# Malibu Lagoon Restoration and Enhancement Project

## Comprehensive Monitoring Report (Year 3)

May 2016

**The Bay Foundation**
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# Malibu Lagoon Restoration and Enhancement Project
## Comprehensive Monitoring Report (Year 3)

31 May 2016

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Photo: Malibu Lagoon Restoration Project at sunrise (M. Grubbs; 11 January 2016).

# Executive Summary

The Malibu Lagoon Restoration and Enhancement Project was completed 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 is an additional water quality indicator of a more well-functioning post-restoration system. Some biological communities, such as vegetation and birds, are predicted to continue establishing over time. Most aspects of the restoration are already well ahead of the goals outlined in the Monitoring Plan (SMBRF 2012). California Rapid Assessment Method (CRAM) surveys continue to be a good indicator of the consistently increasing condition of the post-restoration wetland habitat areas. However, 2015 saw some anomalous data trends, likely due to the effects of El Niño, including warmer oceanic waters and extended berm closure events. Each component of the post-restoration monitoring program is summarized, below.

***California Rapid Assessment Method:*** Post-restoration surveys show a consistent increase in final CRAM scores over time. The overall CRAM score increased from 50 pre-restoration to 68 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. As predicted, the biotic structure attribute continues to increase as the vegetation community increases in overall cover and complexity over time. The overall CRAM final score is also likely to remain 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:*** 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. While Transect 1, 2, and 4 showed a slight decrease in estimated sediment area, findings show no significant changes. Transects 3 and 5 also showed consistent estimated sediment results across years, with no evidence of sediment deposition. Sediment appears to be moving in accordance with predicted tidal and closed berm water regimes.

***Physical Monitoring – Berm Morphology:*** While not a requirement of performance criteria monitoring, a separate, regional El Niño collaborative study monitored berm morphology throughout the wet season. High resolution positional and elevational data were collected following storm events to capture sediment shifts that the berm may have experienced. Results of the short-term berm morphology study displayed the dynamic geomorphology of the sand berm at the mouth of the Malibu Lagoon.

***Water Quality – Automated Water Quality Monitoring:*** Year 3 post-restoration permanent sonde water quality dissolved oxygen data exceeded both of the success criteria at Station 2. One of the two success criteria (1.5 mg/L) was exceeded at both of the remaining Stations (5 and 8); however, the other success criteria (1.0 mg/L) was not met at Station 5 or 8. During closed conditions across the mouth of the main Lagoon, salinity levels were lower as freshwater inputs from Malibu Creek raised the water elevations. In general, as temperature increased in a closed Lagoon scenario, levels of dissolved oxygen decreased. Declining trends in dissolved oxygen levels and increases in water temperature have been seen repeatedly in data from the 2015-2016 winter season in bar-built estuaries throughout Southern California. It is important to continue evaluating dissolved oxygen data in a long term context as the variability may be due to any number of factors, including biofouling, temperature fluctuations, and El Niño effects.

Lastly, sonde probe failure and equipment malfunctions led to a significant period of missing data during the cooler closed bar conditions, or October to December of 2015 at Station 8 (back channel), during a time period where both of the other sondes showed a trend of increasing dissolved oxygen and decreasing water temperatures. Since the Station 8 sonde was not able to capture the increase in oxygen, it affected the overall percentages. There are no comparative pre-restoration data to this back channel station due to the inability to install sonde equipment given the sedimentation, anoxia, and "muck" conditions that dominated the pre-restoration back channels.

***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. 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 in May 2014 and May 2015 never fell below 11 mg/L and 8 mg/L, respectively. 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. 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:*** Nutrient inputs to the system have remained consistent before and after the restoration process, and the inputs to the restoration area are primarily from upstream, not within the project site. This was well-represented in the data results. Anomalous data collected during the December 2014 surveys (Year 2 results) are possibly the result of non-project area discharges, as the December 2014 samples were collected during the Tapia Facility's permitted discharge dates into Malibu Creek (November 15 – April 15). Anomalous data were not seen in the January 2016 data within the Tapia discharge period, and consistent low concentrations of nutrients remained present through the Year 3 surveys (2015). Additionally, based on the most recent Heal the Bay Beach Report Card data, the post-restoration trend of declining numbers of TMDL exceedances continues.

***Sediment Quality – Sediment Constituent Sampling:*** Sediment grain size distributions experienced an increase in the percentage of fine grain sediments between May 2014 and December 2014 for multiple stations, but a significant decrease was recorded for most stations in May 2015, with a subsequent modest increase in January 2016. Additionally, seasonal patterns of water and sediment movement, including a slight build up during closed conditions and the subsequent 'flushing' of water and sediment out of the Lagoon when it breaches, is consistent with the project goals.

Sediment nutrients remained fairly consistent between pre- and post-restoration surveys, with post-restoration data displaying more uniform distributions and smaller ranges. For example, the post-restoration total phosphorous sample range was 31 – 450 mg/kg for the 2015 surveys, compared to 0.09 – 1,420 mg/kg during pre-restoration conditions. 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 sampling periods. Sediment nutrient data are currently meeting success criteria, which includes reducing overall nutrient sequestering over time, based on lower total nitrogen (TN) and total phosphate (TP) maximum values post-restoration.

***Biological Monitoring – Benthic Invertebrates:*** The invertebrate survey data results initially established as a shift from a depauperate, pollution-tolerant invertebrate community, to a healthier, diverse invertebrate community that included a higher percentage abundance of sensitive species and numbers of taxa. This trend reversed to some degree in the January 2016 survey data results, indicating a decrease in sensitive taxa between December 2014 and January 2016. However, the overall community still currently has abundances and numbers of sensitive taxa that are higher than pre-restoration conditions and no decreases across multiple years; thus, the benthic community is still meeting the project success criteria. It will be important to evaluate these data in conjunction with the next several years to have a full evaluation of trends over time.

***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 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. Both native fish species richness and overall native fish abundances were higher in both of the post-restoration summer surveys than in the pre-restoration summer survey. Non-native fish abundances were lower, post-restoration, and the non-native species richness was the same.

***Biological Monitoring – Avian Community Surveys:*** Several patterns have emerged after three 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. Additional monitoring will be necessary to confirm the data trends. Special-status species in Year 3 continue to make heavy use of the site, in particular the beach and lower lagoon area (e.g., Brown Pelican and Snowy Plover). The total number of individual birds recorded during 2015 included 11,299 individual birds identified, representing a nearly 30% increase over the prior years' total.

Counts of open country species nearly doubled those identified during the pre-restoration years. Counts of scrub and woodland species also increased from 2013 and 2014 results, but remain less than pre-restoration numbers; however, species richness in this guild doubled since the first post-restoration year. Fish-eating waterbirds showed relatively dramatic increases, presumably due to a richer and more predictable fish fauna – and more room to forage – in the expanded, post-restoration lagoon. Counts of large waders (herons/egrets) and waterfowl show no clear trend overall; however, many species in these groups continue to use the site heavily. Birds associated with freshwater marsh habitat surged in numbers over 2014, with two species identified that had not been recorded on the survey since the pre-restoration years (Marsh Wren and Red-winged Blackbird). Counts of shorebirds overall continued to be lower than pre-restoration levels in Year 3.

***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. A 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.

***Vegetation – Plant Cover Transects:*** Vegetation cover has shown a relative increase over time, with a large increase after the initial post-restoration baseline survey. Vegetation cover is predicted to continue to develop and become more complex over time as mature plants have a chance to grow and spread. Non-native species on each transect represented between zero and one percent 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. All transects have already met the non-native success criteria for Year 3 (i.e. < 10% cover) and Transects 1 and 2 are well above the native vegetation cover success criteria (i.e. > 50%); however, Transect 3 continues to establish and spread at a slower rate, likely due to the ongoing drought in Southern California. Continued observation and monitoring is recommended, and future supplemental plantings may be recommended if drought conditions continue.

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

***Conclusions:*** Year 3 data support the ongoing trend of increasing health and recovery of Malibu Lagoon following the restoration effort in 2013. Continued monitoring and scientific evaluation of the parameters and success criteria are necessary to confirm this trend over time. The majority of monitoring components have met or exceeded established success criteria and none require the implementation of adaptive management measures at this time. All criteria and parameters should be carefully tracked to evaluate their continued stability under post-restoration conditions. The rapid indicator score (CRAM) continues to increase, and the site-intensive data support those results. The vegetation community has continued to become more complex over time, and as this establishment continues, bird and wildlife use of the site have shifted and progressed accordingly. Many communities of birds and native fish have returned to the site, with the added function of a fish nursery habitat. The mats of algae that smothered the Lagoon in pre-restoration conditions are now significantly reduced and well below established criteria limits. While the Year 3 monitoring data indicate that El Niño may have potentially affected both the dissolved oxygen and benthic invertebrate community, all five years of data will be imperative to establish long-term trends for all parameters. Previous conclusions drawn from scientific publications of Southern California estuaries during the 1997-1998 El Niño suggest that ocean temperature anomalies may result in a cascade of changes to shallow water estuarine systems, including impacts to diversity and abundances of benthic or fish communities (Williams et al. 2001, Nordby and Zedler 1991).

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 3 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 27 January 2016. During the Year 3 monitoring period, the Lagoon berm breached on 16 December 2015, and the 'open condition monitoring' occurred between the date of the breach and 27 January 2016 according to the protocols and during appropriate tidal conditions. An aerial overview of Malibu Lagoon highlighting the restoration and monitoring areas in relation to the main lagoon and Surfrider Beach are displayed in Figures 1 and 2.

Figure 1. Aerial view of Malibu Lagoon from Lighthawk flight on 23 June 2015 (closed berm).


Figure 2. Map of project location site (Western Channels) and the Malibu Lagoon (Google Earth – May 2015).

### *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 and 2015. 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 (fall/winter) and once during closed conditions (late spring), 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 wetland habitats in the Assessment Area.

## 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*

Six post-restoration surveys were completed within the wetland habitats on site during the following dates: 14 February 2013, 4 October 2013, 7 May 2014, 23 December 2014, 5 May 2015, and 20 January 2016 (Figure 3); the May 2014 and 2015 sampling events were extra surveys 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 25-100 scale, with 25 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 4), 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 4 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 3. Landscape photo of a portion of the CRAM AA at Malibu on the most recent survey, 19 January 2016.


Figure 4. 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 68 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. The increase in CRAM score since the Year 2 (2014) surveys can be attributed to an increase in the biotic structure attribute.

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 | 05/05/15 * | 01/19/16 |
|---|---|---|---|---|---|---|---|
| Attribute 1: Buffer and Landscape Context | 38 | 38 | 38 | 38 | 53 | 53 | 53 |
| Attribute 2: Hydrology Attribute | 50 | 58 | 58 | 58 | 58 | 58 | 58 |
| Attribute 3: Physical Structure Attribute | 50 | 88 | 75 | 75 | 88 | 88 | 88 |
| Attribute 4: Biotic Structure Attribute | 61 | 39 | 56 | 53 | 64 | 64 | 72 |
| **Overall AA Score** | **50** | **56** | **57** | **56** | **66** | **66** | **68** |

### *Performance Evaluation*

Post-restoration surveys show a consistent increase in final CRAM scores over time. As predicted, the biotic structure attribute continues to increase as the vegetation community increases in overall cover and complexity over time. The overall CRAM final score is also likely to remain 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 for three consecutive post-restoration years on 14 February 2013, 18 December 2014, 19 January 2016 (Figures 5 and 6). Horizontal and vertical locations of cross-section end-points were fixed by monuments. Sediment scour or deposition depths were calculated from the data.

Figure 5. Cross-channel elevation surveys at Malibu Lagoon, 19 January 2016.

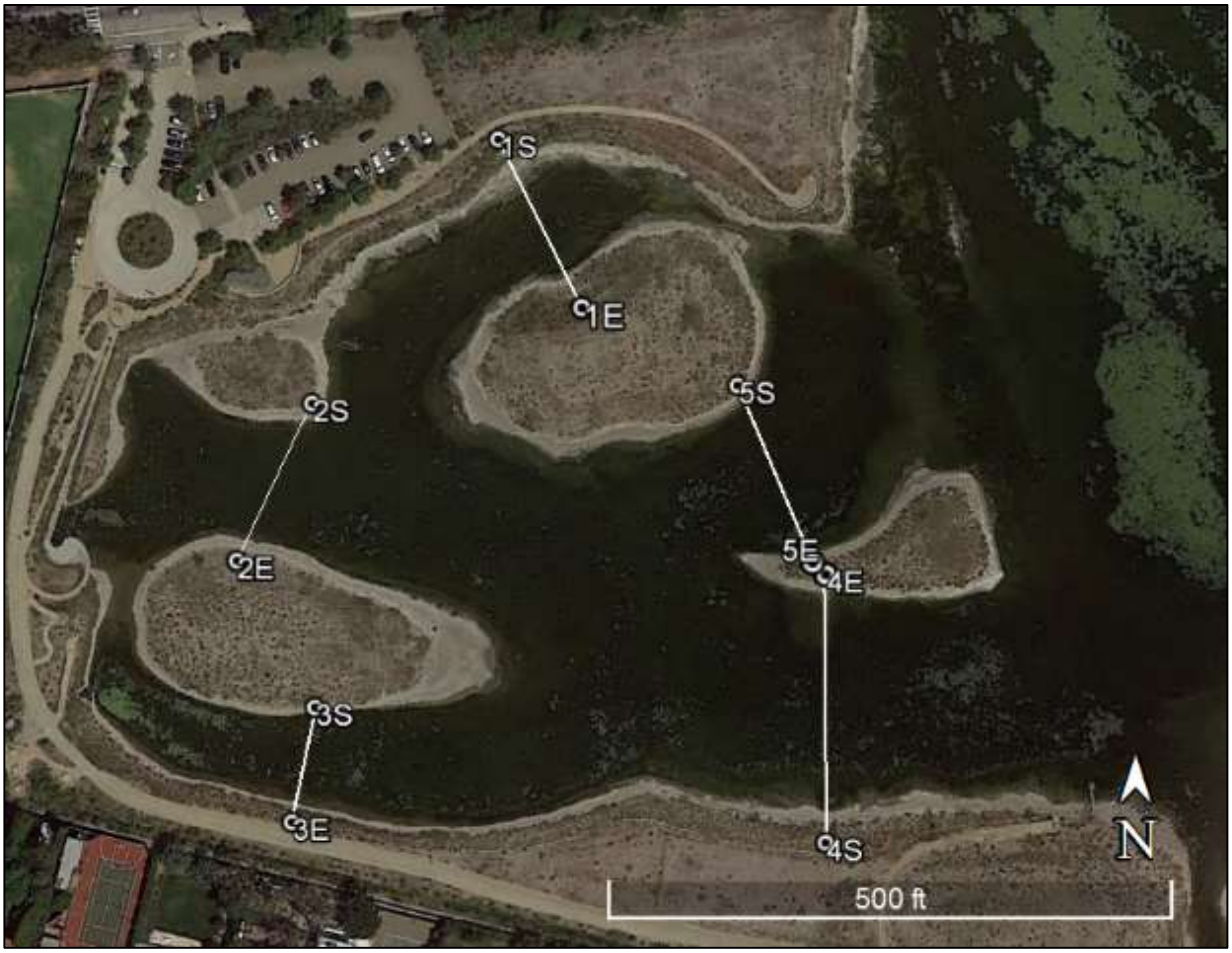



Figure 6. Map of cross-channel elevation transect locations.

