged Blackbird	X		
	Sora	X		
	Virginia Rail	X		
Marine/Beach	Black Oystercatcher	X	X	
	Bonaparte's Gull	X	X	X
	Brant	X	X	
	Brandt's Cormorant	X	X	
	Brown Pelican	X	X	X
	Caspian Tern	X	X	X
	Double-crested Cormorant	X	X	X
	Elegant Tern	X	X	X
	Forster's Tern	X	X	
	Glaucous-winged Gull	X	X	X
	Heermann's Gull	X	X	X
	Herring Gull	X	X	X
	Horned Grebe	X		
	Least Tern	X		
	Mew Gull	X		X
	Red-breasted Merganser	X	X	X
	Red-throated Loon		X	X
	Royal Tern		X	X
	Ruddy Turnstone	X	X	X
	Sanderling	X	X	X
	Snowy Plover	X	X	X
	Surfbird			X
	Western Grebe		X	X
	Western Gull	X	X	X
Shorebirds	American Avocet	X	X	
	Black-bellied Plover	X	X	X
	Dunlin	X	X	X
	Greater Yellowlegs	X	X	
	Least Sandpiper	X	X	X
	Long-billed Curlew	X		
	Long-billed Dowitcher	X		
	Marbled Godwit	X	X	X

		Pre-restoration	Post-restoration	
Guild	**Species**	**2005-06**	**2013 (Year 1)**	**2014 (Year 2)**
	Semipalmated Plover	X	X	X
	Spotted Sandpiper	X	X	X
	Western Sandpiper	X	X	X
	Whimbrel	X	X	X
	Willet	X	X	X
Waders	Black-crowned Night Heron	X	X	X
	Great Blue Heron	X	X	X
	Great Egret	X	X	X
	Green Heron	X		X
	Snowy Egret	X	X	X
Waterfowl	American Coot	X	X	X
	American Wigeon	X	X	X
	Blue-winged Teal	X		
	Bufflehead	X	X	X
	Cinnamon Teal	X		
	Eared Grebe	X	X	X
	Gadwall	X	X	X
	Green-winged Teal	X	X	X
	Lesser Scaup	X	X	X
	Mallard	X	X	X
	Northern Pintail	X		X
	Northern Shoveler	X	X	X
	Pied-billed Grebe	X	X	X
	Ruddy Duck	X	X	X
	Snow Goose	X		
Fish-eaters	Brandt's Cormorant	X	X	
	Caspian Tern	X	X	X
	Double-crested Cormorant	X	X	X
	Elegant Tern	X	X	X
	Forster's Tern	X	X	
	California Brown Pelican	X	X	X
	Horned Grebe	X		
	Least Tern	X		
	Red-breasted Merganser	X	X	X
	Red-throated Loon		X	X
	Royal Tern		X	X
	Western Grebe		X	X
	Black-crowned Night Heron	X	X	X
	Great Blue Heron	X	X	X

		Pre-restoration	Post-restoration	
Guild	Species	2005-06	2013 (Year 1)	2014 (Year 2)
	Great Egret	X	X	X
	Green Heron	X		X
	Snowy Egret	X	X	X
	Eared Grebe	X	X	X
	Pied-billed Grebe	X	X	X
	Ruddy Duck	X	X	X
	TOTAL	76	65	62

Landbird results

The total number of identified individuals and total observed species declined between pre- and post-restoration surveys for all landbird guilds. The largest decline was documented in the presence of urban guild species which displayed a reduction of up to 87% of recorded individuals between pre-restoration and post-restoration surveys. The smallest decline was demonstrated by the open country species whose total number of individuals recorded declined by 21% between the pre-restoration and post-restoration surveys. The total number of recorded species for the 2005-2006 (combined), 2013, and 2014 surveys were 30, 22, and 24 species, respectively.

Waterbird results

Changes between pre- and post-restoration bird communities are variable by guild but an overall decline in total observed species was documented. Post-restoration changes were most dramatic for species typical of freshwater marsh habitats and for shorebirds overall, which by late 2014 had declined by 91% and 69%, respectively, from pre-restoration survey counts. However, a 20% increase has been documented for fish-eating waterbirds. Marine/beach species, waders, and waterfowl all remained relatively constant across all survey periods. The total recorded species for the 2005-2006 (combined), 2013, and 2014 surveys were 75, 64, and 61 species, respectively.

Performance Evaluation

As no specific success criteria was identified for avifaunal community surveys and absolute quantities cannot be extracted due to the high mobility of bird species and the inherent limits of quarterly bird surveys, caution must be exercised regarding the interpretation of data. This assessment should be interpreted as an insight as to how the bird community may be changing with the modification, maturation, or removal of preferred habitat types, as well as variable survey conditions. Additionally, species richness is of limited value as each guild is highly variable, functionally, and total species richness is not indicative of project success.

Sharp declines in urban species were likely attributed to the permanent removal of most of the hardscape at the site, including bridges and permanent structures. Reductions in observed freshwater marsh species was likely due to a reduction of large areas of emergent freshwater-dominant vegetation (e.g. California Tule). Conditions preferable for shorebirds typically consist of mudflats and other tidally-wet areas and the visibility and accessibility of these habitats were limited during 2014 surveys due to inundation as a result of the extended closed lagoon conditions. Additionally, the continued maturation of vegetation assemblages may result in increased observations of individuals within several guilds (e.g. shorebirds, scrub/woodland). Lastly, increases in the quantity of individuals in the fish-eating guild may be a result of the construction of larger intertidal channel habitat areas and more available foraging area.

The avian community, including special status species like the California Brown Pelican (California Fully Protected) and Western Snowy Plover (Federally Threatened), continued to heavily use the site throughout the restoration process as well as post-restoration.

Vegetation – SAV/Algal Percent Cover Monitoring

Introduction

Algae and submerged aquatic vegetation (SAV) surveys provide important information about primary productivity within a system and trophic structure. Algae abundance and growth can also be useful indicators of eutrophication and tidal flushing (Zedler 2001). Since the Lagoon had significant issues with eutrophication and an excess of algal growth pre-restoration, they are important components to monitor post-restoration.

Methods

Post-restoration algae and submerged aquatic vegetation monitoring was conducted on 14 February 2013 and 23 December 2014. Floating, mat, and attached submerged aquatic vegetation and macroalgae were monitored at eight stations (Figure 12). Three, 50-meter transects were surveyed at each station using a line-intercept method. Transects were averaged by station using the length of each transect to determine total percent cover (± standard error).

Results

All stations had a total average algal cover of approximately 10% or less, and several stations had less than 1% average cover across multiple survey events (Stations 3, 6, 7) (Table 15). The category 'wrack' is an amalgamation of several types of unattached or floating kelp species, including those in the genera *Macrocystis, Phyllospadix, Dictyota, Egregia,* and *Eisenia.* The *Cladophora* cover is a small attached 'turf-like' green alga.

Table 16. Algae data as station average total cover ± standard error for the two post-restoration surveys.

	2/14/2013		12/23/2014	
	wrack % cover	*Cladophora* % cover	wrack % cover	*Cladophora* % cover
Station 1	2.93 ± 0.53	0.05 ± 0.05	9.86 ± 3.7	0.31 ± 0.21
Station 2	0.44 ± 0.28	0.01 ± 0.01	7.58 ± 2.12	0.1 ± 0.1
Station 3	0.2 ± 0.2	0.67 ± 0.67	0.95 ± 0.53	0 ± 0
Station 4	1.67 ± 0.33	0.43 ± 0.3	1.12 ± 0.29	0.17 ± 0.07
Station 5	0 ± 0	0 ± 0	3.84 ± 1.5	0 ± 0
Station 6	0 ± 0	0 ± 0	0.18 ± 0.05	0.05 ± 0.05
Station 7	0.36 ± 0.06	0.11 ± 0	0.29 ± 0.11	0 ± 0
Station 8	0.68 ± 0.52	4.4 ± 2.42	0.25 ± 0.11	0 ± 0

Performance Evaluation

There was significant and excessive algal growth in the Lagoon pre-restoration; algae cover was one of the key indicators of eutrophication to the system. The surveys and data were difficult to collect due to the massive amounts of organic matter and unconsolidated fine-grained sediments causing an inability to deploy transects. While no pre-restoration "baseline" was identified due to high variability in cover (2nd Nature 2010), the actual pre-restoration percent algal cover ranged from ~ 0 – 40% cover, which was dominated by floating algal mats, often becoming trapped in the back channels and decaying over time. The post-restoration cover data were dominated by 'wrack', or floating / detached marine kelp species, and after two years, still remained below a 10% total cover range and well within the success criteria recommendations. The highest cover was seen in the main Lagoon channel outside of the restoration area. Additionally, wind-driven circulation in the post-restoration channels tended to disperse the algal blooms, thereby reducing any potential impacts from the algae becoming trapped in one location.

Submerged aquatic vegetation (SAV) seagrasses are longer-living species such as *Phyllospadix* sp. These types of SAV uptake and fix nutrients, which reduces eutrophication indicators and mitigates for lower-oxygenated conditions. A small amount of live *Phyllospadix* cover was present on the most recent survey, 23 December 2014, and will continue to be assessed in all future surveys.

Lastly, eutrophication was evaluated based on an increase in number of days where the dissolved oxygen levels were above the recommended thresholds (i.e. 5, 3, and 1 mg/L). As discussed in the data sonde section of the water quality chapter, this criteria was successfully met.

Vegetation – Plant Cover Transect Monitoring

Introduction

Long-term monitoring of vegetation cover is one of the most common methods of evaluating the health and functioning of a wetland system (Zedler 2001); changes in the relative presences of native and non-native plant species may affect the distributions of associated wildlife species. Additionally, increases in vegetation cover and complexity following restoration events are one of the most common indicators of the return many wetland habitat functions.

Methods

Data for absolute percent cover of native/nonnative vegetation species were collected along three, 50-meter transects (Figure 29) using the line-intercept method on 7 May 2014 and 18 December 2014. These data were combined with the first post-restoration survey on 15 March 2013 to provide a comprehensive set of post-restoration vegetation surveys to track cover over time.

Each transect location was recorded with a submeter global positioning system (GPS) unit and photographed at each end. Absolute cover data were calculated based on the total distance for each species within each transect. Species data were collected to an accuracy of 0.01 m along each 50-meter transect. Species were categorized into native or non-native and added together. Cover data were relative, as non-vegetated mudflat and channel habitats were removed from the total transect length. Data were displayed as a bar graph for each transect.

Figure 29. Map of vegetation transect locations and start/end points.