### *Results*

Results were calculated for all five post-restoration cross-section transects comparatively across both survey dates (Figures 7-11). 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 105 and 234 ft (Figures 7-11). All elevation data were surveyed using the North American Vertical Datum of 1988 (NAVD 88). Area for each cross-section transect was approximated using a Riemann sums method and resulting estimated areas were compared across survey dates (Figure 12). Resolution varied across each survey; the least resolution in the 2013 data resulted in the highest standard error for area approximation during that time period. While Transect 1, 2, and 4 had a slight decrease in estimated area, findings show no significant change. Transects 3 and 5 also showed consistent estimated areas, with no evidence of sediment deposition.

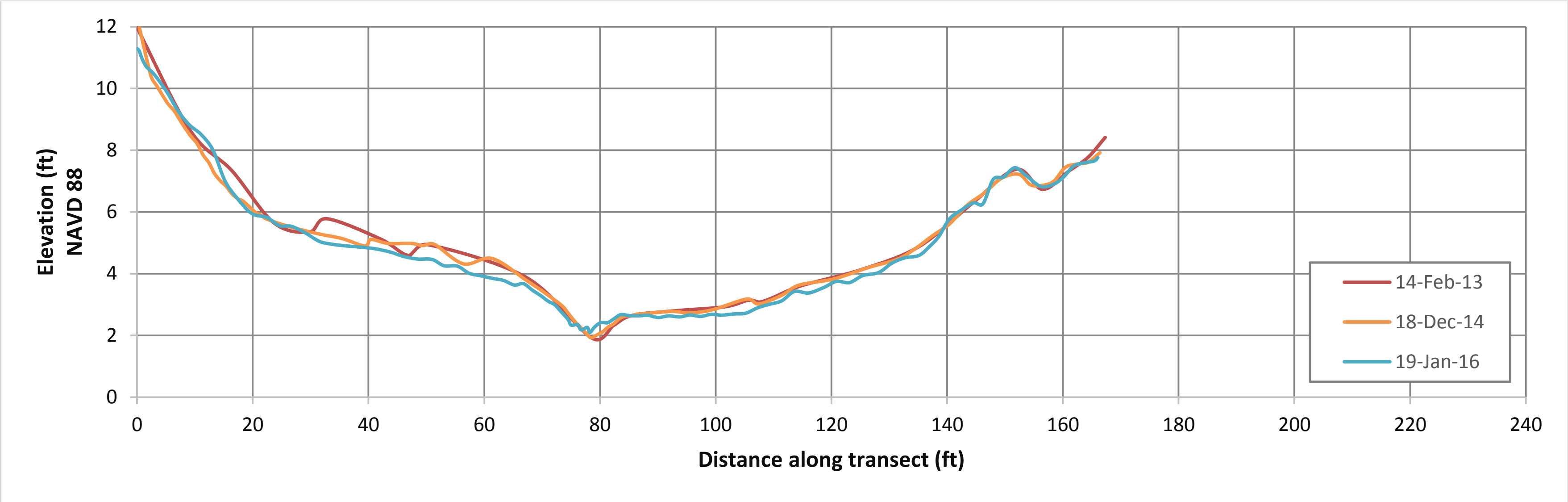



Figure 7. Channel Cross-section Transect 1.

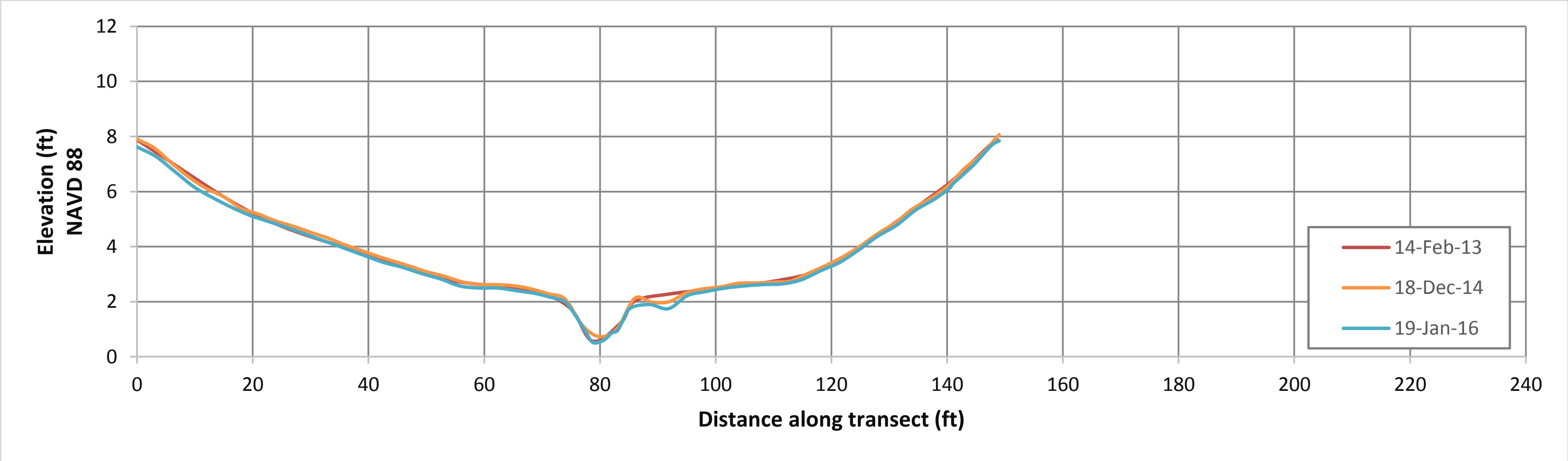



Figure 8. Channel Cross-section Transect 2.

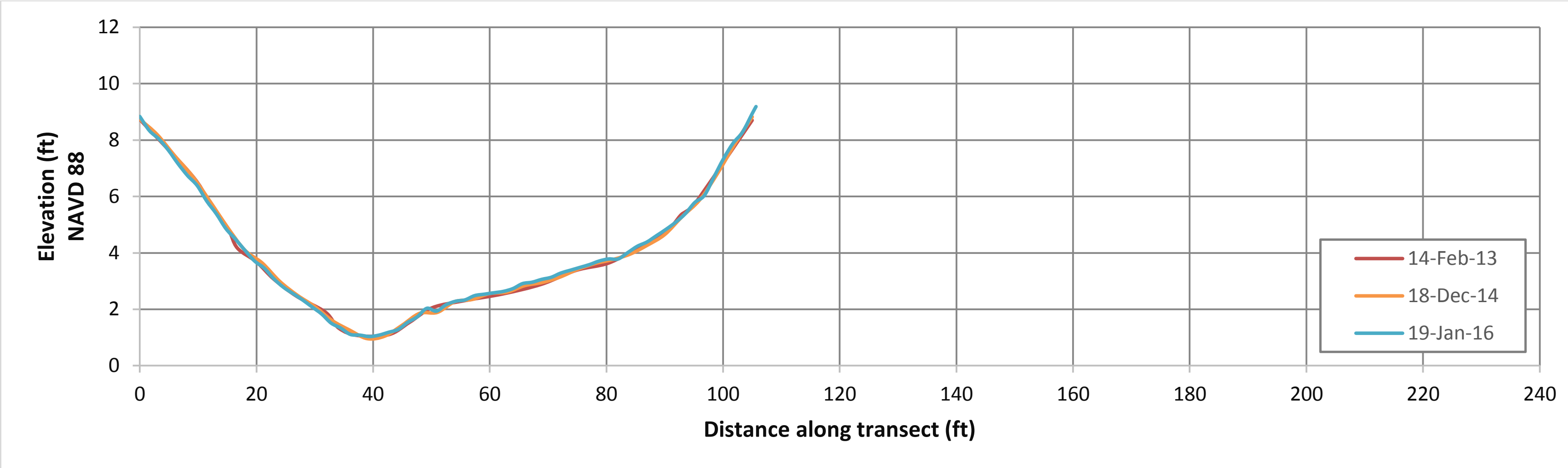



Figure 9. Channel Cross-section Transect 3.

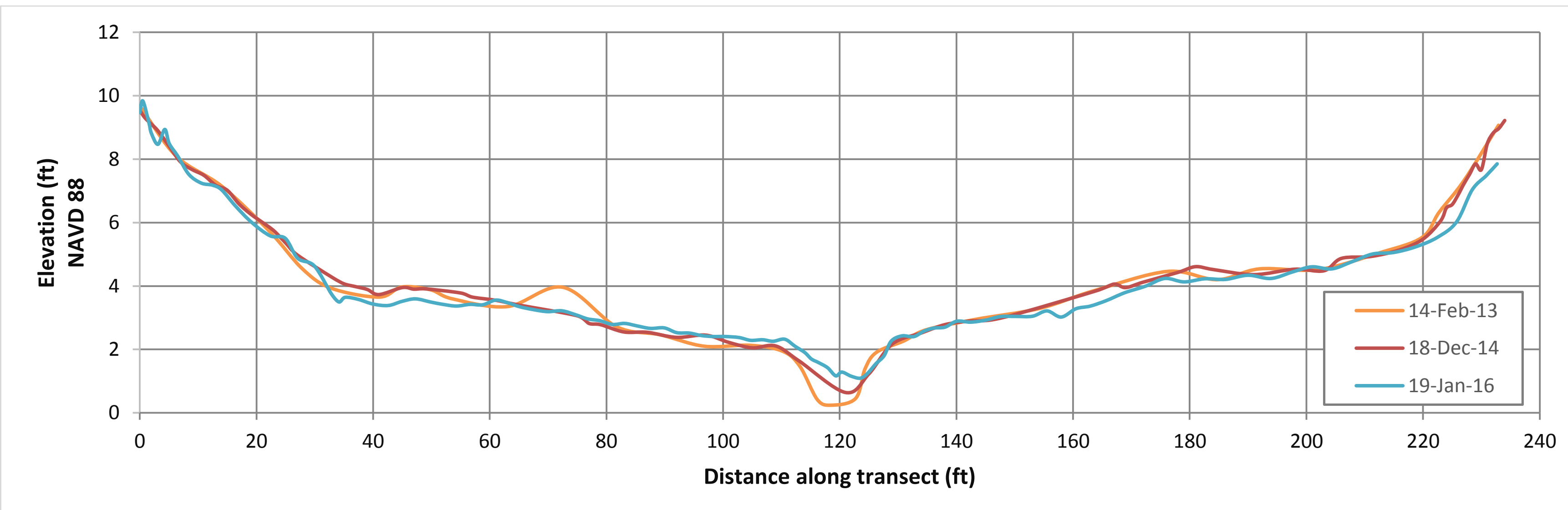



Figure 10. Channel Cross-section Transect 4.

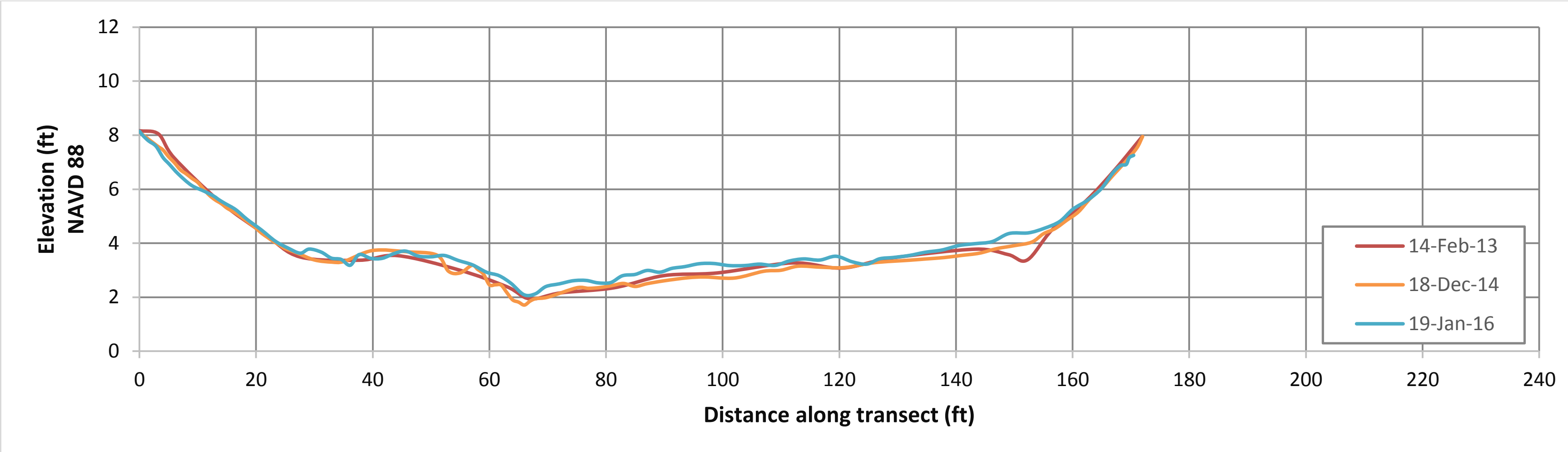



Figure 11. Channel Cross-section Transect 5.

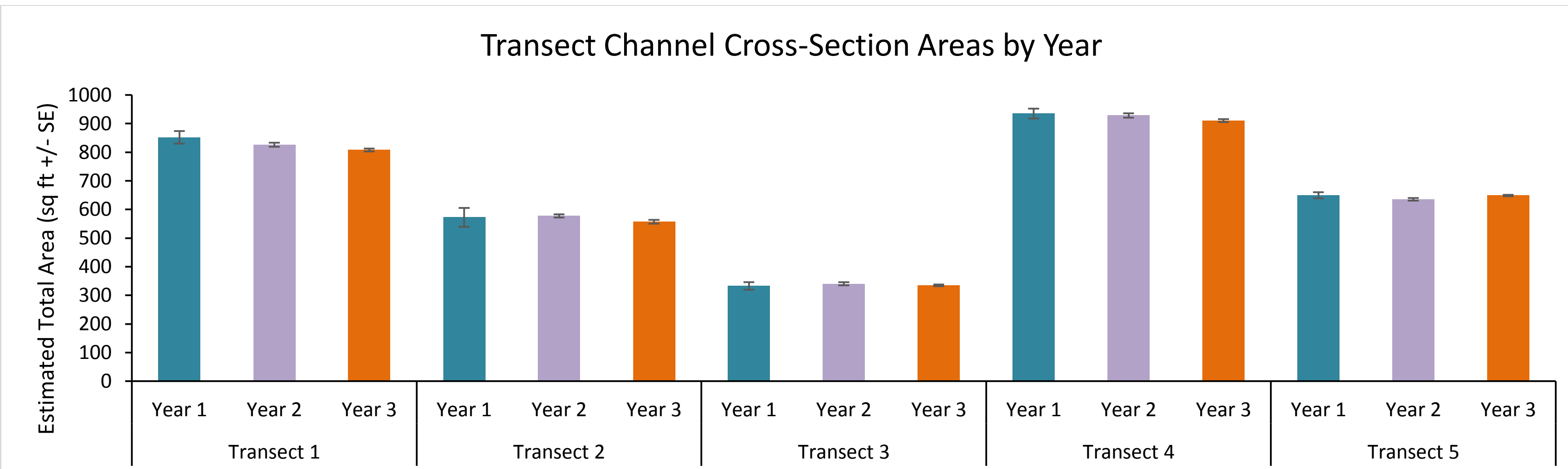



Figure 12. Transect channel cross-section areas by year.

### *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 and error inherent to the sampling method. No significant shifts or sedimentation occurred.

## Physical Monitoring – Berm Morphology Surveys

### *Introduction*

The ocean entrance to Malibu lagoon is characterized by a beach berm that opens and closes seasonally. This coastal entrance is important because it provides water exchange between the open ocean and Malibu lagoon. Berm and beach face morphology studies have been a subject of increasing investigation, particularly in seasonal-open inlets, and previous studies have shown that opening and closing processes are due to seasonal variations in streamflow and wave climate (Morris et al. 2010).

### *Methods*

From 15 December 2015 to 3 March 2016, four berm morphology surveys were conducted as part of a separate, regional El Niño collaborative study. On 15 December 2015, a baseline closed lagoon condition survey was performed followed by three subsequent surveys following the lagoon breach. The three open lagoon condition surveys were timed to occur following storm events to capture any sediment shifts that the berm may have experienced due to storm conditions. Table 3 lists details of the berm morphology surveys conducted as part of this separate El Niño collaborative study.

Berm morphology surveys were conducted using a high resolution Trimble Geo7X GPS receiver, and data were post-processed using differential correction to achieve maximum accuracy. Transects were walked along the highest point along the length of the beach at the mouth of the estuary to capture the berm crest height and position. During open lagoon conditions, walking transects also included the newly-formed channel. Data were analyzed in ArcMap 10.2, and elevation points were used to create profile graphs. Malibu Lagoon breached during the evening of 16 December 2015.

Table 3. Dates and lagoon conditions for physical berm profile surveys. Tide heights are reported as Mean Sea Level.

| Date | Lagoon Condition | Tide |
|---|---|---|
| 15 December 2015 | Closed | N/A |
| 22 December 2015 | Open | high; 6.5 ft MSL |
| 19 January 2016 | Open | high; 5.8 ft MSL |
| 3 March 2016 | Open | high; 4.5 ft MSL |

### *Results*

The results of the short-term berm elevation protocol implementation display the dynamic geomorphology of the sand berm at the mouth of the Malibu Lagoon estuary from pre-breach (closed condition) to post-breach (open condition) formation. Figure 13 displays the transect location of the berm crest along the beach front and Figure 14 displays the cross-section elevation of each transect beginning at the southwest corner of the berm. Results indicate that the sand berm and tidal channel experienced both lateral and vertical shifts following the initial lagoon breach.

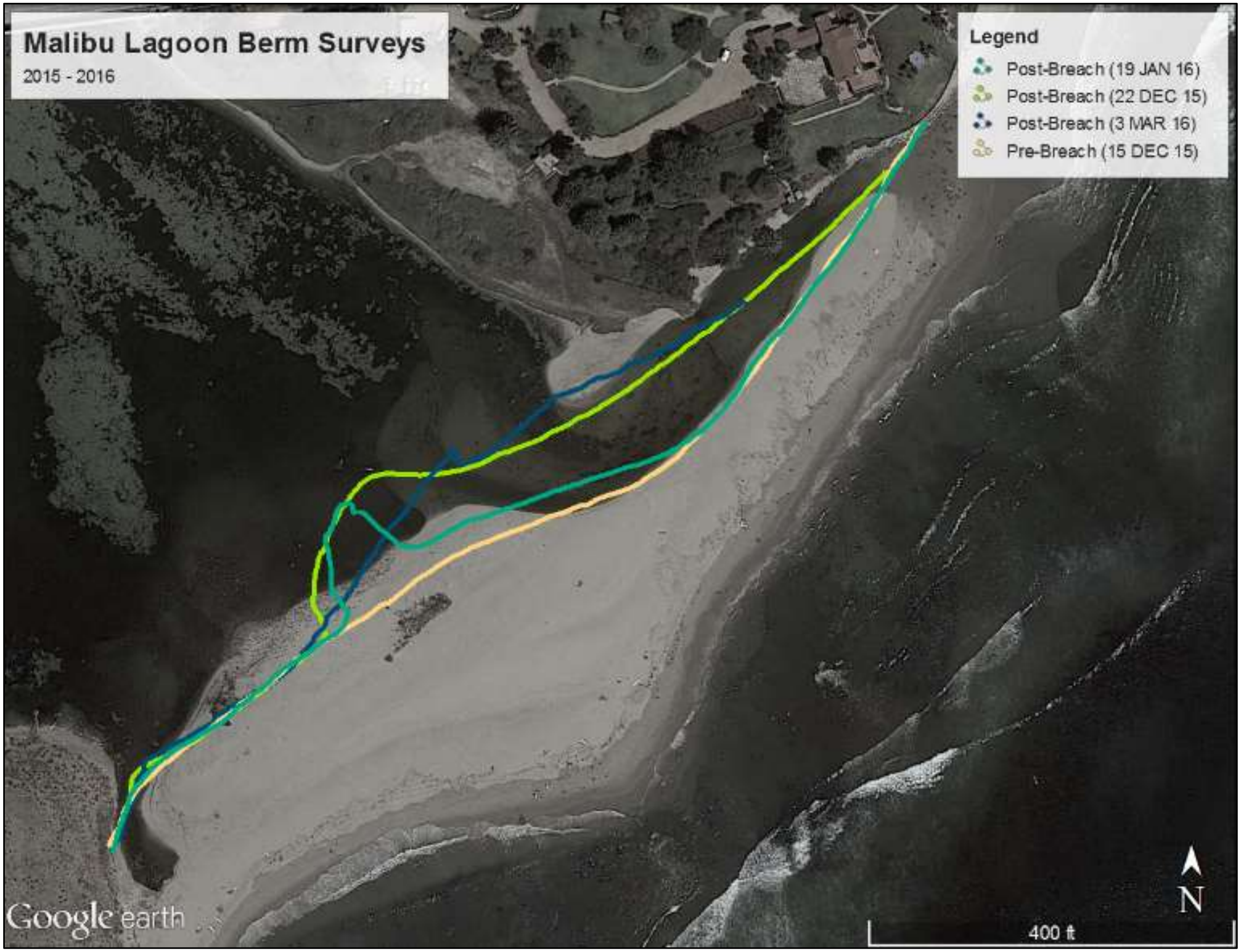



Figure 13. Map of berm walking transects for each of the four surveys.


Figure 14. Graph of berm survey elevation profiles (meters) during the each of the four surveys.

### *Performance Evaluation*

Lagoon channel and mouth sediment shifts were observed, displaying the dynamic geomorphology of the sand berm. Following the Lagoon breach in December 2015, the channel mouth migrated east and down the beach, eventually splitting off into a secondary smaller channel, and closing in May 2016. The berm survey was an opportunistic data set included as part of a regional southern California bar-built estuary evaluation and was not a metric included in the restoration success criteria; therefore, a performance evaluation was not conducted for these results.

## 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 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. Equipment consisted of Yellow Springs Instruments (YSI) 600XLM and Hydrolab DS5X multi-parameter data loggers. 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 and www.ott.com.

Data were collected between May 2013 and December 2015 at three permanent post-restoration stations. Dates of deployment varied by station due to probe malfunctions, servicing, or calibration glitches (Table 4). 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 15). When possible, data were compared to pre-restoration data collected from hydrologically similar back channels (ML2 and ML6) (Figure 16). 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 17). YSI calibration instructions (www.ysi.com) and Hydrolab calibration instructions (www.ott.com) were followed for each calibration and each probe. Data output from the sondes were exported into a spreadsheet and QAQC 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. Additionally, YSI data loggers at Station 2 and Station 6 were replaced with new Hydrolab data loggers because of probe failure.

Table 4. Reasons for data gaps due to malfunction, servicing, or calibration issues with the sondes (Year 3).

| Station | Start Gap | End Gap | Parameter | Reason |
|---|---|---|---|---|
| 2 | 1/1/2015 | 1/21/2015 | All | Sonde malfunction, sent to manufacturer for repairs |
| | 2/12/2015 | 5/4/2015 | All | Probe malfunction |
| | 5/5/2015 | 6/16/2015 | Salinity | Probe malfunction |
| | 6/15/2015 | 6/20/2015 | DO | Probe malfunction |
| | 7/20/2015 | 7/24/2015 | DO | Probe malfunction |
| | 10/23/2015 | 11/20/2015 | Salinity, depth | Probe malfunction |
| | 1/1/2015 | 12/31/2015 | ORP | Calibration issues |
| 5 | 1/1/2015 | 1/18/2015 | All | Probe malfunction |
| | 3/5/2015 | 4/3/2015 | pH, ORP | Calibration issues, probe malfunction |
| | 5/5/2015 | 5/7/2015 | All | Calibration issues |
| | 7/29/2015 | 7/30/2015 | All | Calibration issues |
| | 10/23/2015 | 11/20/2015 | pH, ORP | Probe malfunction |
| | 12/22/2015 | 12/31/2015 | pH, ORP | Probe malfunction |
| 8 | 5/5/2015 | 5/7/2015 | All | Calibration issues |
| | 9/29/2015 | 12/23/2015 | All | Sonde pulled for probe replacement |
| | 12/23/2015 | 12/31/2015 | pH, ORP | Probe malfunction |


Figure 15. 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 (in yellow).

Figure 16. Map of pre-restoration water quality monitoring stations. ML2 and ML6 are the locations of the pre-restoration permanently-deployed YSI data sondes.


Figure 17. In-field sonde calibration; 29 September 2015.

### *Results*

Graphs displaying data from post-construction monitoring at Stations 2, 5, and 8 are presented in Figures 18-20. Figures 18a, 19a, and 20a demonstrate the relationship between water salinity (parts per thousand; 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 18b, 19b, and 20b demonstrate the relationship between temperature (°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. Table 5 summarizes the overall percentage of dissolved oxygen readings above each specified threshold. Figures 18c, 19c, and 20c illustrate the relationship between pH and oxidation reduction potential (ORP). ORP was not collected at Station 2 due to a probe malfunction and failure to meet calibration standards.

Table 5. Percentages of readings during closed conditions above thresholds identified in SMBRF 2012. Note: Figures 18-20 follow the 'Performance Evaluation' subsection for formatting purposes.

| | Dissolved Oxygen Threshold (mg/ L) | | | |
|---|---|---|---|---|
| Station | 1 | 1.5 | 3 | 5 |
| 2 | 94.36% | 90.16% | 77.91% | 60.84% |
| 5 | 74.05% | 69.33% | 61.09% | 52.57% |
| 8 | 53.35% | 48.36% | 39.17% | 26.57% |

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 of readings) and below 1.5 mg/L for more than 50% of the time (i.e. 12 total hours of readings) during closed conditions. Results of the analyses displayed 34 and 76 consecutive 24-hour periods below 1 mg/L (25% time) for Station 5 and Station 8, respectively. Additionally, results displayed 33 and 30 consecutive 24-hour periods below 1.5 mg/L (50% time) for Station 5 and Station 8, respectively. Station 2 results displayed only one 24-hour period below 1 mg/L (25% time) and no days below 1.5 mg/L (50% time).

Data from the back channel sonde displayed a decrease 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 74% (Station 5) and 53% (Station 8) of the time compared to approximately 83% (ML2) and 89% (ML6) during pre-restoration deployment (Table 6). The percentage of post-restoration closed condition readings above 1.5 mg/L dissolved oxygen were approximately 69.33% (Station 5) and 48.36% (Station 8), compared to 81% (ML2) and 86% (ML6) during pre-restoration conditions.

Table 6. Pre- and post-restoration proportion of dissolved oxygen readings above 1 mg/L threshold. Asterisk indicates a lack of data for that time period due to sonde malfunctions.

| Pre-restoration Station | Pre-restoration (Baseline) | Post – restoration Station | Post-restoration (Year 2) | Post-restoration (Year 3) | Post-restoration average |
|---|---|---|---|---|---|
| --- | --- | 8 | 95.76% | 53.35% | 81.83% |
| ML2 | 89.50% | 5 | 96.97% | 74.05% | 88.72% |
| ML6 | 82.79% | 2 | N/A* | 94.36% | 94.36% |

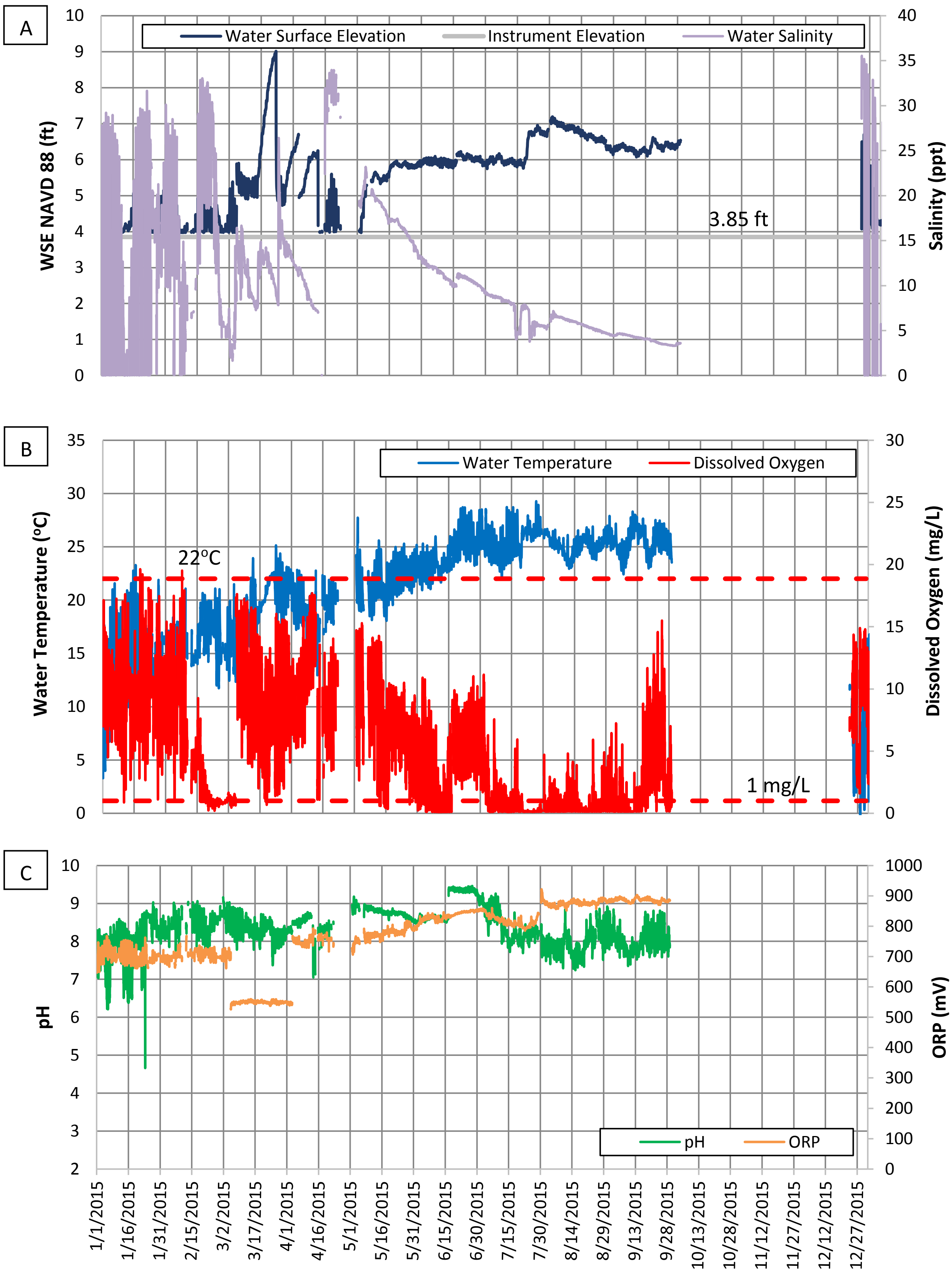



Figure 18. Graphs illustrating continuous water quality parameters from Station 8 (2015).