Results

After two years, absolute cover for native vegetation species was the highest on Transect 1, at 84.3% and lowest on Transect 3 at 25.3% (Figure 30). All transects showed an increase in native vegetation cover over time and a decrease in bare ground. A maximum of 41 native species were identified within 10 meters of Transect 2; Transect 3 had the lowest species richness at 13 native species.

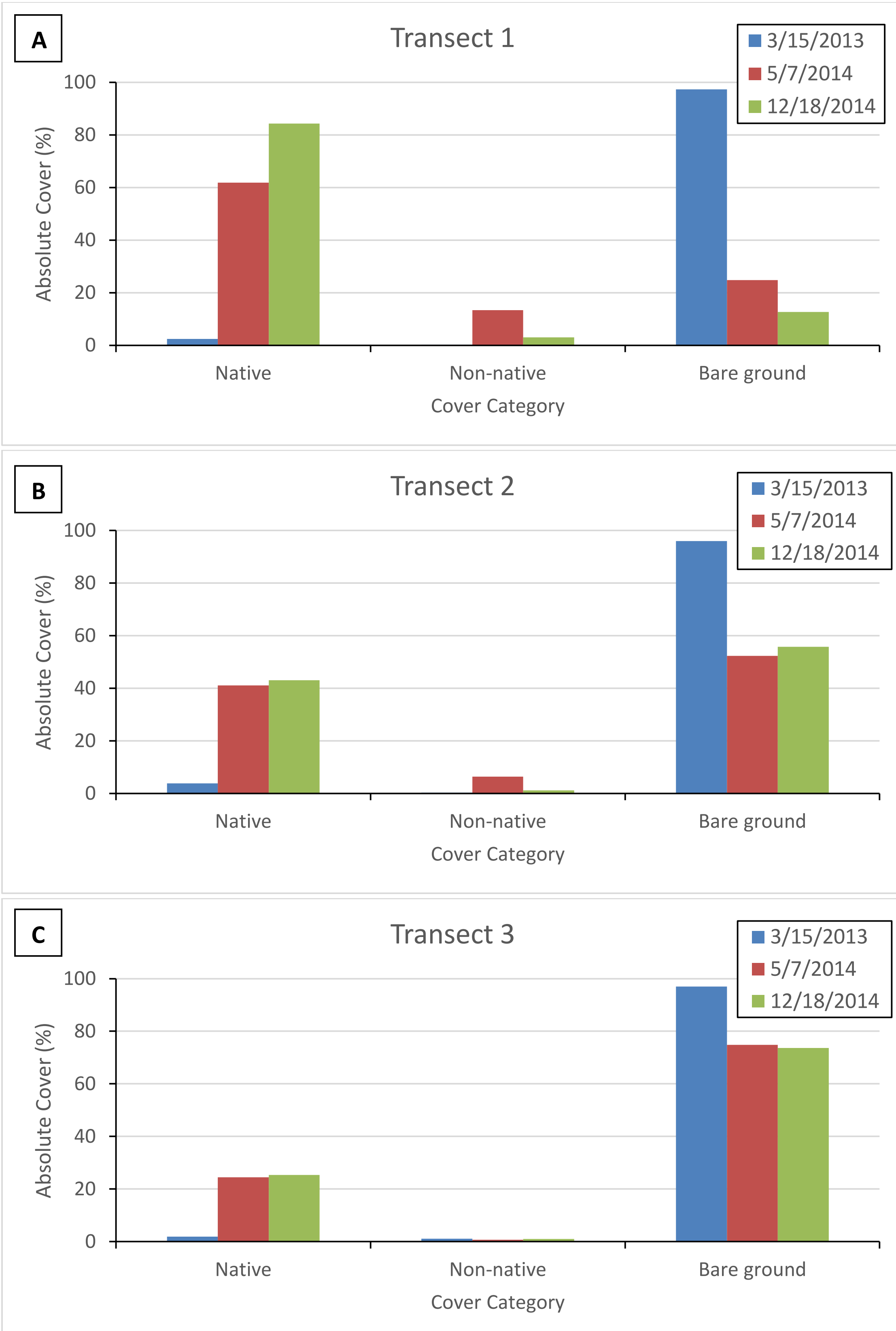


Figure 30. Graph displaying absolute cover of vegetation across each Transect: (A) 1, (B) 2, and (C) 3.

Performance Evaluation

The vegetation cover as assessed by these three transects has shown a consistent increase over time, with a large increase after the initial post-restoration baseline survey. Transect 2 and 3 are establishing at slower rates, but consistently over time. Additional evaluation years will discuss how the vegetation cover data relate to restoration success criteria. Non-native species on each transect continue to represent 3% or less absolute cover in the most recent sampling period. Reductions or variability in non-native cover may be the result of extensive weeding and non-native species removal efforts.

Vegetation cover is predicted to continue to develop and become more complex over time as mature plants have a chance to grow (similarly to the biotic CRAM metric). The number and species richness of vegetation planted throughout the Lagoon is variable based on habitat, but has over 67,000 individual plants of over 70 species in total throughout the site, in addition to the areas that received hydroseeding treatments. Thirteen to 41 native plant species were identified immediately adjacent to the transects, compared to an average of six dominant species pre-restoration.

Vegetation – Photo-Point Monitoring

Introduction

The primary purpose of this sampling method is to qualitatively capture broad changes in the landscape and vegetation communities over seasons or years. This method collects georeferenced photos for use in site management (e.g. invasive species tracking) and long-term data collection.

Methods

Three permanent, photo-monitoring locations (Table 16 and Figure 31) were established to visually document the establishment of vegetation and large-scale landscape changes following restoration. Stations were located using GPS and baseline photographs. The baseline photo-point survey was conducted immediately post-restoration on 15 March 2013 during a low tide; post-restoration surveys were conducted again on 7 May 2014 and 18 December 2014 (Table 16). Approximate bearing is relative to the center of the photograph; detailed bearing ranges are included on the datasheets.

Table 17. GPS coordinates, bearings, and time of photo-point surveys.

Date	Station	Approximate Bearing	Time	Number of Photos
March 15, 2013	Photo Point 1	155º	8:15 AM	1
	Photo Point 2	300º, 75º	8:30 AM	2
	Photo Point 3	220º, 100º	8:46 AM	2
May 7, 2014	Photo Point 1	155º	11:22 AM	1
	Photo Point 2	300º, 75º	11:13 AM	2
	Photo Point 3	220º, 100º	11:08 AM	2
December 18, 2014	Photo Point 1	155º	12:47 PM	1
	Photo Point 2	300º, 75º	12:41 PM	2
	Photo Point 3	220º, 100º	12:37 PM	2

Figure 31. Map of photo-point locations and bearings.

Results

A total of five photos were taken at three locations to assess a range of habitat types across the restoration area. Figures 32 - 36 (A - C) display the photos from the five locations post-restoration on the three survey dates, respectively.

Figure 32. Photograph of Photo Point 1, bearing 155° on (A) 15 March 2013; (B) 7 May 2014; (C) 18 December 2014.

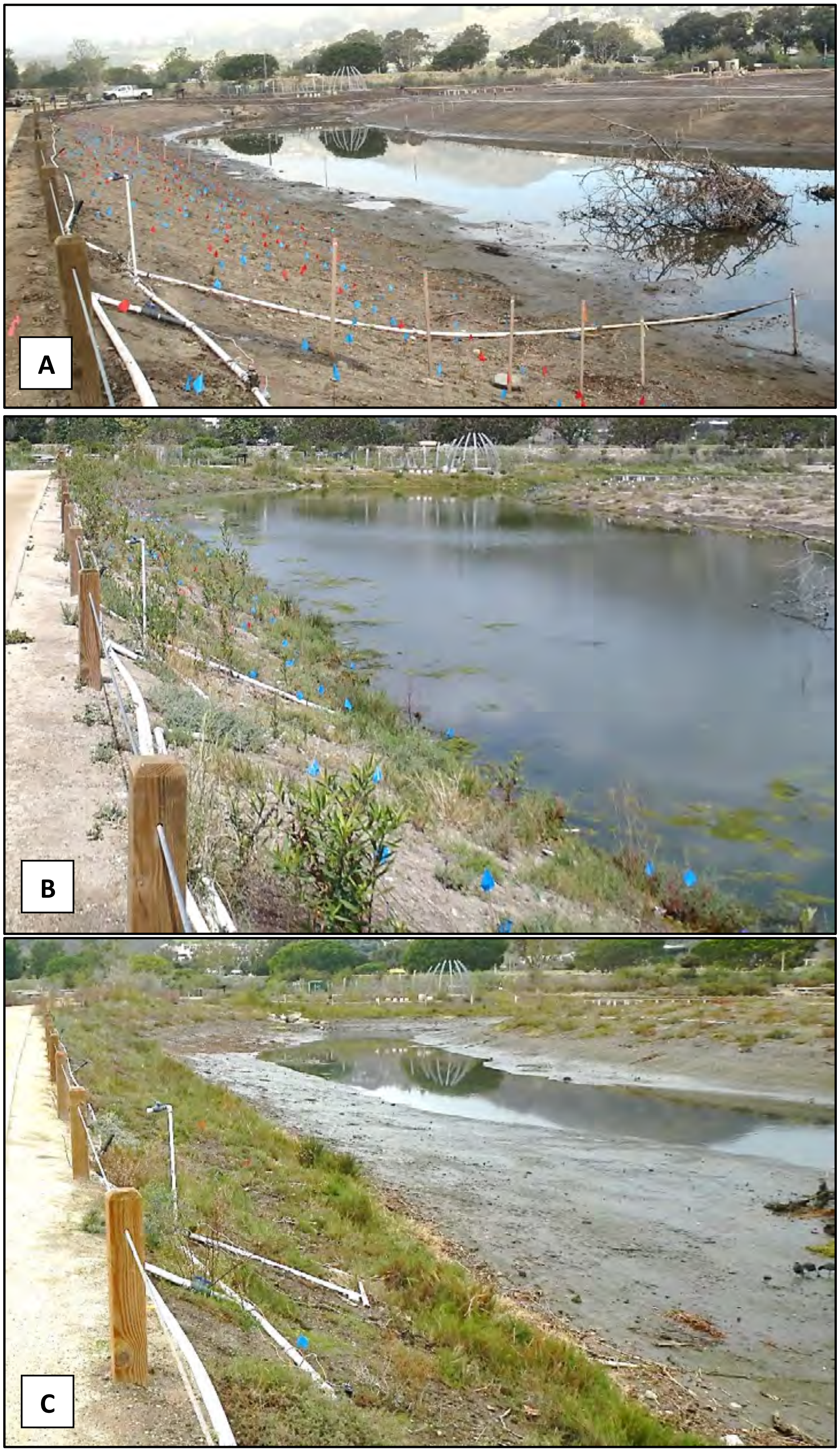


Figure 33. Photograph of Photo Point 2, bearing 300° on (A) 15 March 2013; (B) 7 May 2014; (C) 18 December 2014.