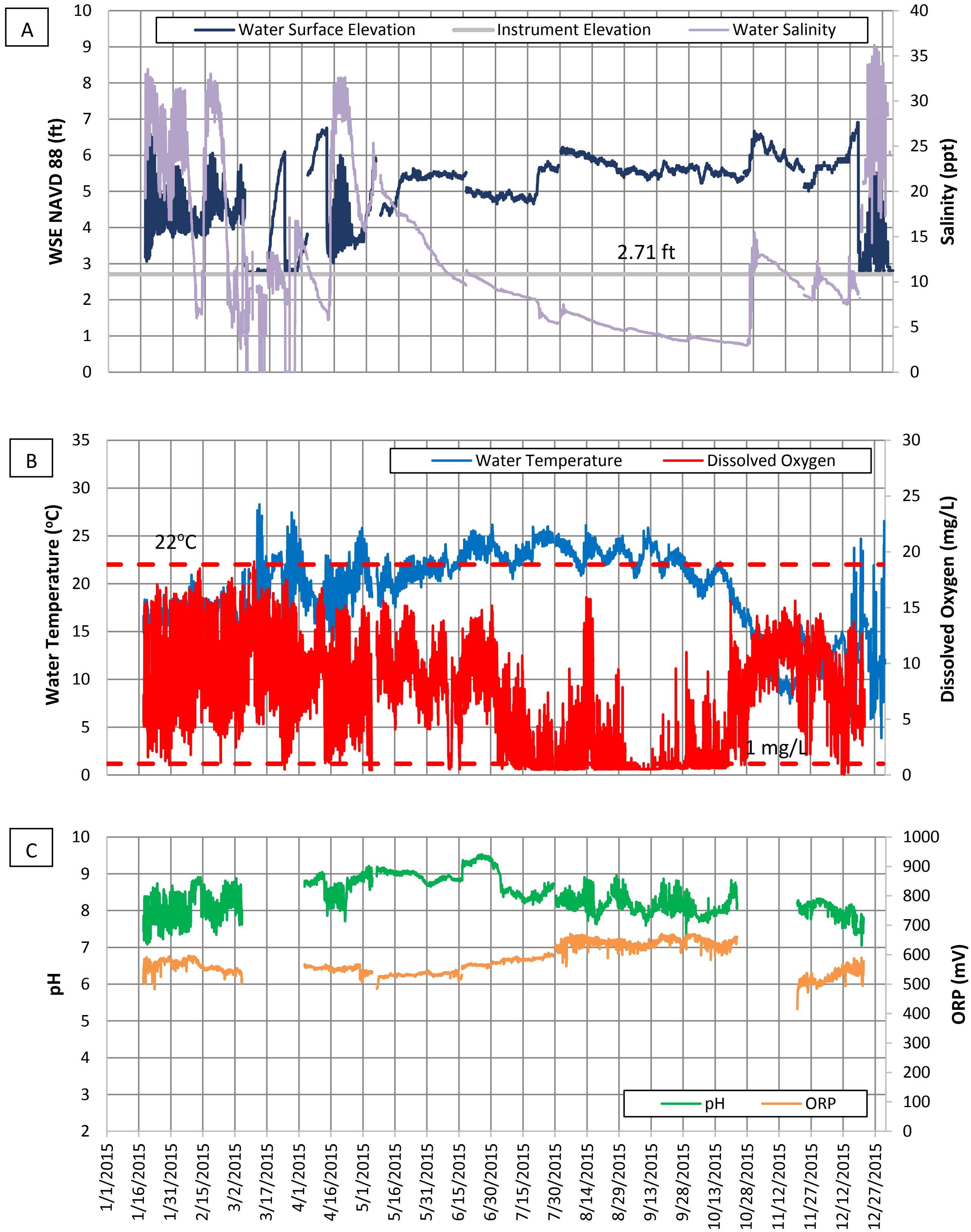



Figure 19. Graphs illustrating continuous water quality parameters from Station 5 (2015).

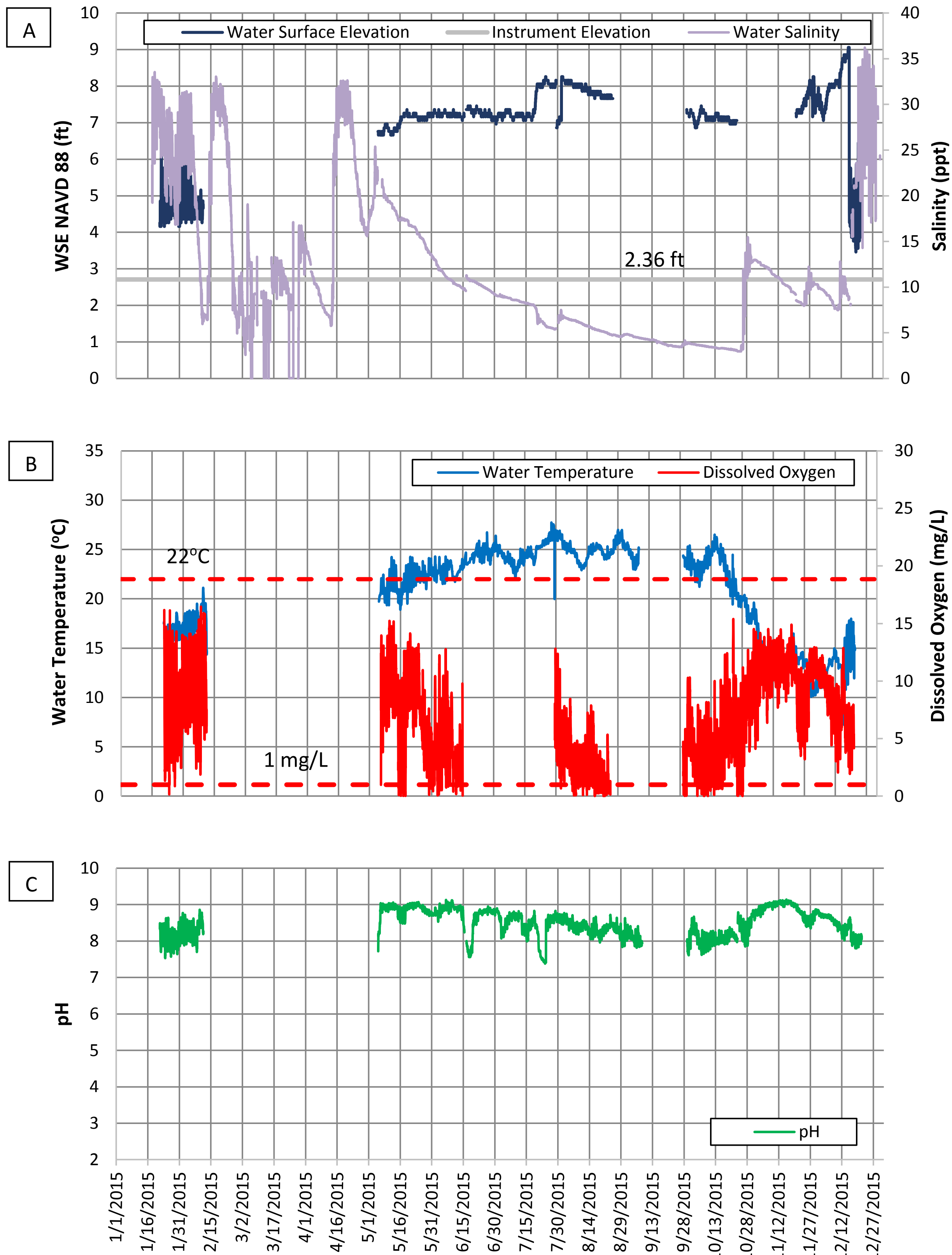



Figure 20. Graphs illustrating continuous water quality parameters from Station 2 (2015).

### *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. Year 2 post-restoration dissolved oxygen data exceeded all success criteria at all Stations for sustained time periods during closed conditions. However, year three post-restoration data only exceeded both of the success criteria at Station 2. One of the two success criteria (1.5 mg/L) was also exceeded at both of the remaining Stations (5 and 8); however, the other success criteria (1.0 mg/L) was not met at Station 5 or 8. Dissolved oxygen success criteria allows 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 34 and 76 consecutive 24-hour periods below 1 mg/L (25% time) for Station 5 and Station 8, respectively. Additionally, results displayed 33 and 30 consecutive 24-hour periods below 1.5 mg/L (50% time) for Station 5 and Station 8, respectively. Station 2 results displayed only one 24-hour period below 1 mg/L (25% time) and no days below 1.5 mg/L (50% time).

This trend in warmer waters and lower levels of dissolved oxygen has been seen repeatedly in data from the 2015-2016 winter season in bar-built estuaries throughout Southern California. Additionally, similarly to the Malibu Lagoon system, most estuaries have experienced prolonged bar (estuary mouth) closures or bar closures that have not happened for decades (e.g. Tijuana National Estuarine Research Reserve). Previous studies from the 1997-1998 El Niño indicate that the effects of this warmer water system may cause a cascade of changes to shallow-water estuarine systems (Williams et al. 2001).

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 and the absorption of oxygen directly by the barnacles. The variability in between-Station dissolved oxygen in year three monitoring was high and contributed to lowering the overall post-restoration dissolved oxygen average. It is important to continue evaluating dissolved oxygen data in a long term context as the variability may be due to any number of factors, including biofouling, temperature fluctuations, and El Niño effects.

Lastly, sonde probe failure and equipment malfunctions led to a significant period of missing data during the cooler closed bar conditions, or October to December of 2015 at Station 8 (back channel). During this time period, both of the other sondes showed a trend of increasing dissolved oxygen and decreasing water temperature, indicating that overall dissolved oxygen averages at Station 8 may have been negatively affected by the data gap. Additionally, sondes tend to 'drift' prior to failure, where collected data encounter sporadic errors becoming more frequent with time. To address this problem, data will now be QAQC'ed monthly to analyze issues as soon as possible. There are no comparative pre-restoration data to this back channel Station due to the inability to install sonde equipment given the sedimentation, anoxia, and "muck" conditions that dominated the pre-restoration back channels.

## 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 ft intervals) of water quality parameters [dissolved oxygen (DO), temperature, salinity and pH] were performed at eight stations during a high tide (N = 3) or closed condition (N = 2) using a YSI 600 XLM hand-held water quality instrument or equivalent (Table 7). 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.

Five post-restoration vertical water quality profile surveys were conducted during the dates and tides listed in Table 7 at all eight water quality stations (Figure 15). The water temperature and pH parameters experienced sensor malfunctions on 27 January 2016; therefore, those data were subsequently omitted from analysis.

Table 7. 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 |
| 7 May 2015 | Closed | N/A |
| 27 January 2016 | Open | high spring; 4.9 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 events (5 May 2014 and 7 May 2015), and cooler temperatures occurred during the three winter sampling events (14 February 2013, 23 December 2014, and 27 January 2016) (Figures 21a and 21b). 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 22a and 22b). During these times, the survey area was exposed to tidal influence. During the closed lagoon condition sampling events (5 May 2014 and 7 May 2015), 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 and substantial reductions) at multiple stations, especially during the closed berm condition sampling event (26 September 2007; 2$^{nd}$ 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 23a and 23b). 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 in May 2014 and May 2015 never fell below 11 mg/L and 8 mg/L respectively. 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 (2$^{nd}$ 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 8 and 9).

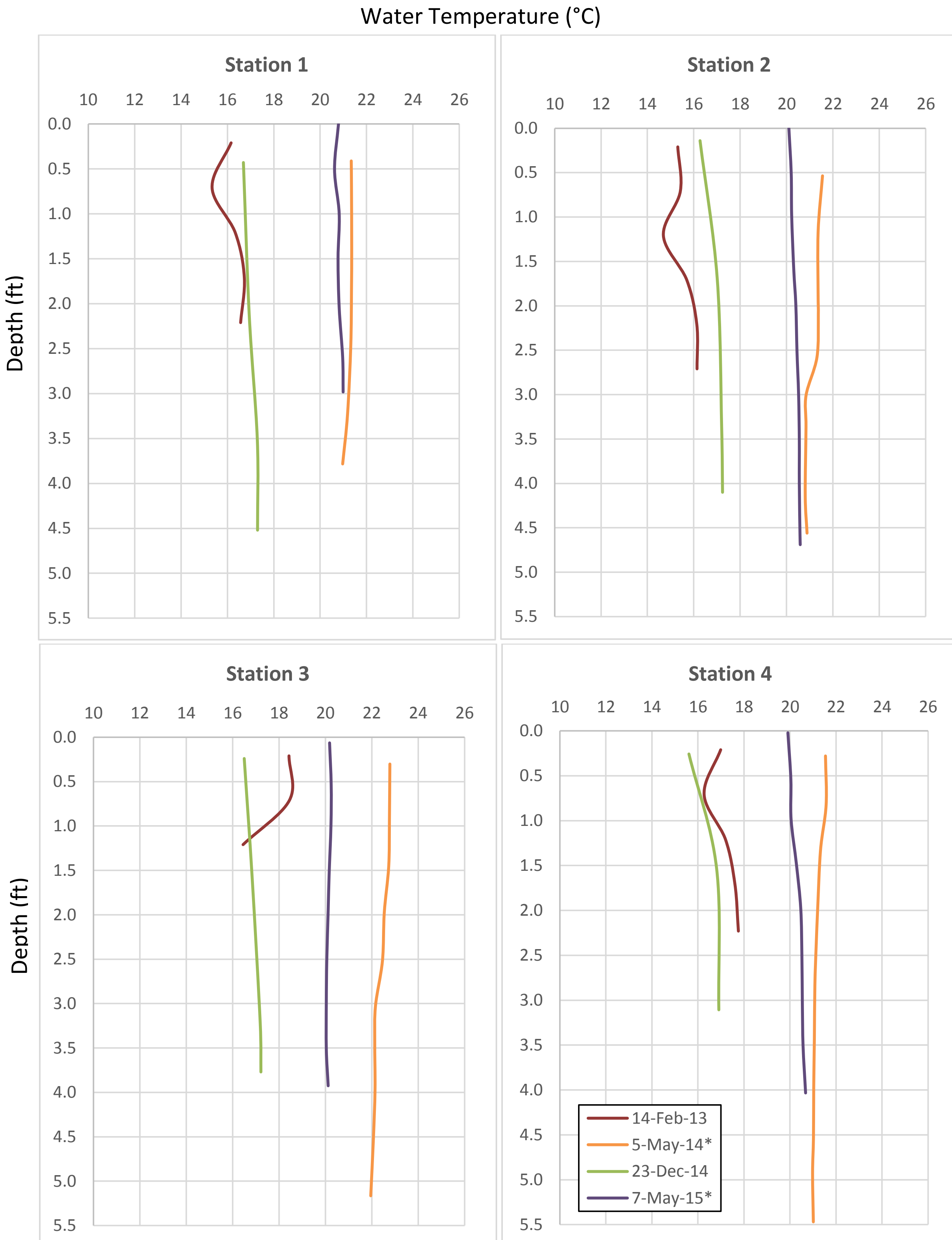



Figure 21a. Post-restoration temperature vertical water quality profiles at Stations 1-4. Asterisk indicates a closed berm condition.

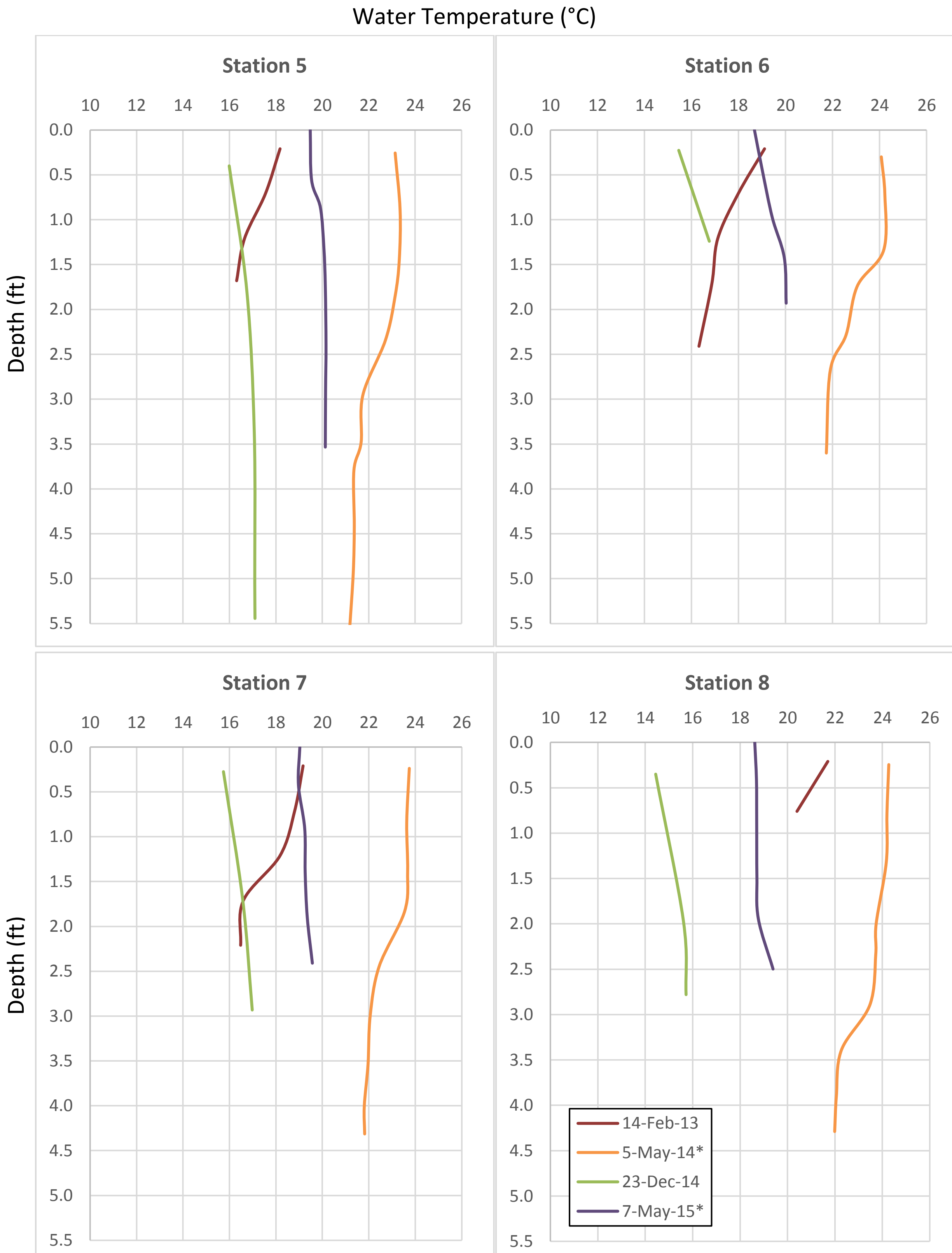



Figure 21b. Post-restoration temperature vertical water quality profiles at Stations 5-8. Asterisk indicates a closed berm condition.

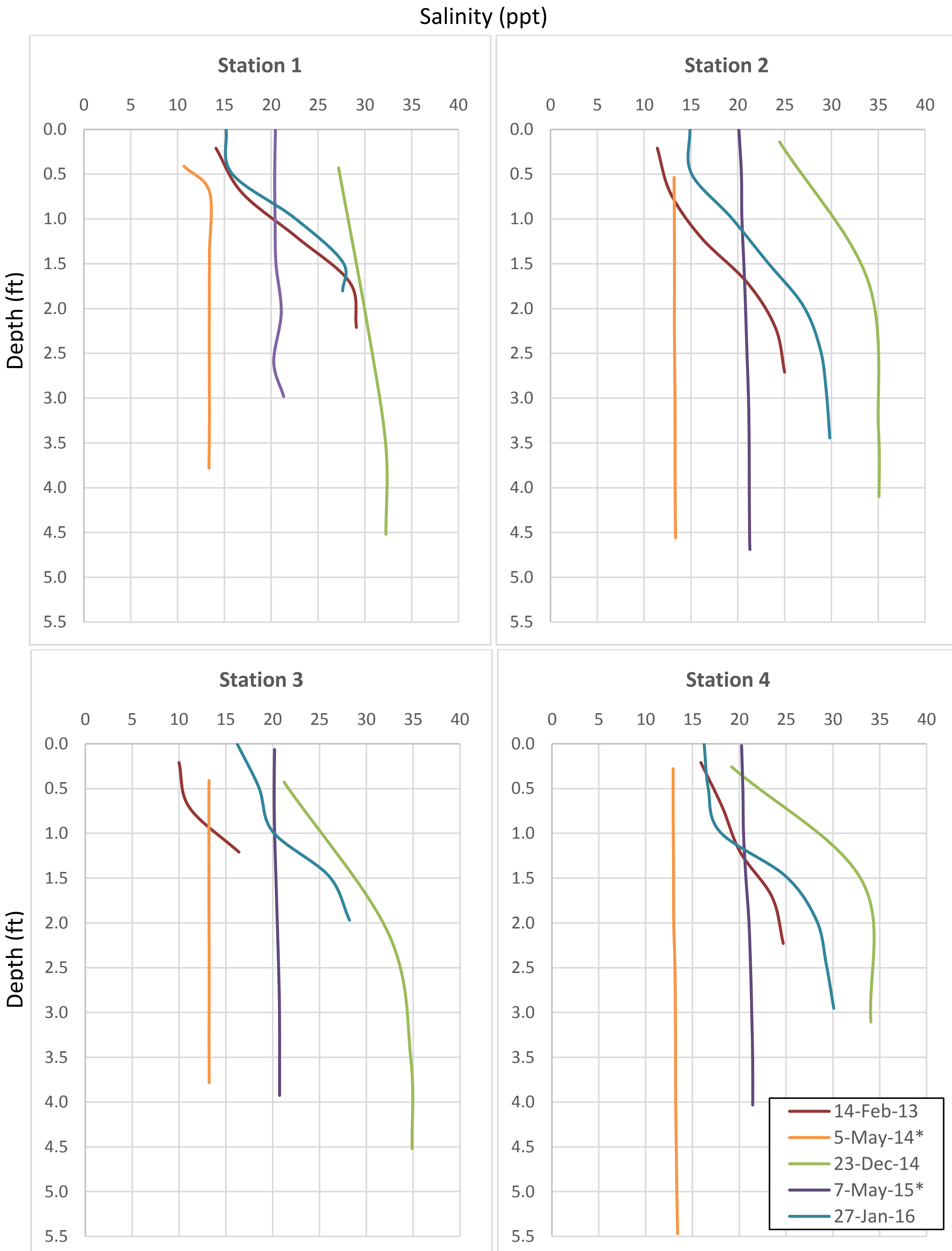



Figure 22a. Post-restoration salinity vertical water quality profiles at Stations 1-4. Asterisk indicates a closed berm condition.

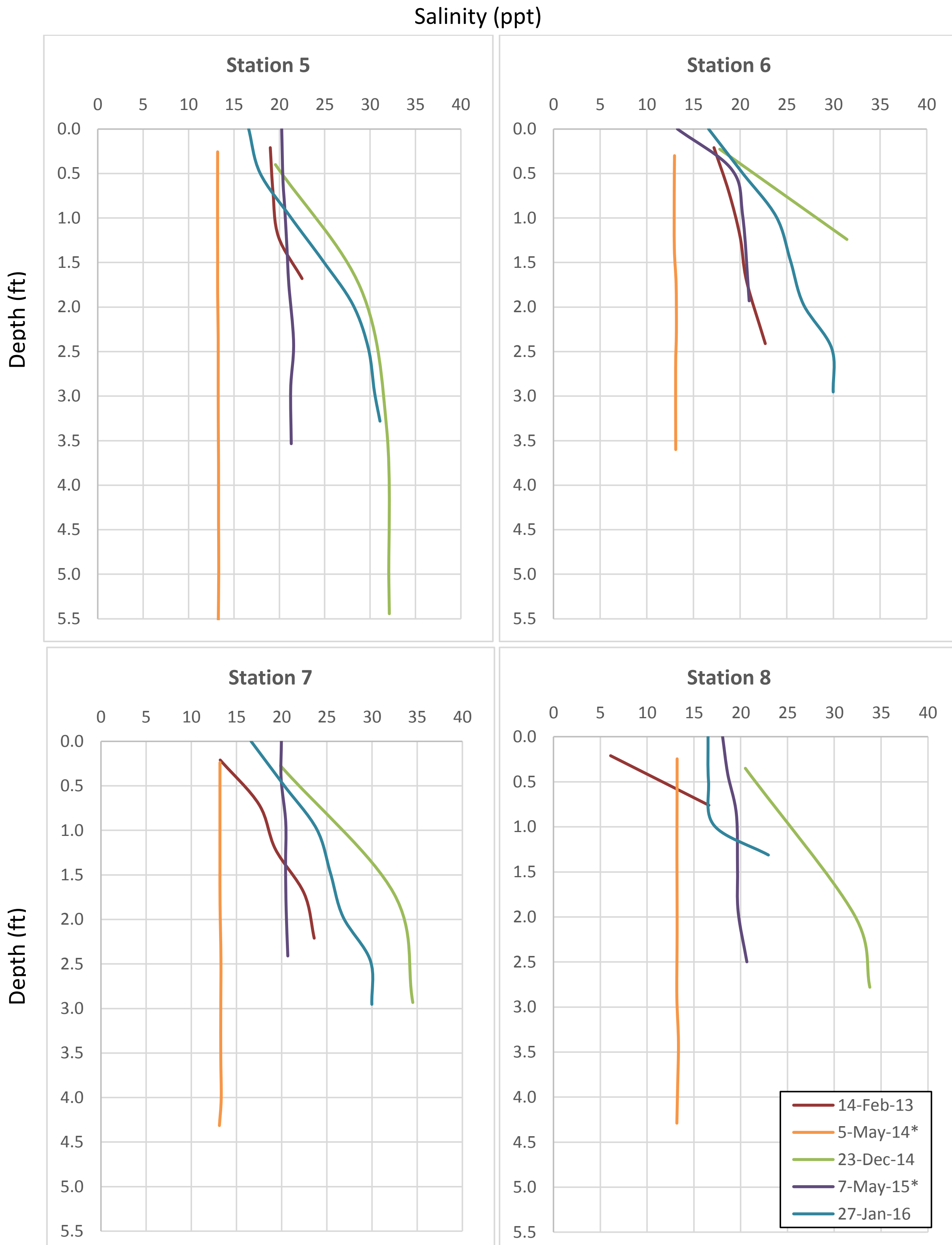



Figure 22b. Post-restoration salinity vertical water quality profiles at Stations 5-8. Asterisk indicates a closed berm condition.