Figure 34. Photograph of Photo Point 2, bearing 75° on (A) 15 March 2013; (B) 7 May 2014; (C) 18 December 2014.

Figure 35. Photograph of Photo Point 3, bearing 220° on (A) 15 March 2013; (B) 7 May 2014; (C) 18 December 2014.

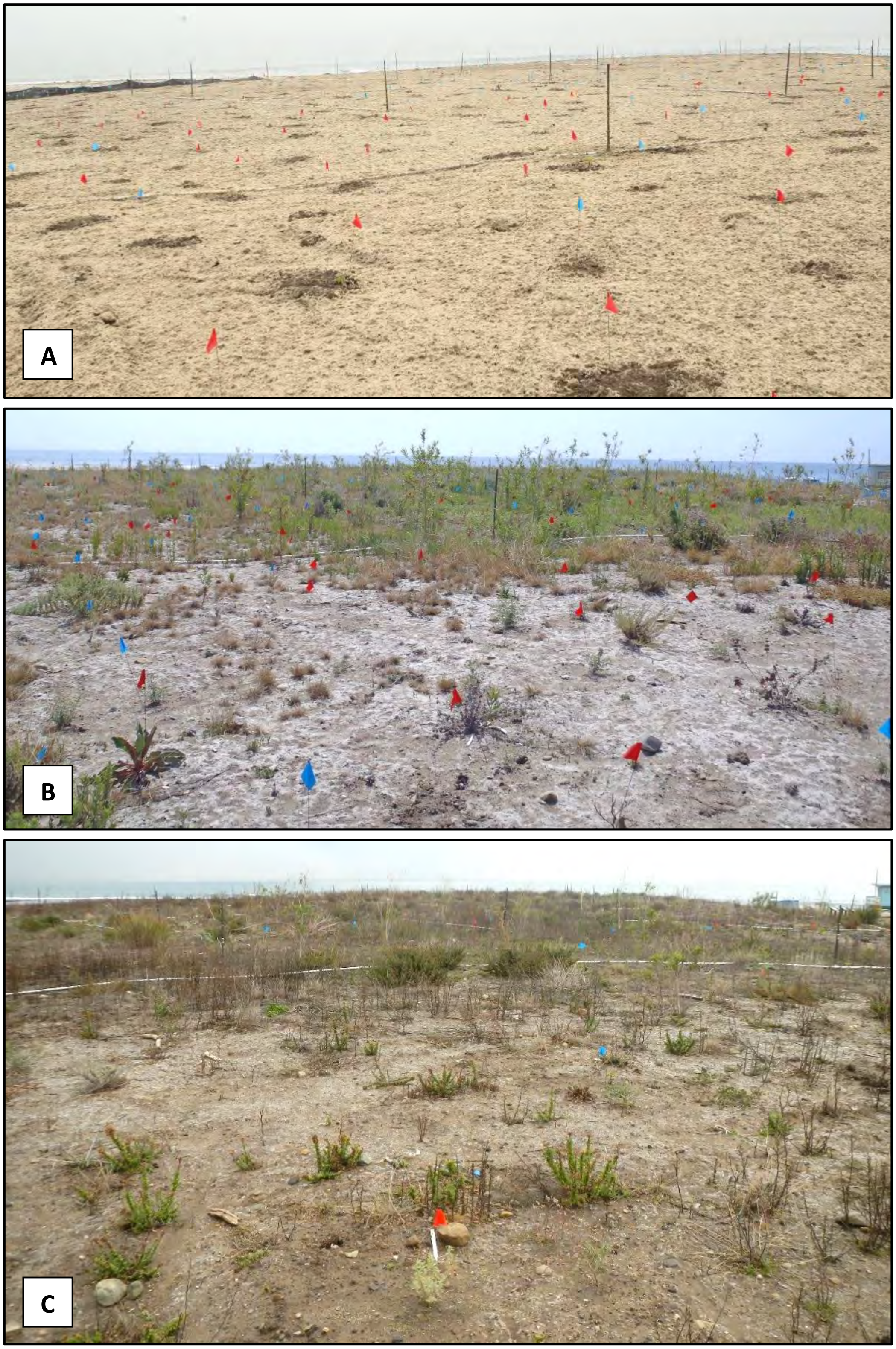


Figure 36. Photograph of Photo Point 3, bearing 100° on (A) 15 March 2013; (B) 7 May 2014; (C) 18 December 2014.

Performance Evaluation

Consistent with the evaluation for plant cover transect monitoring, the post-restoration georeferenced photos show a consistent increase in vegetation over time, with a large increase after the initial post-restoration Photo Point survey.

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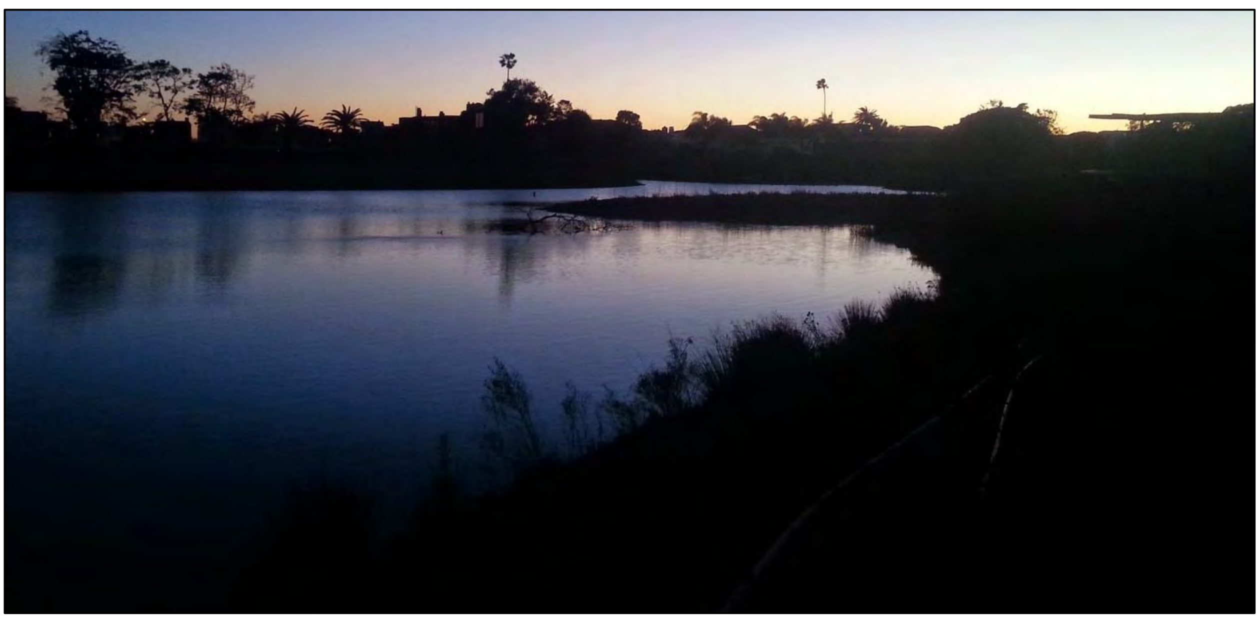


Photo: Malibu Lagoon Restoration at sunset (I. Medel, 24 November 2014).

Appendix 1. Malibu Lagoon Post-construction Fish Survey Results: May 2014 (Prepared by R. Dagit)

Malibu Lagoon
Post Construction Fish Survey May 2014

Prepared for:
Angeles District
California Department of Parks and Recreation

Prepared by:
Rosi Dagit
RCD of the Santa Monica Mountains
PO Box 638, Agoura Hills, CA 91376

12 June 2014

Table of Contents

EXECUTIVE SUMMARY

A post construction fish survey of Malibu Lagoon was conducted on Thursday, 15 May 2014 by a team from the RCD of the Santa Monica Mountains with assistance from Jamie King, CDPR.

A total of six permanent sites were seined to depletion, with additional spot seines conducted along the beach side of the lagoon. One site established for monitoring in 2013 was inaccessible due to depth resulting from the closed condition of the lagoon. We therefore added a site (2a) to comply with the monitoring plan requirements.

A single, adult steelhead trout (*Onchorhynchus mykiss*) was observed swimming near site 3. It was estimated to be approximately 20 inches long. On

Tidewater and arrow gobies were observed and released unharmed. A new goby, possibly a Bay goby (*Lepidogobius lepidus*) was also observed and identified by photo by Dr. Camm Swift, but no voucher taken.

Striped mullet and carp were observed jumping throughout the lagoon, but none were captured in the nets. Most importantly, only a single mosquitofish was captured, compared to thousands of native fish larva, with topsmelt and gobies dominant in number.

Species captured during the May survey include:

Unidentified goby larva (<5 cm)	
Tidewater goby adult (6-8 cm)	*Eucyclogobius newberryi*
Arrow goby (<5 cm)	*Cleavlandia ios*
Bay goby (<5cm)	*Lepidogobius lepidus*
CA killifish juveniles (<5cm)	*Fundulus parvipinnis*
Long-jawed mudsucker (<5 cm)	*Gillichthys mirabilis*
Topsmelt larva (<5 cm)	*Atherinops sp*
Topsmelt juvenile (6 cm)	*Atherinops sp*
Unidentified smelt larva (<5 cm)	*Atherinops sp*
Staghorn sculpin (<5 cm)	*Leptocottus armatus*
Diamond turbot	*Hypsopsetta guttulata*
striped mullet	*Mugil cephalus*
Non-Native Fish Species	
Mississippi silversides (5-10 cm)	*Menidia berylina*
Mosquitofish juveniles (<5cm)	*Gambusia affinis*
Carp	*Cyprinus carpio*
Invertebrates	
Oriental shrimp	*Shrimp sp.*
Hemigraspus crabs	
Water boatman juveniles	
Amphipods	

ACKNOWLEDGEMENTS

We wish to thank Suzanne Goode and Jamie King, CDPR for their assistance. The contract for this work was provided by CDPR.

Dr. Camm Swift kindly reviewed photographs to confirm identification of species.

Field Assistants from the RCDSMM and the Topanga Creek Stream Team are the unsung heroes of fish seining surveys. Those who hauled nets, buckets, water quality equipment and other gear, all with good cheer and great enthusiasm include:

Jenna Krug, Conservation Biologist
Steve Williams, Conservation Biologist
Sandra Albers, Conservation Biologist
Krista Adamek, Biologist
Crystal Garcia, Watershed Steward
Delmar Lathers, Stream Team
Elizabeth Montgomery, Watershed Steward
Jayni Shuman, Stream Team
Ken Wheeland, Stream Team
Megan Williams, Stream Team

The CDFW DIDSON team from Santa Barbara office kindly provided their skill and expertise in deploying the DIDSON camera at Malibu Lagoon on 5 June 2014. Thanks to Chris Lima, Sam Bankstone, Patrick Riparreti and Ben Lakish.

PURPOSE OF SURVEY

The Malibu Lagoon restoration was completed in Fall 2012. A total of six locations were identified by the Malibu Lagoon Restoration and Enhancement Hydrologic and Biological Project Monitoring Plan (Ambramson 2012) and accepted by various permitting agencies. Sites were distributed throughout the restoration area to provide documentation of fish diversity, abundance, distribution, and to replicate as closely as possible the stations used previously in the 2005 pre-construction survey. Surveys are to be conducted in spring and fall annually until 2019.

The first post-construction sampling was conducted on 8 January 2013 during a low tide when the lagoon was connected to the ocean. Tide was high at 0546 (6.3') and low at 1305 (-0.8'). This permitted surveying as the tide receded during the day. Water quality variables were measured only at the permanent sites.

The second post-construction survey took place on 15 May 2014. The lagoon berm closed to the ocean on 12 April 2014, so water levels within the lagoon were up to 7.4 feet above mean high water. The full moon on 14 May generated high tides (6.2' at 2133) that overwashed into the lagoon at both the east and west ends.

METHODS

A. Blocking Net Sampling Method for Permanent Stations

A meter tape was played out along the shoreline at the waters edge extending 10 meters. Two 10m x 2m blocking nets were pulled out perpendicular from the shore. Then the two nets were pulled together to form a triangle, trapping any fish inside. Two teams with 3m x 1m seines walked carefully to the apex of the triangle and pulled from the apex towards the shore. Seines were beached at the waters edge and all contents examined. All fish were moved into buckets of clean, cold water standing by each net. Types of algae were noted. Fish were identified and Fork Length measured, then they were released outside of the blocked area. Seining pulls continued until three consecutive pulls were empty.

Note: If we got a single oriental shrimp, water boatman or other invertebrates in the pull, with no fish either before or after, it was considered empty.

Each blocking net was then seined to shore and was checked for any contents.

B. Spot Survey Sampling Methods for the Main Lagoon

- Using 2m x 1 m seines, 3 teams pulled parallel to shoreline in Spot 1-3 along beach bank, from west to east

Equipment needed:

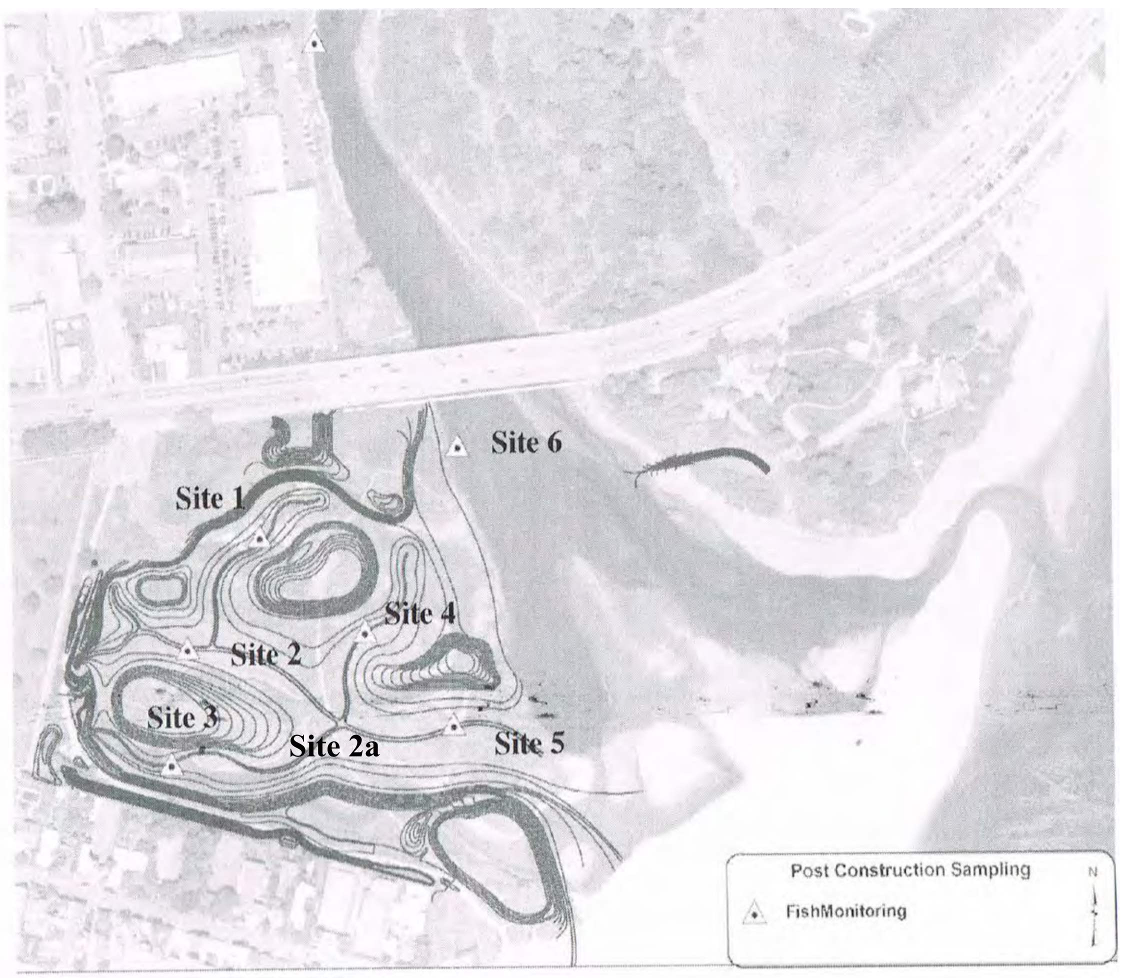
WQ testing Kit (calibrated)
- 2 10m x 2m blocking nets
- 2m x 1 m seines (2)
- 3m x 1 m seines (2)
- buckets (8)
- fish measuring boards (2)
- ziplock baggies
- fish id books
- camera

- 30 m tape
- data sheets
- ice chest for voucher specimens
- GPS
- meter sticks for depth
- sharpies, pencils

Table 1. GPS Coordinates for permanent monitoring sites Malibu Lagoon Restoration (Decimal degrees)

Site	Latitude	Longitude
1	34.02.032	-118.41.054
2	34.01.983	-118.41.084
2a	34.01.970	-118.41.058
3	34.01.958	-118.41.086
4	34.01.947	-118.40.963
5	34.02.000	-118.41.006
6	34.02.049	-118.40.974

Figure 1. Map of the Permanent Monitoring Sites, Malibu Lagoon Restoration (Established in January 2013 and revised in May 2014)



RESULTS

Table 2. Water Quality and site conditions at the permanent monitoring sites 15 May 2014

Variable	Site 1	Site 2	Site 2a	Site 3	Site 5	Site 6
Max depth (cm)	60	90	40	120	65	65
Avg depth (cm)	50	75	25	75	50	45
Water T°C	23	22.2	22.5	23.2	22	21
Air T°C	33	35	30.5	35	29	30
Salinity ppt	9	11	11	11	11	10
DO mg/l	12.6	12.17	12.27	13.68	14.65	9.58
pH	9.05	8.95	8.93	8.98	9.03	8.80
Conductivity	19.20	19.90	19.70	19.50	19.90	19.70
% Floating Algae cover	10	50	0	50	20	50
% Submerged/ Attached Algae cover	40	50	0	50	50	30
% emergent vegetation bank cover	100	20	0	60	60	20
Time start	1135	1420	1450	1340	1255	1010

NOTE: Site 4 too deep to seine with lagoon closed

A total of ten native fish species and one non-native species were observed/captured in the May 2014 survey.

A single, adult steelhead trout (*Onchorhynchus mykiss*) was observed swimming near site 3. It was estimated to be approximately 20 inches long.

Tidewater and arrow gobies were observed and released unharmed. A single tidewater goby was killed inadvertently while being moved into the holding bucket. A new goby, possibly a Bay goby (*Lepidogobius lepidus*) was also observed and identified by photo by Dr. Camm Swift, but no voucher taken.

Striped mullet and carp were observed jumping throughout the lagoon, but none were captured in the nets. Most importantly, only a single mosquitofish was captured, compared to thousands of native fish larva, with topsmelt and gobies dominant in number.

Table 3. Summary of Fish captured/observed 15 May 2014

Lagoon-ocean connection conditions	**Closed**	**Site 1**	**Site 2**	**Site 2a**	**Site 3**	**Site 5**	**Site 6**	**Beach Spot 1**	**Beach Spot 2**	**Beach Spot 3**	**TOTALS**
Seine pull total to depletions		11	7	5	10	6	20	1	2	3	
Native Fish Species											
Steelhead trout	*Onchorhynchus mykiss*				1						1
Unidentified goby larva (<5 cm)		500									500
Tidewater goby adult (<5 cm)	*Eucyclogobius newberryi*		1	2	3		4		1	2	**13**
Tidewater goby adult (6-8 cm)	*Eucyclogobius newberryi*										**0**
Arrow goby (<5 cm)	*Cleavlandia ios*	1				1	1		1	1	**5**
Bay goby?	*Lepidogobius lepidus*						2				**2**
CA killifish juveniles (<5cm)	*Fundulus parvipinnis*										0
CA killifish juveniles (5-10 cm)	*Fundulus parvipinnis*									5	5
Long-jawed mudsucker (<5 cm)	*Gillichthys mirabilis*				1		2			2	5
Long-jawed mudsucker (5-10 cm)	*Gillichthys mirabilis*										0
Topsmelt larva (<5 cm)	*Atherinops sp*										0
Topsmelt juvenile (6 cm)	*Atherinops sp*	4							3	15	24
Topsmelt adult (16 cm)	*Atherinops sp*										0
Unidentified smelt larva (<5 cm)	*Atherinops sp*	500	47	5700		176	7865	1000		5	15293
Staghorn sculpin (<5 cm)	*Leptocottus armatus*	1			1		6		3		11
Staghorn sculpin (5-10 cm)	*Leptocottus armatus*										0
Opaleye	*Girella nigricans*										0
Diamond turbot	*Hypsopsetta guttulata*								1		1