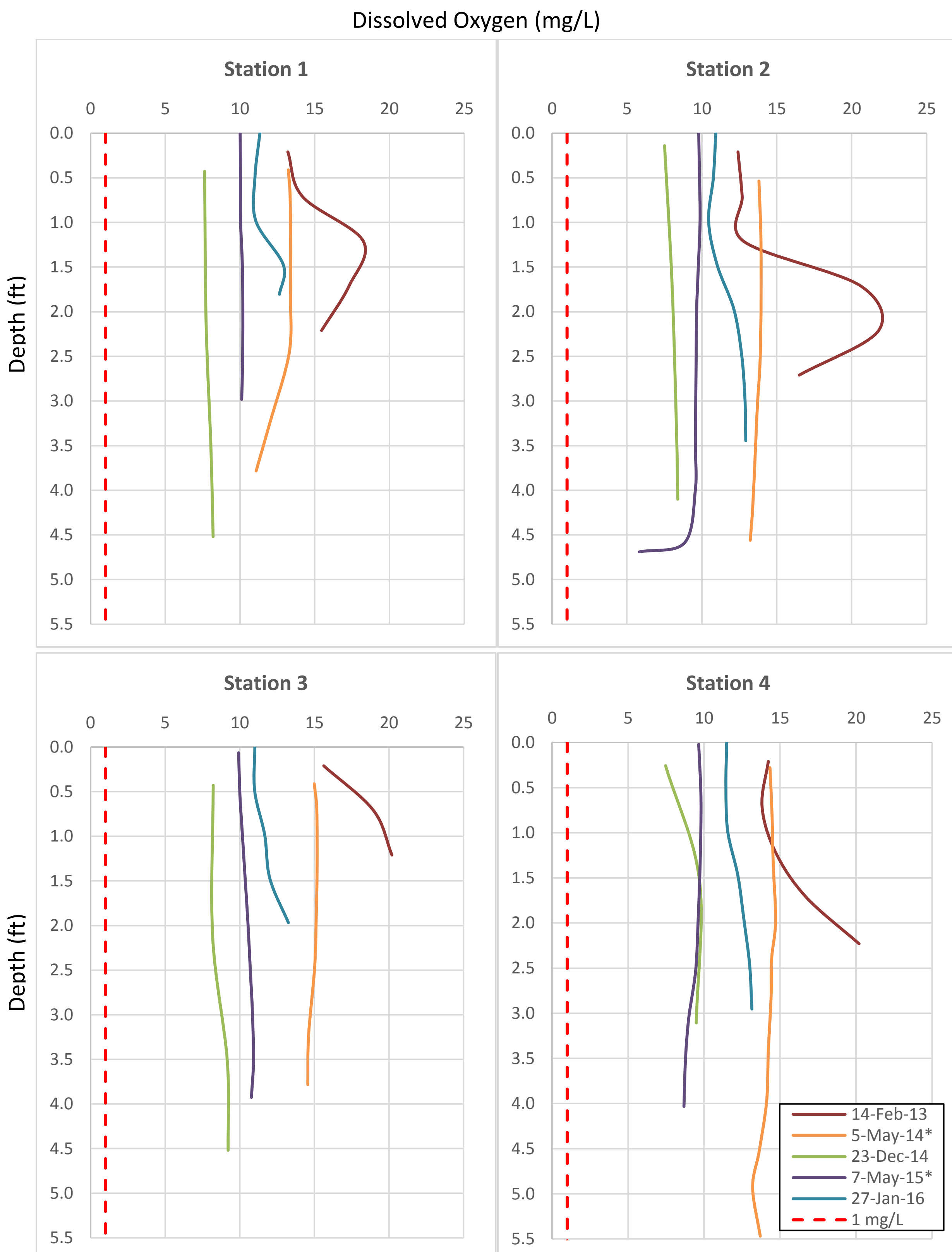



Figure 23a. Post-restoration dissolved oxygen vertical water quality profiles at Stations 1-4 (red line represents 1 mg/L threshold). Asterisk indicates a closed berm condition.

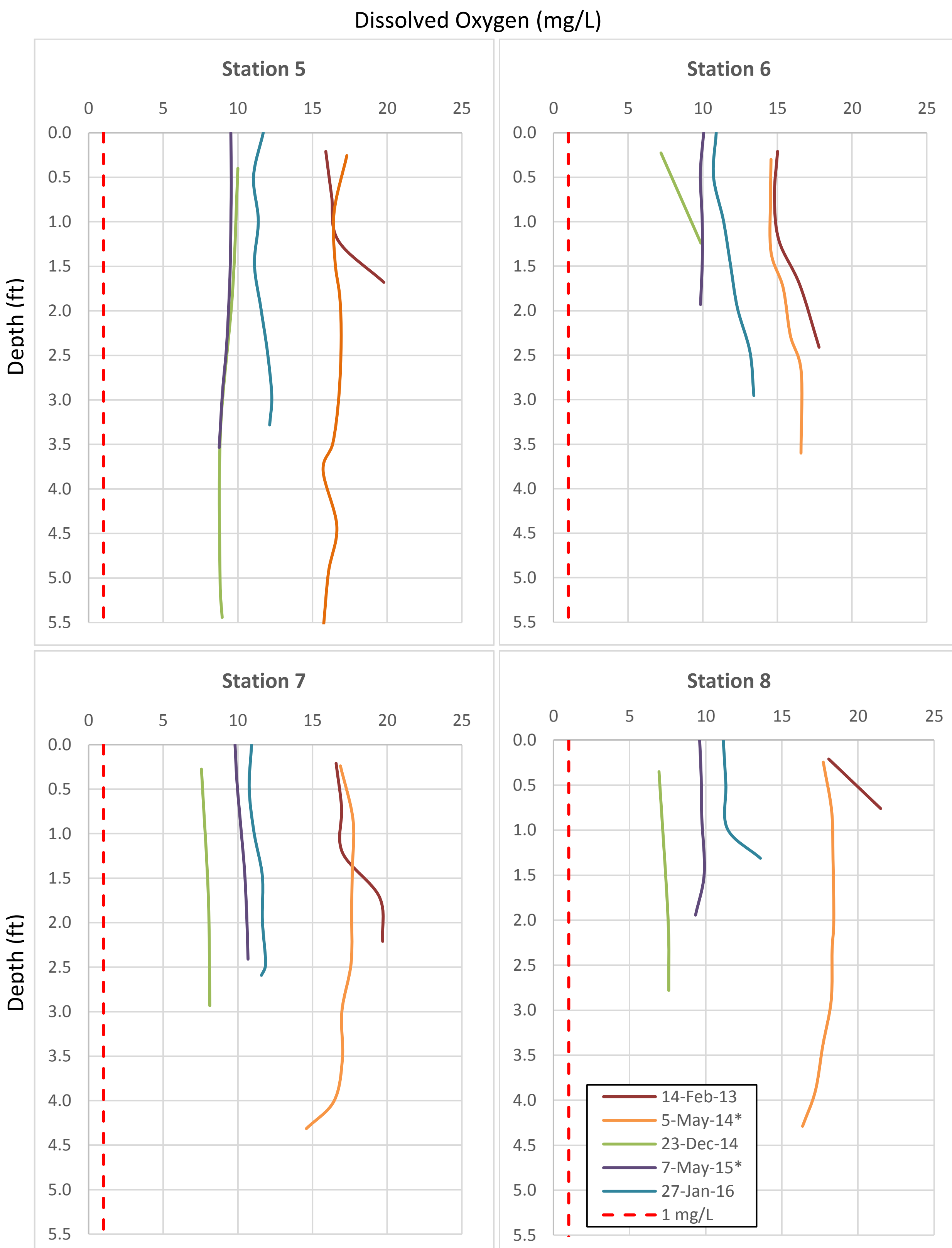



Figure 23b. Post-restoration dissolved oxygen vertical water quality profiles at Stations 5-8 (red line represents 1 mg/L threshold). Asterisk indicates a closed berm condition.

Table 8. Minimum and maximum values for each parameter measured across each survey date. Asterisk indicates a closed berm condition. "N/A" indicates a probe failure for that parameter as described in methods above.

| Survey Date | Temperature (°C) | | Salinity (ppt) | | Dissolved Oxygen (mg/L) | | pH | |
|---|---|---|---|---|---|---|---|---|
| | Min | Max | Min | Max | Min | Max | Min | Max |
| 14-Feb-13 | 14.69 | 21.70 | 6.10 | 29.10 | 12.41 | 21.80 | 8.00 | 8.55 |
| 5-May-14 * | 20.81 | 24.27 | 10.68 | 13.42 | 11.08 | 18.41 | 9.03 | 9.33 |
| 23-Dec-14 | 14.44 | 17.30 | 17.82 | 35.08 | 6.93 | 10.00 | 7.24 | 8.06 |
| 7-May-15 * | 20.99 | 18.62 | 13.28 | 20.21 | 10.92 | 8.68 | 8.86 | 7.79 |
| 27-Jan-16 | N/A | N/A | 14.88 | 31.09 | 10.45 | 13.59 | N/A | N/A |

Table 9. 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 |
|---|---|---|---|---|---|---|---|---|---|
| 14-Feb-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-May-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 |
| | | | | | | | | | |
| 23-Dec-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 |

| Date | Station | Average Temperature (°C) | SE Temp | Average Salinity (ppt) | SE Salinity | Average DO (mg/L) | SE DO | Average pH | SE pH |
|---|---|---|---|---|---|---|---|---|---|
| 7-May-2015* | 1 | 20.83 | 0.05 | 20.63 | 0.15 | 10.10 | 0.03 | 8.76 | 0.01 |
| | 2 | 20.41 | 0.05 | 20.87 | 0.12 | 9.26 | 0.35 | 8.84 | 0 |
| | 3 | 20.13 | 0.03 | 20.48 | 0.08 | 10.48 | 0.12 | 8.78 | 0.01 |
| | 4 | 20.34 | 0.09 | 20.92 | 0.16 | 9.39 | 0.15 | 8.85 | 0 |
| | 5 | 19.95 | 0.10 | 20.90 | 0.17 | 9.32 | 0.11 | 8.80 | 0.01 |
| | 6 | 19.42 | 0.26 | 18.41 | 1.75 | 9.94 | 0.04 | 8.76 | 0.02 |
| | 7 | 19.24 | 0.09 | 20.33 | 0.12 | 10.28 | 0.14 | 8.61 | 0.03 |
| | 8 | 18.81 | 0.12 | 19.38 | 0.37 | 9.65 | 0.09 | 8.27 | 0.12 |
| | | | | | | | | | |
| 27-Jan-2016 | 1 | - | - | 21.73 | 2.72 | 11.79 | 0.41 | - | - |
| | 2 | - | - | 23.43 | 2.23 | 11.72 | 0.36 | - | - |
| | 3 | - | - | 21.80 | 2.28 | 11.79 | 0.42 | - | - |
| | 4 | - | - | 23.35 | 2.35 | 12.21 | 0.28 | - | - |
| | 5 | - | - | 24.99 | 2.05 | 11.64 | 0.16 | - | - |
| | 6 | - | - | 24.67 | 1.86 | 11.96 | 0.40 | - | - |
| | 7 | - | - | 23.61 | 2.07 | 11.35 | 0.16 | - | - |
| | 8 | - | - | 18.30 | 1.56 | 11.87 | 0.58 | - | - |

### *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 in May 2014 and May 2015 never fell below 11 mg/L and 8 mg/L respectively. 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*

Year 3 semi-annual surface water and bottom water samples were collected at the eight vertical profile Stations (Figure 15) on 7 May 2015 and 27 January 2016, as described in the Monitoring Plan. May 2015 samples were processed by Eurofins Calscience, Inc., and January 2016 samples were processed by TestAmerica, 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 2008-2015 (data were received from Heal the Bay on 26 May 2016).

### *Results*

Graphs displaying data from pre- and post-construction monitoring at all Stations are presented in Figures 24 (bottom) and 25 (surface). Figures 24a, 24b, 25a, and 25b display the values of nitrate plus nitrite as N concentrations for pre- and post-restoration surveys. Figures 24c, 24d, 25c, and 25d display the values of Total Kjeldahl nitrogen (TKN) concentrations for pre- and post-restoration surveys. Figures 24e, 24f, 25e, and 25f display the values of total phosphorous (TP) concentrations for pre- and post-restoration surveys. Figures 24g, 24h, 25g, and 25h display the values for orthophosphate concentrations for pre- and post-restoration surveys. Figures 24i, 24j, 25i, and 25j display the values for ammonia concentrations for pre- and post-restoration surveys. Figures 25k and 25l 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). Note that several of the sample concentration values overlap in the graphs (e.g. Figure 24b, multiple zero readings) and the y-axes vary based on constituent.

The post-restoration nutrient concentrations remained relatively constant. The exceptions found in the 30 December 2014 surveys (Year 2 Report), which showed higher nutrient concentrations across multiple parameters [i.e. TKN (in bottom samples only), TP, and chlorophyll *a*], were not identified in either of the 2015 (Year 3) surveys. In fact, 65% of results in the January 2016 samples were listed as “ND”, or “non-detect”, which means that the concentrations were below the detection limit of the equipment and are represented in the graphs as zeros. The higher concentrations in December 2014 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 10), as well as higher “grades” post-restoration (i.e. B, B, and A, respectively) than preceding the restoration (C, B, and F, respectively).

Table 10. Summary annual grade from the bacteria Beach Report Card Heal the Bay data (received 26 May 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 |
| 2015 | A | 11 |