Lagoon-ocean connection conditions	Closed	Site 1	Site 2	Site 2a	Site 3	Site 5	Site 6	Beach Spot 1	Beach Spot 2	Beach Spot 3	TOTALS
Seine pull total to depletions		11	7	5	10	6	20	1	2	3	
Native Fish Species											
Garabaldi (28 cm FL) dead dropped by birds	*Hypsypops rubicundus*										0
Northern anchovy <5 cm	*Engraulis mordax*										0
striped mullet	*Mugil cephalus*										0
Non-Native Fish Species											
Mississippi silversides (5-10 cm)	*Menidia berylina*	2									
Mosquitofish juveniles (<5cm)	*Gambusia affinis*										0
Mosquitofish gravid females (5-10 cm)	*Gambusia affinis*										0
Carp	*Cyprinus carpio*										0
Mississippi silversides	*Menida audens*										0
Invertebrates											
Oriental shrimp	*Shrimp sp.*	25	104	1	35	20	22	2			209
Hemigraspus crabs			1		2	1		2	2		8
Water boatman juveniles		430	360	20		200	1464	30			2504
Amphipods											0
Isopods											0
Ctenophore sp (<2 cm)											0
Salp sp (<2 cm)											0
Sea hare (5-10 cm)	*Aplysia californica*										0

Lagoon-ocean connection conditions	Closed	Site 1	Site 2	Site 2a	Site 3	Site 5	Site 6	Beach Spot 1	Beach Spot 2	Beach Spot 3	TOTALS
Seine pull total to depletions		11	7	5	10	6	20	1	2	3	
Native Fish Species											
Segmented worm <2 cm)											0

DIDSON CAMERA DEPLOYMENT

On Thursday, 5 June 2014, a team from the Santa Barbara office of CDFW brought a DIDSON camera to deploy in Malibu lagoon in hopes of capturing the O. mykiss in action. Using a generator carried to the watershed overlook near Site 6 for power, we deployed the camera at Site 4, outside the clumps of algae . The camera was deployed for 45 minutes at Site 4, 45 minutes at Site 1, 20 minutes at Site 3 (visibility was really poor), and 30 minutes near the bird blind in the far west channel. A GoPro camera was attached to the DIDSON camera frame to capture video images to compare to the ultra-sound images allowing more direct comparison and fish identification. Processing the images and correlating them is in progress.

Figure 2. DIDSON camera at Site 4. Camera between the 2 men.

Figure 3. DIDSON camera at Site 1. Kayak used to herd fish towards the camera.

Figure 4. DIDSON camera at Site 3.

SUMMARY

The Spring 2014 construction Survey covering both the permanent stations and the perimeter of the main lagoon was completed in one day with a team of 12 people.

The five native fish species documented in the January 2013 post construction survey (diamond turbot, northern anchovy, staghorn sculpin, tidewater goby, and topsmelt) reflect the winter, marine influenced conditions, as compared to the 10 native fish species observed in May 2014 (steelhead trout, diamond turbot, CA killifish, long-jawed mudsucker, staghorn sculpin, tidewater goby, arrow goby, possible bay goby, topsmelt and striped mullet). This is compared to the five native species (CA killifish, long-jawed mudsucker, opaleye, tidewater goby and topsmelt) observed in the June pre-construction survey of 2005. **Tidewater gobies were observed in both the pre- and post construction surveys.**

Oriental shrimp were observed in both the pre and post-construction surveys. Only a single mosquitofish (*Gambusia affinis*) was captured in May 2014, which represents a major shift from non-native fish dominance prior to restoration. Mississippi silversides were also observed.

Surveys in the restoration area were encouraging. The presence of staghorn sculpin, goby and topsmelt juveniles indicated recent spawning and sufficient conditions to support rearing, despite the fact that vegetation is not yet fully re-established.

Seining in the main body of the lagoon also documented juvenile staghorn sculpin and topsmelt, but additionally supported very small diamond turbot, CA killifish, long-jawed mudsucker, and tidewater goby. Presence of these juveniles indicates recent spawning and the potential for recruitment.

The DIDSON camera deployment conducted on 5 June 2014 captured images of the topsmelt and stripped mullet, but unfortunately no *O. mykiss* were observed.

Appendix A. Photographs of fish species

Steelhead trout ~ 20 inches swimming at west end of restoration area
Photo by Jayni Shuman, RCDSMM Stream Team

Tidewater goby

Arrow goby

Bay goby (id not confirmed as voucher not kept)


Staghorn sculpin


Topsmelt


topsmelt and goby larva


thousands of larval topsmelt

Diamond turbot and tidewater goby

CA Kilifish

Appendix B. Site Photos

Site 1

Site 2

Site 2a

Site 3

Site 5

Site 6

Appendix 2. Malibu Lagoon Post-construction Fish Survey Results: December 2014 (Prepared by R. Dagit)

Malibu Lagoon
Post Construction Fish Survey December 2014

Prepared for:
Angeles District
California Department of Parks and Recreation

Prepared by:
Rosi Dagit
RCD of the Santa Monica Mountains
PO Box 638, Agoura Hills, CA 91376

December 2014
Updated with final fish identification 3 March 2015

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EXECUTIVE SUMMARY

A post construction fish survey of Malibu Lagoon was conducted on Thursday, 11 December 2014 by a team from the RCD of the Santa Monica Mountains with assistance from CDPR.

The lagoon breached on 2 December 2014 at the west end near first point, then breached again in the mid-section a few days later. The initial breach closed and the mid-section breach remains open and passable. We also observed LA County Department of Beaches and Harbors installing a sand berm to protect the Adamson House area.

A total of six permanent sites were seined to depletion, with additional spot seines conducted along the beach side of the lagoon. One site established for monitoring in 2013 (Site 4) continued to be inaccessible. We therefore continued to use site (2a) to comply with the monitoring plan requirements.

No tidewater gobies or steelhead trout were observed.

Striped mullet were observed jumping throughout the lagoon, but only small juveniles (<5 cm) were captured in the nets. The dominant species found throughout the lagoon are topsmelt and Mississippi silversides, with a few northern anchovy in the mix. These identifications are based on review of voucher specimens by Dr. Rick Freeney at the Natural History Museum in February 2015.

Species captured during the December survey include:

Topsmelt	*Atherinops sp*
Northern anchovy	*Engraulis mordax*
striped mullet larva (<5 cm)	*Mugil cephalus*
Non-Native Fish Species	
Mississippi silversides (5-10 cm)	*Menidia berylina*
Mosquitofish	*Gambusia affinis*
Invertebrates	
Oriental shrimp	*Shrimp sp.*
Hemigraspus crabs	

ACKNOWLEDGEMENTS

We wish to thank Suzanne Goode and Jamie King, CDPR for their assistance. The contract for this work was provided by CDPR. State Park also provided Lauren Zamieto and Evelyn Aguilar to help with the seining.

Dr. Camm Swift kindly reviewed photographs to confirm identification of species. We have scheduled an appointment with Dr. Rick Feeney, curator of fishes at the Natural History Museum for February to key out the unidentified fishes.

Field Assistants from the RCDSMM and the Topanga Creek Stream Team are the unsung heroes of fish seining surveys. Those who hauled nets, buckets, water quality equipment and other gear, all with good cheer and great enthusiasm include:

Steve Williams, Conservation Biologist
Sandra Albers, Conservation Biologist
Krista Adamek, Biologist
Elizabeth Montgomery, Biologist
Jayni Shuman, Stream Team
Ken Wheeland, Stream Team
Andre Sanchez, Watershed Steward

PURPOSE OF SURVEY

The Malibu Lagoon restoration was completed in Fall 2012. A total of six locations were identified by the Malibu Lagoon Restoration and Enhancement Hydrologic and Biological Project Monitoring Plan (Ambramson 2012) and accepted by various permitting agencies. Sites were distributed throughout the restoration area to provide documentation of fish diversity, abundance, distribution, and to replicate as closely as possible the stations used previously in the 2005 pre-construction survey. Surveys are to be conducted in spring and fall annually until 2019.

The first post-construction sampling was conducted on 8 January 2013 during a low tide when the lagoon was connected to the ocean. Tide was high at 0546 (6.3') and low at 1305 (-0.8'). This permitted surveying as the tide receded during the day. Water quality variables were measured only at the permanent sites.

The second post-construction survey took place on 15 May 2014. The lagoon berm closed to the ocean on 12 April 2014, so water levels within the lagoon were up to 7.4 feet above mean high water. The full moon on 14 May generated high tides (6.2' at 2133) that overwashed into the lagoon at both the east and west ends.

This third survey took place on 11 December 2014, approximately 10 days following the breaching of the lagoon and reconnection to the ocean. The all day survey started with low tide conditions (0536, 2.8') exposing large areas of the mudflats that gradually were covered as the tide rose (high tide 1258, 3.9'). Weather was overcast and windy with a storm arriving in the late afternoon. The lagoon initially breached to the west near First Point, then breached again at the mid-section. During the survey, the mid-lagoon breach was the only one remaining connected.

METHODS

A. Blocking Net Sampling Method for Permanent Stations

A meter tape was played out along the shoreline at the waters edge extending 10 meters. Two 10m x 2m blocking nets were pulled out perpendicular from the shore. Then the two nets were pulled together to form a triangle, trapping any fish inside. Two teams with 3m x 1m seines walked carefully to the apex of the triangle and pulled from the apex towards the shore. Seines were beached at the waters edge and all contents examined. All fish were moved into buckets of clean, cold water standing by each net. Types of algae were noted. Fish were identified and Fork Length measured, then they were released outside of the blocked area. Seining pulls continued until three consecutive pulls were empty.

Note: If we got a single oriental shrimp, water boatman or other invertebrates in the pull, with no fish either before or after, it was considered empty.

Each blocking net was then seined to shore and was checked for any contents.