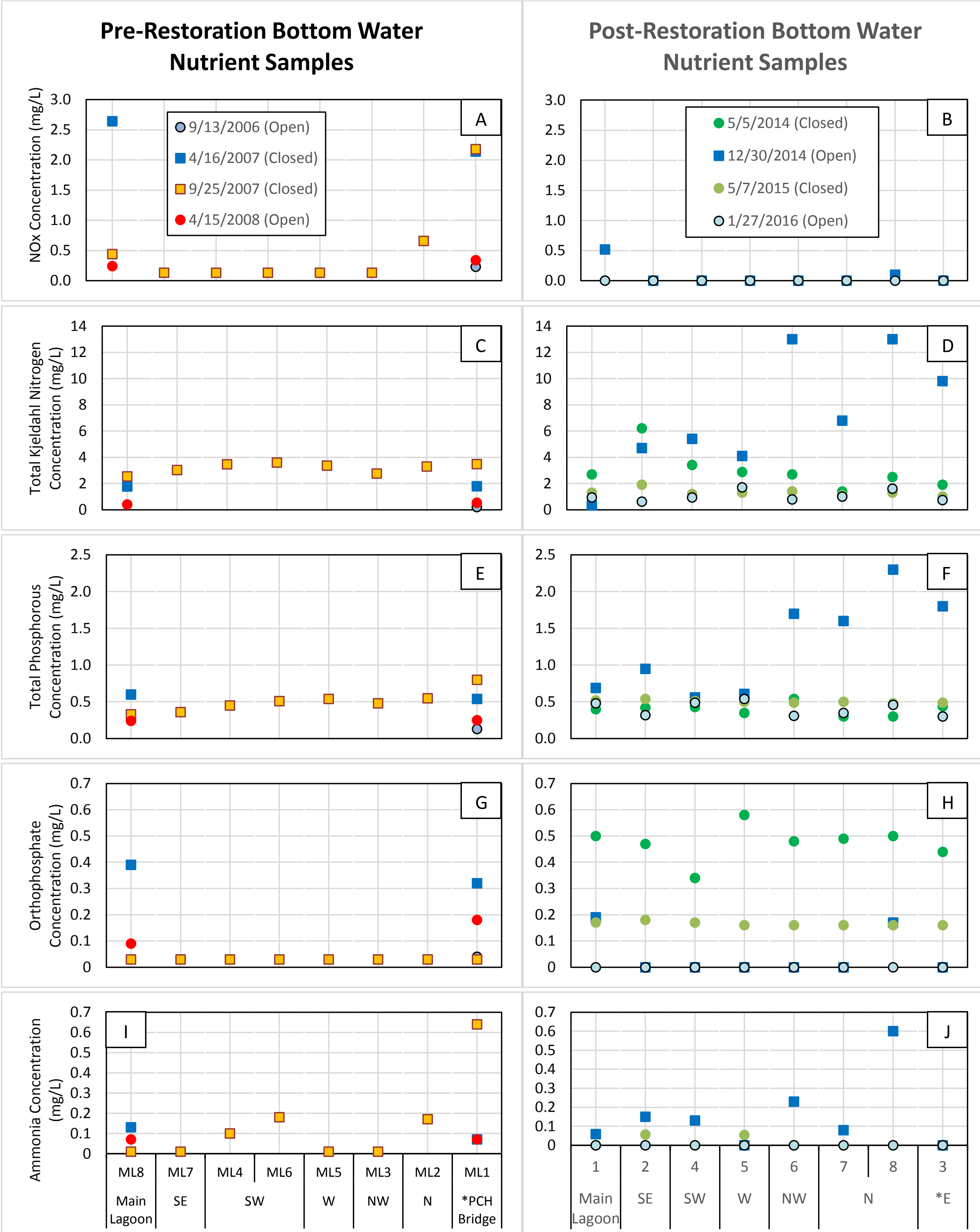
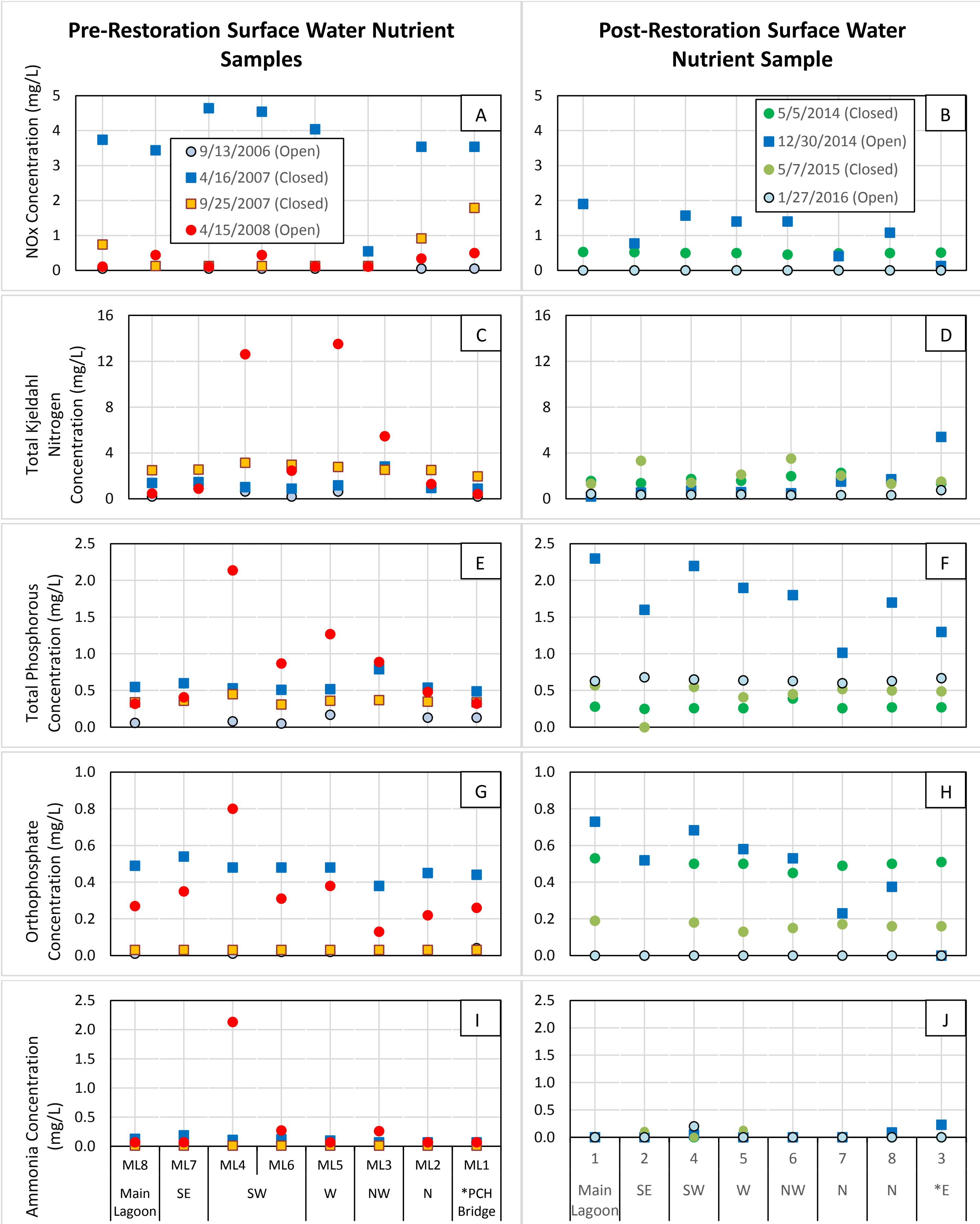



Figure 24. Graphs displaying bottom water nutrients concentrations from pre- (left) and post-restoration (right) surveys.



Pre-Restoration Surface Water Nutrient Samples
Post-Restoration Surface Water Nutrient Sample
A
B
C
D
E
F
G
H
I
J
NOx Concentration (mg/L)
Total Kjeldahl Nitrogen Concentration (mg/L)
Total Phosphorous Concentration (mg/L)
Orthophosphate Concentration (mg/L)
Ammonia Concentration (mg/L)
9/13/2006 (Open)
4/16/2007 (Closed)
9/25/2007 (Closed)
4/15/2008 (Open)
5/5/2014 (Closed)
12/30/2014 (Open)
5/7/2015 (Closed)
1/27/2016 (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
N
*E

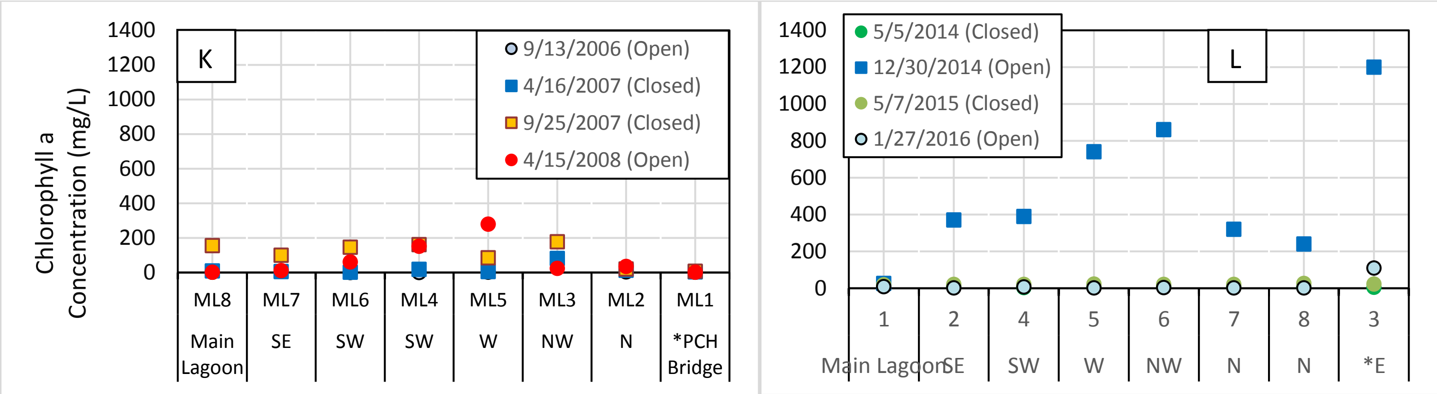



Figure 25. Graphs displaying surface water nutrients concentrations from pre- (left) and post-restoration (right) surveys.

### *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 (Year 2 results) are possibly the result of non-project area discharges, as the December 2014 samples were collected during the Tapia Facility's permitted discharge dates into Malibu Creek (November 15 – April 15). Anomalous data were not seen in the January 2016 data within the Tapia discharge period, and consistent low concentrations of nutrients remained present through the Year 3 surveys.

Additionally, based on Heal the Bay Beach Report Card data, the post-restoration trend appears to be declining numbers of TMDL exceedances and an increased "grade", post-restoration; however, more data points (years) are needed to evaluate a long-term trend as 2013-2015 had reduced rainfall, compared to the average for the area. Interestingly, the Surfrider location has not been on the Heal the Bay "Beach Bummer" list since the restoration was completed in 2013.

## Sediment Quality – Sediment Grain Size and 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 15) on 30 December 2014, 7 May 2015, and 21 January 2016. Year 3 samples taken on 7 May 2015 were processed by Eurofins Calscience, Inc. and 21 January 2016 samples were processed by TestAmerica, Inc., including: grain size, total organic carbon, percent moisture, nitrate plus nitrite as Nitrogen, total phosphorus, TKN (ammonia, organic, and reduced nitrogen), and total nitrogen (includes TKN nitrogen). May 2014 and December 2014 laboratory results reported median grain size, while May 2015 reported mean grain size, and January 2016 reported dominant grain percentage. The dominant grain percentage generally corresponded to median grain size, with some exceptions. In the future, only median grain size will be analyzed.

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 26). 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, May 2015, and January 2016 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 based on the laboratory conducting the analysis at that time.

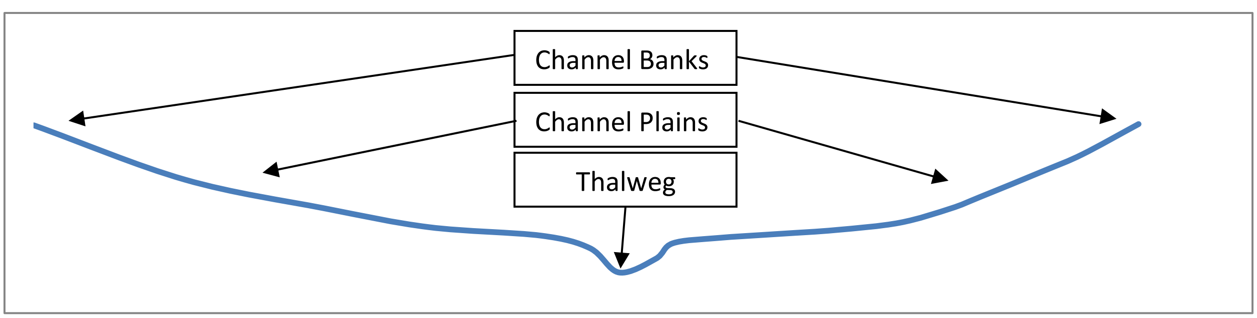



Figure 26. Representative channel cross section displaying the locations of sediment quality collection zones.

Sediment data were collected during pre-restoration conditions at four sampling locations (Figure 27) 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 27. 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 May 2014, December 2014, May 2015, and January 2016 surveys were summarized in Table 11. Overall, the thalweg sampling locations exhibited lower proportions of gravel than the channel plain and channel bank composite samples; however, the January 2016 survey showed an increased proportion of thalweg gravel at Stations 1 and 8 (adjacent to the Malibu Creek). Of the eight Stations surveyed during all sampling periods, the proportion of fine grained sediment (i.e. silt and clay) generally varied according to open or closed conditions. As an example, the Year 2 Malibu Report indicated the largest increase occurred at Station 8 which experienced an increased percentage of fine grained sediments from 1.2% in April 2014 (closed) to 44% in December 2014 (open). However, for the May 2015 survey (closed) the percentage decreased again back down to 1.26% and then increased slightly to 19.3% in January 2016 (open), showing seasonal patterns of water flushing throughout the Lagoon.

Table 11. Sediment grain size analysis for all cross sections. 'Channel Banks' and 'Channel Plains' categories for May 2014, May 2015, and January 2016 surveys are each composited from the left and right sides of the channel (see Figure 26). 'Channel' category for December 2014 is a composite of the 'Channel Banks' and 'Channel Plains' 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 Banks | 65.2 | 34.8 | 0.0 | Silt |
| | | Channel Plains | 14.1 | 56.3 | 29.6 | Medium Sand |
| | | Thalweg | 55.1 | 44.9 | 0.0 | Silt |
| | 3 | Channel Banks | 15.5 | 69.0 | 15.6 | Fine Sand |
| | | Channel Plains | 6.5 | 81.0 | 12.5 | Medium Sand |
| | | Thalweg | 69.8 | 30.2 | 0.0 | Silt |
| | 4 | Channel Banks | 2.4 | 74.3 | 23.3 | Medium Sand |
| | | Channel Plains | 16.4 | 76.5 | 7.1 | Fine Sand |
| | | Thalweg | 22.9 | 77.1 | 0.0 | Fine Sand |
| | 5 | Channel Banks | 13.3 | 74.9 | 11.8 | Medium Sand |
| | | Channel Plains | 11.1 | 83.4 | 5.5 | Medium Sand |
| | | Thalweg | 64.5 | 35.5 | 0.0 | Silt |
| | 8 | Channel Banks | 33.3 | 66.7 | 0.0 | Fine Sand |
| | | Channel Plains | 5.3 | 67.8 | 26.9 | Medium Sand |
| | | Thalweg | 1.2 | 41.6 | 57.2 | Gravel |
| | | | | | | |
| 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 |

| | Station | Location | Total Silt and Clay % (0 to 0.0625 mm) | Sand % (0.0625 mm to 2 mm) | Gravel % (>2 mm) | Mean Grain Size |
|---|---|---|---|---|---|---|
| May 2015 | 1 | Channel Banks | 34.82 | 56.76 | 8.4 | Silt |
| | | Channel Plains | 56.23 | 36.85 | 6.9 | Silt |
| | | Thalweg | 70.48 | 28.61 | 0.9 | Silt |
| | 2 | Channel Banks | 37.11 | 62.78 | 0.1 | Silt |
| | | Channel Plains | 68.14 | 31.85 | 0.0 | Silt |
| | | Thalweg | 7.16 | 92.36 | 0.5 | Course Sand |
| | 3 | Channel Banks | 11.06 | 76.85 | 12.1 | Course Sand |
| | | Channel Plains | 13.24 | 85.31 | 1.4 | Course Sand |
| | | Thalweg | 4.12 | 81.1 | 14.8 | Course Sand |
| | 4 | Channel Banks | 19.38 | 78.29 | 2.3 | Medium Sand |
| | | Channel Plains | 39.44 | 58.47 | 2.1 | Silt |
| | | Thalweg | 38.83 | 60.00 | 1.2 | Silt |
| | 5 | Channel Banks | 3.17 | 89.69 | 7.1 | Course Sand |
| | | Channel Plains | 6.76 | 87.36 | 5.9 | Very Course Sand |
| | | Thalweg | 0.80 | 79.18 | 20.0 | Very Course Sand |
| | 6 | Channel Banks | 33.01 | 59.84 | 7.1 | Silt |
| | | Channel Plains | 33.74 | 66.26 | 0.0 | Silt |
| | | Thalweg | 36.6 | 57.28 | 6.1 | Silt |
| | 7 | Channel Banks | 4.20 | 87.00 | 8.8 | Course Sand |
| | | Channel Plains | 13.59 | 72.32 | 14.1 | Sand |
| | | Thalweg | 40.72 | 50.14 | 9.1 | Silt |
| | 8 | Channel Banks | 2.72 | 90.73 | 6.6 | Medium Sand |
| | | Channel Plains | 22.28 | 77.73 | 0.0 | Sand |
| | | Thalweg | 1.26 | 85.83 | 12.9 | Course Sand |