B. Spot Survey Sampling Methods for the Main Lagoon

- Using 2m x 1 m seines, 3 teams pulled parallel to shoreline in Spot 1-3 along beach bank, from west to east

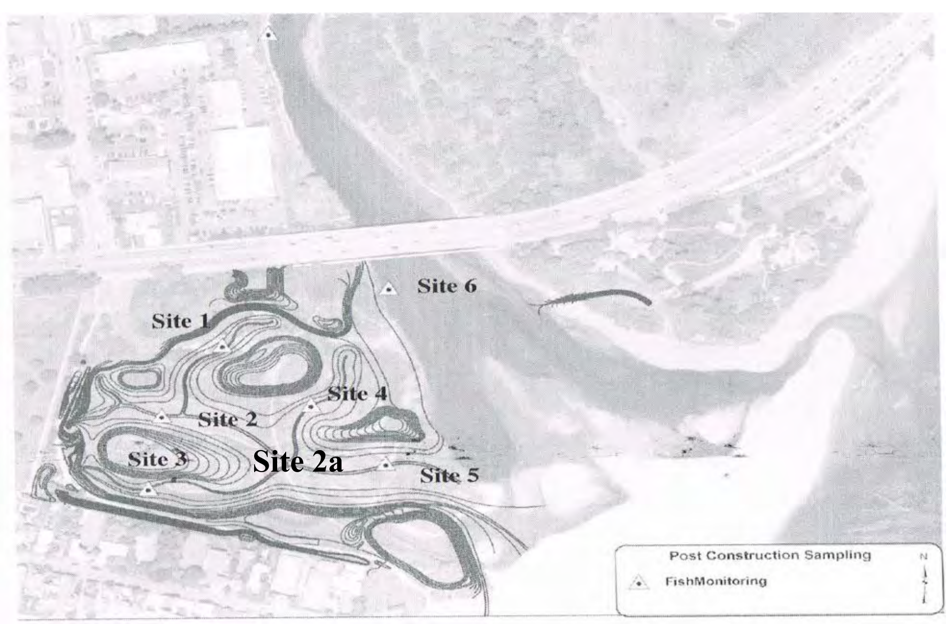
Equipment needed:

WQ testing Kit (calibrated)
- 2 10m x 2m blocking nets
- 2m x 1 m seines (2)
- 3m x 1 m seines (2)
- buckets (8)
- 30 m tape
- data sheets
- ice chest for voucher specimens
- fish measuring boards (2)
- ziplock baggies
- fish id books
- camera
- GPS
- meter sticks for depth
- sharpies, pencils

Table 1. GPS Coordinates for permanent monitoring sites Malibu Lagoon Restoration (Decimal degrees)

Site	Latitude	Longitude
1	34.02.032	-118.41.054
2	34.01.983	-118.41.084
2a	34.01.970	-118.41.058
3	34.01.958	-118.41.086
4 (not sampled)	34.01.947	-118.40.963
5	34.02.000	-118.41.006
6	34.02.049	-118.40.974

Figure 1. Map of the Permanent Monitoring Sites, Malibu Lagoon Restoration (Established in January 2013 and revised in May 2014)



RESULTS

Table 2. Water Quality and site conditions at the permanent monitoring sites 11 Dec 2014

Variable	Site 1	Site 2	Site 2a	Site 3	Site 5	Site 6
Max depth (cm)	30	75	30	80	50	20
Avg depth (cm)	25	50	25	60	30	20
Water T°C	17.4	16.8	17	15.8	16.6	17.6
Air T°C	17.1	19	19	17	17.5	18
Salinity ppt	17	18	20	15	24	16
DO mg/l	8.68	12.69	9.23	5.21	7.66	9.1
pH	8.92	8.67	8.42	8.43	8.39	8.4
Conductivity	Above range					
% Floating Algae cover	0	0	0	0	0	0
% Submerged/ Attached Algae cover	0	0	0	0	20	0
% emergent vegetation bank cover	0	0	0	0	0	0
Time start	1430	1315	1450	1015	0930	1355

NOTE: Site 4 dry

The dominant fish species were an as yet identified anchovy (*Anchoa sp.*), mixed with what may be some topsmelt, Mississippi silversides and northern anchovy. Until their identification is confirmed, we have left those species on the list as question marks. Juvenile mullet were also collected, and although listed here as striped mullet, identification of all these will be confirmed from voucher specimens by the Natural History Museum in 2015.

Table 3. Summary of Fish captured/observed 11 December 2014

Lagoon-ocean connection conditions	**open**	**Site 1**	**Site 2**	**Site 2a**	**Site 3**	**Site 5**	**Site 6**	**Beach Spot 1**	**Beach Spot 2**	**Beach Spot 3**	**TOTALS**
Seine pull total to depletions		20	16	11	38	10	10	3	3	2	
Native Fish Species											
Topsmelt juvenile (6 cm)	*Atherinops sp*					1	1				2
Northern anchovy <5 cm	*Engraulis mordax*										0
striped mullet (<5 cm)	*Mugil cephalus*		2		1	2	1	1			7
Non-Native Fish Species											0
Mississippi silversides	*Menida audens*	303	64	35	309	11	79	8	66	95	970
Mosquitofish	*Gambusia affinis*					1	1				2
Invertebrates											0
Oriental shrimp	*Shrimp sp.*	10	0	0	26	4	1		2		43
Hemigraspus crabs					1						1

SUMMARY
The Fall/Winter 2014 construction survey covering both the permanent stations and the perimeter of the main lagoon was completed in one day with a team of 10 people.

Overall fish diversity was quite low in this survey, possibly due to the recent breach of the sand berm as well as the low tide conditions during the start of the survey. Much of the lagoon habitat was exposed mudflats, and water levels in the sample locations lower than for previous surveys.

It is interesting that the most dominant species observed are Mississippi silversides, with a few topsmelt, stripped mullet, and northern anchovies. Oriental shrimp remain another frequently captured species. The low numbers of mosquitofish (*Gambusia affinis*) continues, reflecting the major shift from non-native fish dominance prior to restoration.

Appendix A. Photographs of fish species

Mississippi Silverside

Topsmelt and Mississippi Silversides

Striped mullet larva

Appendix B. Site Photos

Site 1

Site 2

Site 2a

Site 3

Site 5

Site 6

Appendix 3. Avian Usage of Post-restoration Malibu Lagoon: Year 2 (2014) (Prepared by D. Cooper)

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Avian Usage of Post-restoration Malibu Lagoon Year 2 (2014)

Malibu Lagoon State Beach

Malibu, California

Prepared for:
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Prepared by:
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Cooper Ecological Monitoring, Inc.

November 4, 2014
Rev. February 13, 2015

Summary

Several patterns have emerged after two years of post-restoration bird monitoring, and while none may be statistically significant, they may provide an indication of how the site's avifauna may be responding to the restoration. Species associated with freshwater marsh and urban habitats have shown the steepest declines, due to the near-total lack of their preferred habitats (large reedbeds) at the site. Counts of shorebirds overall have continued their declined into year 2, though certain beach-associated shorebird species (e.g., Sanderling, Snowy Plover and Black-bellied Plover) have been less affected and show little change from prior years. Birds of scrub and woodland appear to be increasing slightly during year 2 from a decline detected in year 1, probably owing to the continued re-growth of scrub at the site, which was essentially denuded and replanted as part of the restoration to native habitat. Counts of waders (herons/egrets) and waterfowl overall show no clear trend, and many species in these groups continue to use the site heavily; however, fish-eating waterbirds show continued increases, presumably due to a richer and more predictable fish fauna in the entire lagoon post-restoration. Several additional years of monitoring will probably be necessary to confirm these trends. Special-status species continue to make heavy use of the site, in particular the beach and lower lagoon area (e.g., Brown Pelican and Snowy Plover)[1].

Introduction and Methods

The reconfiguration of Malibu Lagoon was completed in spring 2013; prior to this, starting in mid-2012, the lagoon had been an active construction site, as the vegetation was removed and the land re-contoured, resulting in wider and deeper channels, and the construction of two large islands. The lagoon mouth has been closed for much of the time post-restoration, which has meant very little exposed mudflat and shallow water. The site, including the restoration project, is more fully described by Cooper (2013), which also compared results from two-day, site-wide surveys of Malibu Lagoon in January 2006 to similar surveys in February 2013[2]. Here I analyze three years of data, each with four quarterly surveys of data, both pre-restoration (2005-06) and post-restoration (2013-14), conducted on the following dates[3].

Pre-restoration dates:

- 28-29 October 2005
- 09 and 11 January 2006

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[1] I have omitted Latin names for ease of reading.

[2] Cooper, D.S. 2013. Avian usage of post-restoration Malibu Lagoon. Report to Santa Monica Bay Restoration Foundation. February 13, 2013.

[3] No comprehensive bird surveys were conducted at Malibu Lagoon between November 2006 and January 2013; however, nesting bird surveys were conducted on a single day in 2011, and on multiple dates through the spring-summer breeding season in 2012.

- 26-27 April 2006
- 22-23 July 2006

Post-restoration dates:

- 11-12 February 2013
- 18-19 April 2013
- 22-23 July 2013
- 28-29 October 2013
- 6-7 January 2014
- 21-22 April 2014
- 22-23 July 2014
- 28-29 October 2014

During each survey period, I would walk the entire site in the morning or afternoon of two consecutive or near-consecutive days in order to capture the variation due to tide and time of day. I began morning surveys between 06:15 and 08:45, and afternoon surveys from 14:45 and 18:30, depending on the time of year and weather conditions. Each visit lasted between one and three hours, depending on how many birds were present, and how long they took to count.

The bird community at Malibu Lagoon may be analyzed in numerous ways. Species richness, simply the total number of bird species, is of limited value, since not every species is "equal" with respect to restoration targets, and a higher or lower number of species is difficult to interpret in a meaningful way. For example, a restoration that replaces grassland with oak woodland might yield the same number of species, but the species themselves would be totally different, such that knowing that 20 species were present in grassland and 22 in oak woodland would not be particularly useful. Or, a restoration may result in a much higher number of species through the year, but many of these may be visiting the site only briefly, some for just a few minutes each year.

Dividing the bird community into ecological guilds based on foraging and habitat preference, and then comparing the abundance of species in these guilds may provide richer information on how the community might be changing over time. In the case of the Malibu Lagoon restoration, a decrease in scrubland species, or an increase in waterfowl, for example, might be expected, owing to the removal in 2012 of both the shrubs and emergent marsh vegetation that had developed in the decades since the last restoration attempt at the site decades ago, along with the recent widening of channels west of the main lagoon. Other analyses could investigate changes in the occurrence of special-status species at the site, or in the makeup of the most abundant species pre- vs. post-restoration.

For the ecological guild analysis, we only considered species that were recorded as more than one individual (including obviously the same individual bird present for more than one day, such as a Mute Swan on 28-29 October 2014), and we omitted aerial foragers as well as species that could not be reliably identified to species (e.g., California and/or Ring-billed Gulls, often recorded as simply "gull sp."). We also omitted two very common species with no specific habitat affinity, Yellow-rumped Warbler and White-crowned Sparrow. And, we omitted a handful of species that could not be easily placed into habitat/taxonomic categories, including Belted Kingfisher (singles recorded in 2013 and 2014) and raptors, the latter typically seen flying over the site and rarely lingering[4].

Caution must be exercised regarding the interpretation of increases and declines, and this assessment should not be treated as a final or definitive statement on the success or failure of the restoration of Malibu Lagoon for birds, but rather just an indication of what changes have already occurred, and how the site might be changing post-restoration. Also, the assignment of species into guilds is inherently subjective (i.e., a species like Bushtit could be either an indicator of scrub, woodland, or even urban habitat, and it occurs readily in all three). And, these numbers should be taken merely as indices, rather than absolute abundances; in the analysis, we pooled the counts by year (simply adding up all counts on each day), rather than trying to derive an average or high count by quarter or by visit. Thus, some of these totals could be divided (by eight) to get something closer to an accurate daily estimate[5].

Results and Discussion

The total number of individual birds recorded during the three survey periods, pre-restoration, year one post-restoration, and year two post-restoration, is remarkably similar (8489, 7563, and 8162, respectively). However, the species richness has dropped, with 117 species detected in late 2005 and 2006 prior to restoration, and 103 species recorded during surveys in 2013-14 (87 spp. in 2013, 88 in 2014), for a total of 140 species recorded on all 12 quarterly surveys. However, as noted above, comparison of sheer numbers and species totals is of limited interpretive use, and these counts should not be treated as statistically significant, since they are based on so few visits. Rather, they should simply be used to detect possible trends, which can be confirmed in future years.

<u>Landbirds</u>

Tables 1 and 2 summarize counts of selected groupings by ecological guilds of species between 2005 (pre-restoration) and 2014 (post-restoration). Treating landbirds first, I

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[4] Raptors recorded include an Osprey in July 2006, a Red-tailed Hawk in February 2013, a Cooper's Hawk, and a White-tailed Kite in October 2013, and single Peregrine Falcons in January and April 2014. Interestingly, no raptors were recorded in 2005-06.

[5] Since only a handful of species are permanent residents at the site, we do not utilize this conversion, but rather use a combined count to illustrate changes over time, which is a key goal of post-restoration surveys.

identify three main categories: birds of "open country" (a catch-all term that includes sparse grassland and bare ground), those of scrub/woodland, and urban species adapted to built structures and other anthropogenic features. All three landbird groups saw a decline in aggregate numbers of individuals, ranging from a 21% drop (in open-country species between 2005-06 and 2014), to an 80-90% drop (in urban species during the same period; see Table 1). Birds found in scrub and woodland showed intermediate, but still noticeable, declines, but these trends may easily be reversed as the vegetation grows back in; note that the total number of scrub/woodland species "recovered" somewhat between 2013 and 2014, almost certainly due to the maturation of shrub plantings at the site. The sharp and dramatic loss of urban species' numbers and diversity was probably related to the removal of most of the hardscape at the site, including bridges and permanent structures, as well as the loss of a small area of lawn, and should be seen as a very positive restoration outcome, as these species have ample habitat in the urban landscape in and around Los Angeles. Figure 1 presents a graph of counts of one representative scrub species, the Song Sparrow, at the site from multiple observers since 2011 (from www.eBird.org); note the pattern of relatively abundance in 2011 (brown line), followed by a decline in late 2012 and early 2013 (blue and green lines), then a potential recovery by the end of 2014 (gray line).

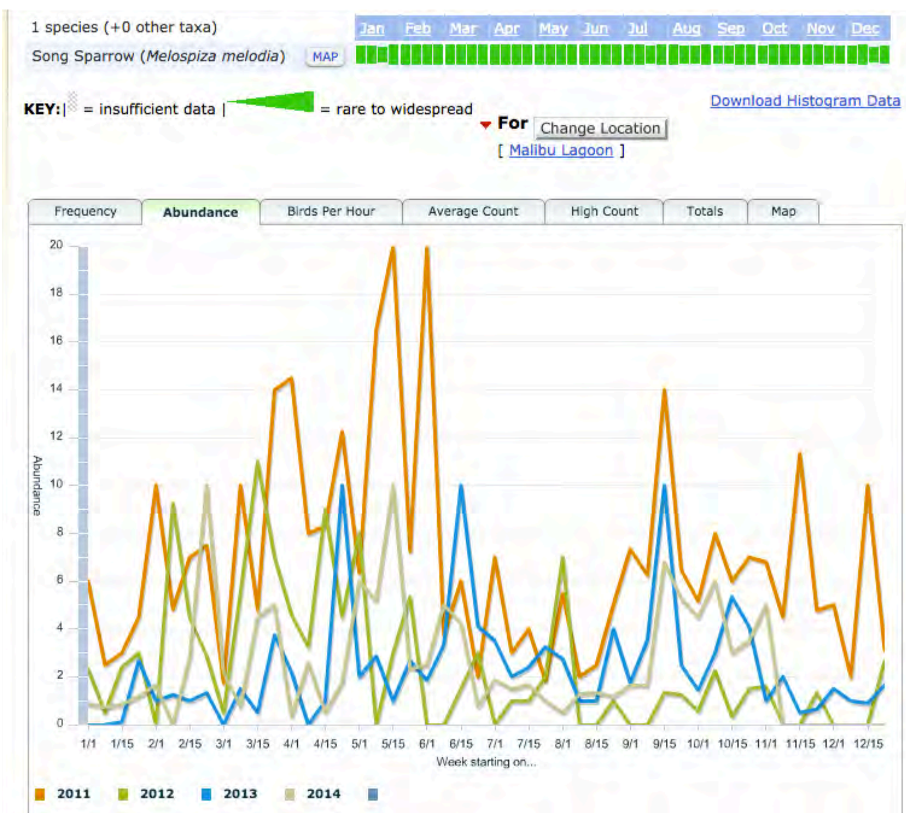

Figure 1. Counts of Song Sparrow at Malibu Lagoon, 2011-2014 (from eBird data).

Waterbirds

For waterbirds, I identified six main groups, or guilds: freshwater marsh birds, marine/beach birds, shorebirds, waders and waterfowl, and fish-eaters. While I generally counted each species for one single guild (with the exception of fish-eaters), significant overlap exists in these categories, which include both taxonomic groupings as well as habitat preferences. For example, several species placed in the "waterfowl" guild are strongly associated with freshwater marsh (e.g., Cinnamon Teal). Looking at all waterbirds, post-restoration changes were most dramatic for species typical of freshwater marsh and for shorebirds overall, which by late 2014 had declined by 91% and 69%, respectively. Essentially all freshwater marsh vegetation was removed during the restoration project, and though it may grow back eventually, it had not done so by the end of 2014, which accounts for the dearth of those species using the site.

Shorebirds represent a very broad range of foraging styles and habitat preferences, but most species listed in this guild favor mudflat and other tidally-wet habitats for foraging, or low saltmarsh vegetation for roosting, both of which were limited at the site as of 2014 owing to the lack of an opening of the lagoon mouth to the sea (and draining of the lagoon), and the fact that the vegetation was still growing in. Cumulative counts of all species dropped by more than half in year 1, and by more than two-thirds by year 2 (Table 2); however, the drop from year 1 to year 2 was less steep than that detected the first year post-restoration, suggesting that this decline may be slowing.

Shorebird species richness (excluding strictly marine species, which are treated as a separate guild) continued to drop somewhat through 2014, with (13 species in 2005-06, 11 species in 2014, and 9 species in 2014) (Table 2). The status of Least Sandpiper at the site since 2011 (Figure 2) is probably representative of several shorebird species, which shows considerable variation, but a clear pattern of higher abundance in 2011 and early 2012. Potential exceptions include the Black-bellied Plover and the Marbled Godwit, which remained fairly numerous at the site; however, these both prefer the sandy beach or the outer edge of the main lagoon for roosting and feeding, neither of which were directly affected by the restoration. Other marine shorebird species, such as Sanderling, Ruddy Turnstone and Snowy Plover, increased or showed mixed trends between the three years.

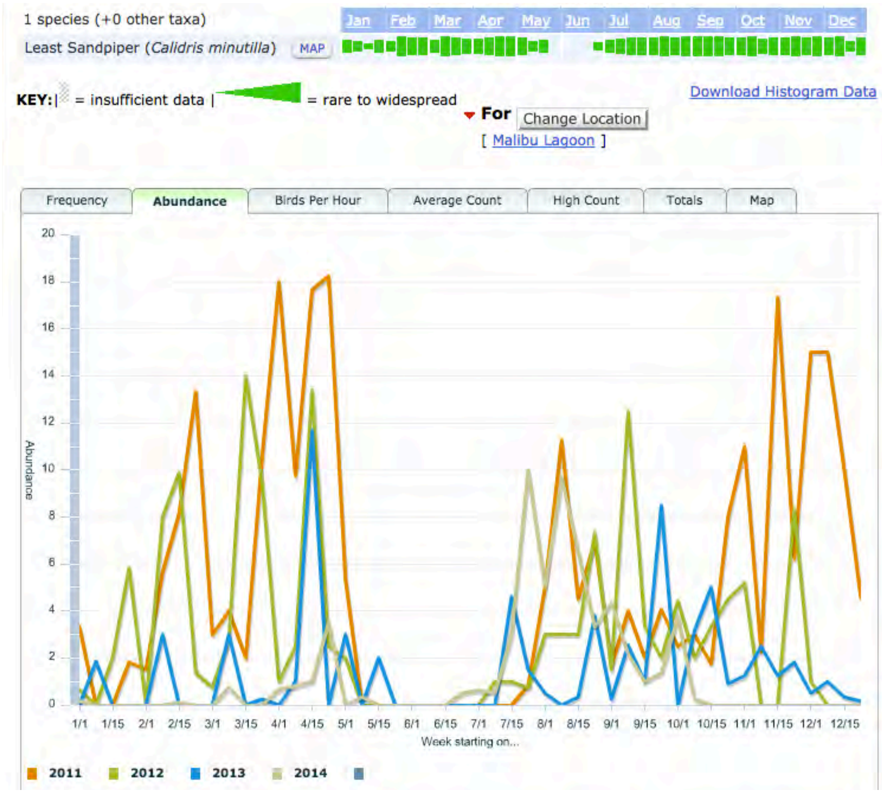

Figure 2. Counts of Least Sandpiper at Malibu Lagoon, 2011-2014 (from eBird data).

Waterbird groups that showed either little change were marine/beach species, waders and waterfowl; all remained relatively constant across all three years, despite some unusually high counts of marine species (e.g., Brown Pelican). It is likely that the lack of alteration to the main lagoon itself during the restoration (other than a possible increase in effective area due to the widening of the western channels) as well as the continued local nesting by large waders (i.e., egrets and herons nesting in and around Malibu Country Mart) resulted in little change in the numbers of these two groups. In the case of waterfowl (mainly ducks), individual numbers of birds increased by 30% in 2013, yet dropped to numbers lower than in 2005-06 by 2014, for a mixed trend similar to that of marine/beach species.

Though the jump in American Coot numbers in 2013 accounts for much of the increase that year, subsequent gains were noted in 2013 for a broad diversity of both dabbling ducks that graze on vegetative matter (e.g., Gadwall) as well as diving species that feed primarily on small fish (e.g., Eared Grebe and Ruddy Duck). By 2014, numbers of individuals fell back to being close to counts in 2005-06, suggesting that 2013 might simply have been an exceptionally good year for waterfowl at the site. Figure 3 illustrates this lack of clear pattern, with unpredictable seasonal peaks during different years. As a note, the late October 2014 survey recorded very few waterfowl, owing to a very warm autumn that had apparently failed to push ducks like Northern Shoveler and Green-winged Teal south by the end of the month (prior years had seen fronts move south in mid-October). Obviously, future years of surveys should clarify which of these fluctuations are trends versus normal variation.

Figure 3. Counts of Northern Shoveler at Malibu Lagoon, 2011-2014 (from eBird data).

One major change to Malibu Lagoon post-restoration was the expansion of channels in the western portion, which left them wider and deeper, and improved circulation. This was probably responsible for the 20% jump in numbers of fish-eating waterbirds in 2013 (Table 2), which continued to be higher than pre-restoration levels the following year (2014). Again, future years of surveys are needed to confirm these patterns.

Other potential analyses that could be conducted using the bird data from Malibu Lagoon include seasonality; for example, for species that are increasing, such as Gadwall, are they doing so mainly in summer, or are we seeing increases every season of the year? And, since data were collected by region of the site (e.g., beach, western channels, main lagoon), are certain waterbirds showing increases in one region but not in others? Foraging guilds could also be explored, such as the relatively abundance of fish-eating versus vegetation-eating species. This could help clarify the role of the actual restoration activity across the site on a particular species or species group; however, many of the waterbirds at the lagoon move freely between the main lagoon and the (now widened) channels to the west, or from the main lagoon out to the beach or inshore waters (e.g., gulls), which makes geographical analysis of such a compact (if complex) site difficult.

<u>Sensitive species</u>

Only a handful of special-status species regularly occur at Malibu, which is not surprising given the small size of the site. These include the Brant (California Species of Special Concern), California Brown Pelican (California Fully Protected), Western Snowy Plover (Federally Threatened), and the California Least Tern (Federally Endangered/State Endangered). Brant are present in small numbers (single digits) irregularly throughout the year, and the site is well outside known wintering and stopover areas for the species. Both the Brown Pelican and Snowy Plover make heavy usage of the site, and are present most of the year (but do not breed locally). Both continued to utilize the site in 2013 and 2014, occurring almost exclusively on the sand spit separating the main lagoon from the beach (which was not affected by the restoration). The California Least Tern occurs as non-breeding visitor in both spring and summer (e.g., up to 20 were recorded July 22-23, 2006); aside from an apparently anomalous nesting attempt in 2013[6], it has not bred at the lagoon at any point in recorded history. And while none was recorded on quarterly surveys in 2014, the species did occur post-restoration that year with up to 20 present from 9 August and 10 September 2014 (www.eBird.org).

The State Threatened Belding's Savannah Sparrow presents an interesting case; while no historical populations is known from the site, dark individuals continue to be observed here, mainly in fall so presumably involving post-breeding visitors (see www.eBird.org), including two photographed on 28 Sept. 2011 (J. Fisher), three on 15 August 2010 (K.L. Garrett), etc. Black Skimmer, a California Species of Special Concern also deserves mention; an unprecedented concentration of 100+ birds in spring/summer 2010 involved at least 15 pairs attempting to nest on exposed sand island in main lagoon (www.eBird.org). Other special-status species that occur at Malibu Lagoon, mainly as rare transients and non-breeding visitors, include Redhead, White-tailed Kite, Northern Harrier, Willow Flycatcher, and Yellow Warbler.

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[6] Several pairs (up to c. 50 birds total) were present and attempted to breed during spring 2013, producing several nesting scrapes and laying eggs. However, the entire colony was subsequently lost, presumably due to predation, by late spring, and re-nesting was not attempted (*fide* T. Ryan).

Table 1. Landbird guilds (singular records and hybrids omitted for brevity; excludes aerial foragers[7] and raptors). Yellow shading indicates species that appear to have increased since 2005-06; the others have either declined at the site or show no clear trend.

Guild	Species	2005-06	2013	2014	% Change (# individuals)
Open country					
	American Pipit	10	3	0	
	Cattle Egret	2	0	0	
	Killdeer	48	31	14	
	Savannah Sparrow	2	3	5	
	Say's Phoebe	1	6	4	
	Western Kingbird	6	0	0	
	Western Meadowlark	0	5	27	
	TOTAL OPEN COUNTRY (# species)	69 (6)	48 (5)	50 (5)	-24%, -21%
Scrub/Woodland					
	Allen's Hummingbird	38	10	10	
	American Robin	0	3	0	
	Anna's Hummingbird	21	0	3	
	Bewick's Wren	15	1	1	
	Bushtit	70	22	35	
	California Towhee	18	9	7	
	Cedar Waxwing	14	0	0	
	Hermit Thrush	0	0	2	
	House Wren	5	2	3	
	Lesser Goldfinch	15	65	24	
	Lincoln's Sparrow	5	0	2	
	Mourning Dove	7	1	1	
	Orange-crowned Warbler	11	0	3	
	Ruby-crowned Kinglet	5	3	8	
	Song Sparrow	51	47	40	
	Spotted Towhee	15	0	2	
	Wilson's Warbler	3	0	0	
	Yellow Warbler	4	0	0	
	TOTAL SCRUB/WOODLAND (# species)	297 (16)	163 (10)	141 (14)	-45%, -53%
Urban					
	American Crow	49	16	6	
	Black Phoebe	28	17	11	
	Brewer's Blackbird	27	0	0	
	Brown-headed Cowbird	14	5	1	
	European Starling	123	1	2	
	Hooded Oriole	7	1	0	
	House Finch	65	11	17	
	Northern Mockingbird	7	3	5	
	TOTAL URBAN (# species)	320 (8)	54 (7)	42 (6)	-83%, -87%

[7] We omit the "aerial insectivore" from the analysis; species such as swifts and swallows were irregularly recorded during the surveys, but no distinction was made as to whether they were actually utilizing the habitat on the ground.

Table 2. Waterbird guilds.

Guild	Species	2005-06	2013	2014	% Change (# individuals)
MARSH/MARINE					
Freshwater marsh					
	Common Yellowthroat	63	16	12	
	Great-tailed Grackle	20	41	5	
	Marsh Wren	3	0	0	
	Red-winged Blackbird	84	0	0	
	Sora	5	0	0	
	Virginia Rail	6	0	0	
	TOTAL FRESHWATER MARSH (# species)	181 (6)	57 (2)	17 (2)	-70%, -91%
Marine/Beach					
	Black Oystercatcher	3	1	0	
	Bonaparte's Gull	1	2	11	
	Brant	4	6	0	
	Brandt's Cormorant	1	1	0	
	Brown Pelican	862	167	4142	
	Caspian Tern	83	13	26	
	Double-cr. Cormorant	109	310	142	
	Elegant Tern	258	219	310	
	Forster's Tern	2	6	0	
	Glaucous-winged Gull	1	2	4	
	Heermann's Gull	216	30	466	
	Herring Gull	1	4	2	
	Horned Grebe	3	0	0	
	Least Tern	30	0	0	
	Mew Gull	2	0	1	
	Red-breasted Merganser	7	8	4	
	Red-throated Loon	0	2	1	
	Royal Tern	0	7	12	
	Ruddy Turnstone	10	34	21	
	Sanderling	58	460	48	
	Snowy Plover	52	202	137	
	Surfbird	0	0	4	
	Western Grebe	0	3	16	
	Western Gull	608	576	325	
	TOTAL MARINE/ BEACH (# species)	2311 (19)	2054 (21)	5672 (18)	-11%, +41%

Table 2. (continued)

Guild	Species	2005-06	2013	2014	% Change (# individuals)
Shorebirds					
	American Avocet	9	6	0	
	Black-bellied Plover	287	224	169	
	Dunlin	5	2	1	
	Greater Yellowlegs	8	1	0	
	Least Sandpiper	71	33	4	
	Long-billed Curlew	2	0	0	
	Long-billed Dowitcher	14	0	0	
	Marbled Godwit	54	15	63	
	Semipalmated Plover	27	16	3	
	Spotted Sandpiper	11	6	7	
	Western Sandpiper	197	21	11	
	Whimbrel	20	27	9	
	Willet	212	47	15	
	TOTAL SHOREBIRDS (# species)	917 (13)	398 (11)	282 (9)	-57%, -69%
Waders					
	Black-cr. Night-heron	31	5	3	
	Great Blue Heron	24	26	9	
	Great Egret	13	13	5	
	Green Heron	1	0	1	
	Snowy Egret	55	77	87	
	TOTAL WADERS (# species)	124 (5)	121 (4)	105 (5)	-1%, -15%
Waterfowl					
	American Coot	628	1096	562	
	American Wigeon	16	49	17	
	Blue-winged Teal	6	0	0	
	Bufflehead	46	26	10	
	Cinnamon Teal	16	0	0	
	Eared Grebe	10	27	74	
	Gadwall	94	164	107	
	Green-winged Teal	147	48	42	
	Lesser Scaup	2	1	1	
	Mallard	170	98	28	
	Northern Pintail	8	0	2	
	Northern Shoveler	47	163	31	
	Pied-billed Grebe	14	28	12	
	Ruddy Duck	55	90	76	
	Snow Goose	8	0	0	
	TOTAL WATERFOWL (# species)	1267 (15)	1790 (11)	962 (12)	+30%, -24%
Fish-eaters[8]					
	Brandt's Cormorant	1	1	0	
	Caspian Tern	83	13	26	
	Double-cr. Cormorant	109	310	142	
	Elegant Tern	258	219	310	
	Forster's Tern	2	6	0	

[8] Excludes California Brown Pelican, which occurred in exceptionally high numbers for several days in late spring 2014.

	Horned Grebe	3	0	0	
	Least Tern	30	0	0	
	Red-breasted Merganser	7	8	4	
	Red-throated Loon	0	2	1	
	Royal Tern	0	7	12	
	Western Grebe	0	3	16	
	Black-cr. Night-heron	31	5	3	
	Great Blue Heron	24	26	9	
	Great Egret	13	13	5	
	Green Heron	1	0	1	
	Snowy Egret	55	77	87	
	Eared Grebe	10	27	74	
	Pied-billed Grebe	14	28	12	
	Ruddy Duck	55	90	76	
	TOTAL FISH-EATERS (# species)	696 (16)	835 (16)	778 (15)	+20%,+12%