| | Station | Location | Total Silt and Clay % (0 to 0.0625 mm) | Sand % (0.0625 mm to 2 mm) | Gravel % (>2 mm) | Dominant Grain Size |
|---|---|---|---|---|---|---|
| January 2016 | 1 | Channel Banks | 32.2 | 67.8 | 0.0 | Fine Sand |
| | | Channel Plains | 28.0 | 66.2 | 5.8 | Fine Sand |
| | | Thalweg | 20.2 | 40.3 | 39.5 | Fine Sand |
| | 2 | Channel Banks | 31.3 | 66.3 | 2.4 | Fine Sand |
| | | Channel Plains | 50.6 | 48.9 | 0.5 | Silt |
| | | Thalweg | 90.0 | 10.0 | 0.0 | Silt |
| | 3 | Channel Banks | 17.6 | 55.9 | 26.5 | Gravel |
| | | Channel Plains | 60.2 | 37.8 | 2.0 | Silt |
| | | Thalweg | 83.1 | 16.9 | 0.0 | Silt |
| | 4 | Channel Banks | 32.6 | 63.2 | 4.2 | Fine Sand |
| | | Channel Plains | 30.3 | 66.4 | 3.3 | Fine Sand |
| | | Thalweg | 19.7 | 76.6 | 3.7 | Fine Sand |
| | 5 | Channel Banks | 17.3 | 72.2 | 10.5 | Medium Sand |
| | | Channel Plains | 18.9 | 77 | 4.1 | Medium Sand |
| | | Thalweg | 4.3 | 93.6 | 2.2 | Fine Sand |
| | 6 | Channel Banks | 22.7 | 55 | 22.4 | Fine Sand |
| | | Channel Plains | 40.4 | 49.2 | 10.4 | Fine Sand |
| | | Thalweg | * | * | * | * |
| | 7 | Channel Banks | 23.4 | 70.7 | 5.9 | Fine Sand |
| | | Channel Plains | 19.9 | 59 | 21.1 | Fine-Medium Sand |
| | | Thalweg | 73.5 | 26.5 | 0.0 | Silt |
| | 8 | Channel Banks | 14.1 | 82.3 | 3.6 | Fine-Medium Sand |
| | | Channel Plains | 21.9 | 57.1 | 21.0 | Fine-Medium Sand |
| | | Thalweg | 19.3 | 58.5 | 22.2 | Medium Sand |

* indicates a sample that was not completed by the processing laboratory even though it was collected and delivered with the other samples.

### Sediment Nutrients

Table 12 displays sediment nutrient values from all Stations for pre-restoration surveys; Table 13 displays post-restoration sediment nutrient values. Overall, nutrient concentrations, specifically nitrate plus nitrite as N and total phosphorous, were lower during the December 2014, May 2015, and January 2016 surveys when compared to May 2014 surveys. On the whole, across all Stations, there was little or no detection of nitrate plus nitrite as N. Total Kjeldahl nitrogen (TKN) and total nitrogen (TN) concentrations remained relatively consistent across survey dates with the exception of spikes in May 2015 at Station 3 bank (1,500 mg/kg, dropped to 270 mg/kg January 2016 survey), Station 6 plain (2,200 mg/kg, dropped to 520 mg/kg January 2016 survey), Station 8 plain (2,200 mg/kg, dropped to 1,000 mg/kg January 2016 survey) and thalweg (1,300 mg/kg, dropped to 440 mg/kg January 2016 survey. For the January 2016 data, spikes were seen at Station 6 Thalweg (1,400 mg/kg) and at Station 8 Thalweg (1,000 mg/kg). However, those spikes were several times smaller than thalweg spikes at several of the pre-restoration Stations (Table 12).

Table 12. 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 | Channel Bank | 14.00 | 3260.00 | 3230.00 | 1180.00 |
| | | Channel Plain | 1.00 | 2050.00 | 2050.00 | 651.00 |
| | | Thalweg | 1.00 | 3500.00 | 3500.00 | 1290.00 |
| | D | Channel Bank | 1.00 | 592.00 | 592.00 | 296.00 |
| | | Channel Plain | 1.00 | 1220.00 | 1220.00 | 505.00 |
| | | Thalweg | 1.00 | 3610.00 | 3610.00 | 0.09 |

| | Station | Location | Nitrate (mg/kg) | TN (mg/kg) | TKN (mg/kg) | TP (mg/kg) |
|---|---|---|---|---|---|---|
| September 2007 | A | Channel Bank | 1.00 | 385.00 | 385.00 | 331.00 |
| | | Channel Plain | 1.00 | 812.00 | 812.00 | 316.00 |
| | | Thalweg | 1.00 | 3610.00 | 3610.00 | 0.09 |
| | B | Channel Bank | 1.00 | 612.00 | 612.00 | 402.00 |
| | | Channel Plain | 1.00 | 1640.00 | 1640.00 | 511.00 |
| | | Thalweg | 1.00 | 1210.00 | 1210.00 | 328.00 |
| | C | Channel Bank | 1.43 | 2466.00 | 2466.00 | 474.00 |
| | | Channel Plain | 1.80 | 655.00 | 653.00 | 535.00 |
| | | Thalweg | 1.00 | 1450.00 | 1450.00 | 253.00 |
| | D | Channel Bank | 1.00 | 466.00 | 466.00 | 289.00 |
| | | Channel Plain | 1.00 | 296.00 | 296.00 | 332.00 |
| | | Thalweg | 1.00 | 997.00 | 997.00 | 344.00 |
| | | | | | | |
| April 2008 | A | Channel Bank | 4.80 | 255.00 | 250.00 | 331.00 |
| | | Channel Plain | ND | 260.00 | 260.00 | 357.00 |
| | | Thalweg | ND | 280.00 | 280.00 | 263.00 |
| | B | Channel Bank | ND | 730.00 | 730.00 | 386.00 |
| | | Channel Plain | ND | 980.00 | 980.00 | 376.00 |
| | | Thalweg | ND | 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 13. 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 |
| | | Channel Plain | 2.22 | 754.00 | 752.00 | 588.00 |
| | | Thalweg | 3.28 | 1921.00 | 1920.00 | 631.00 |
| | 3 | Channel Bank | 0.72 | 572.00 | 571.00 | 608.00 |
| | | Channel Plain | 2.47 | 788.50 | 786.00 | 678.00 |
| | | Thalweg | 0.66 | 1340.70 | 1340.00 | 575.00 |
| | 4 | Channel Bank | 0.51 | 276.00 | 276.00 | 245.00 |
| | | Channel Plain | 2.47 | 788.50 | 786.00 | 678.00 |
| | | Thalweg | 1.41 | 533.00 | 532.00 | 501.00 |
| | | Channel Bank | 1.39 | 385.00 | 384.00 | 625.00 |

| | Station | Location | Nitrate + Nitrite, as N (mg/kg) | TN (mg/kg) | TKN (mg/kg) | TP (mg/kg) |
|---|---|---|---|---|---|---|
| | 5 | Channel Plain | 3.23 | 453.20 | 450.00 | 526.00 |
| | | Thalweg | 1.41 | 595.00 | 594.00 | 428.00 |
| | 8 | Channel Bank | 1.10 | 388.00 | 387.00 | 646.00 |
| | | Channel Plain | 1.28 | 366.00 | 365.00 | 406.00 |
| | | Thalweg | 0.52 | 553.00 | 553.00 | 348.90 |
| | | | | | | |
| December 2014 | 1 | Channel | ND | 810.00 | 800.00 | 130.67 |
| | | Thalweg | ND | 98.00 | 98.00 | 250.00 |
| | 2 | Channel | ND | 840.00 | 840.00 | 200.00 |
| | | Thalweg | 0.62 | 850.00 | 850.00 | 180.00 |
| | 3 | Channel | ND | 630.00 | 630.00 | 230.00 |
| | | Thalweg | ND | 390.00 | 390.00 | 180.00 |
| | 4 | Channel | ND | 430.00 | 430.00 | 245.00 |
| | | Thalweg | ND | 330.00 | 335.00 | 210.00 |
| | 5 | Channel | ND | 420.00 | 420.00 | 200.00 |
| | | Thalweg | ND | 690.00 | 690.00 | 110.00 |
| | 6 | Channel | 0.93 | 800.00 | 800.00 | 56.00 |
| | | Thalweg | ND | 220.00 | 220.00 | 250.00 |
| | 7 | Channel | 1.40 | 550.00 | 550.00 | 270.00 |
| | | Thalweg | ND | 390.00 | 390.00 | 190.00 |
| | 8 | Channel | 5.20 | 520.00 | 510.00 | 210.00 |
| | | Thalweg | ND | 720.00 | 720.00 | 120.00 |
| | | | | | | |
| May 2015 | 1 | Channel Bank | 3.00 | 3.00 | ND | 290.00 |
| | | Channel Plain | ND | 530.00 | 530.00 | 190.00 |
| | | Thalweg | ND | 690.00 | 690.00 | 190.00 |
| | 2 | Channel Bank | 0.89 | 690.00 | 690.00 | 260.00 |
| | | Channel Plain | ND | 760.00 | 760.00 | 200.00 |
| | | Thalweg | ND | 84.00 | 84.00 | 190.00 |
| | 3 | Channel Bank | ND | 1500.00 | 1500.00 | 220.00 |
| | | Channel Plain | ND | 460.00 | 460.00 | 210.00 |
| | | Thalweg | ND | 210.00 | 210.00 | 170.00 |
| | 4 | Channel Bank | ND | 460.00 | 460.00 | 270.00 |
| | | Channel Plain | ND | 520.00 | 520.00 | 210.00 |
| | | Thalweg | ND | 460.00 | 410.00 | 210.00 |
| | 5 | Channel Bank | 0.60 | 280.00 | 280.00 | 270.00 |
| | | Channel Plain | ND | 360.00 | 360.00 | 230.00 |
| | | Thalweg | ND | 210.00 | 210.00 | 210.00 |
| | 6 | Channel Bank | ND | 480.00 | 480.00 | 180.00 |

| | Station | Location | Nitrate + Nitrite, as N (mg/kg) | TN (mg/kg) | TKN (mg/kg) | TP (mg/kg) |
|---|---|---|---|---|---|---|
| | | Channel Plain | ND | 2200.00 | 2200.00 | 31.00 |
| | | Thalweg | ND | ND | ND | 57.00 |
| | 7 | Channel Bank | 1.1 | 450.00 | 450.00 | 210.00 |
| | | Channel Plain | ND | 970.00 | 970.00 | 41.00 |
| | | Thalweg | ND | 420.00 | 420.00 | 220.00 |
| | 8 | Channel Bank | ND | 170.00 | 200.00 | 230.00 |
| | | Channel Plain | ND | 2200.00 | 2200.00 | 70.00 |
| | | Thalweg | ND | 1300.00 | 1300.00 | 380.00 |
| | | | | | | |
| January 2016 | 1 | Channel Bank | 1.30 | 520.00 | 520.00 | 280.00 |
| | | Channel Plain | ND | 390.00 | 390.00 | 230.00 |
| | | Thalweg | ND | 770.00 | 770.00 | 200.00 |
| | 2 | Channel Bank | ND | 420.00 | 420.00 | 220.00 |
| | | Channel Plain | ND | 530.00 | 530.00 | 160.00 |
| | | Thalweg | ND | 660.00 | 660.00 | 180.00 |
| | 3 | Channel Bank | 3.00 | 270.00 | 270.00 | 240.00 |
| | | Channel Plain | ND | 660.00 | 660.00 | 210.00 |
| | | Thalweg | ND | 940.00 | 940.00 | 270.00 |
| | 4 | Channel Bank | ND | 300.00 | 300.00 | 330.00 |
| | | Channel Plain | ND | 180.00 | 180.00 | 200.00 |
| | | Thalweg | ND | 970.00 | 970.00 | 220.00 |
| | 5 | Channel Bank | 1.10 | 520.00 | 520.00 | 270.00 |
| | | Channel Plain | ND | 62.00 | 62.00 | 220.00 |
| | | Thalweg | ND | 290.00 | 290.00 | 220.00 |
| | 6 | Channel Bank | ND | 430.00 | 430.00 | 390.00 |
| | | Channel Plain | ND | 520.00 | 520.00 | 260.00 |
| | | Thalweg | ND | 1400.00 | 1400.00 | 230.00 |
| | 7 | Channel Bank | ND | 510.00 | 510.00 | 410.00 |
| | | Channel Plain | ND | 630.00 | 630.00 | 450.00 |
| | | Thalweg | ND | 600.00 | 600.00 | 180.00 |
| | 8 | Channel Bank | ND | 400.00 | 400.00 | 400.00 |
| | | Channel Plain | ND | 1000.00 | 1000.00 | 280.00 |
| | | Thalweg | ND | 440.00 | 440.00 | 320.00 |

### *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, but a significant decrease was recorded for most Stations in May 2015, with a subsequent modest increase in January 2016. As the deposition and fluctuation of fine-grained sediments is a predictable occurrence in variable 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 7-11) 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 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. Several stations are showing a trend towards larger-grained sediments. Additionally, seasonal patterns of water and sediment movement, including a slight build up during closed conditions and the subsequent 'flushing' of water and sediment out of the Lagoon when it breaches, is consistent with the project goals.

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 in 2014 surveys, and 31 – 450 mg/kg for the 2015 surveys, compared to 0.09 – 1,420 mg/kg during pre-restoration conditions. As another example, the post-restoration total nitrogen sample range was 98 – 1,921 mg/kg in 2014 and 62 – 2,200 mg/kg in 2015 compared to a pre-restoration range of 61.8 – 3,610 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 sampling periods.

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 varied between surveys, possibly from nutrients and associated sediments settled out of the water column within lower water energy environments during the closed conditions (i.e. May 2014 and May 2015 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 as follows:

- 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 15) on 5 May 2014, 30 December 2014, and 21 January 2016 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 26 taxa represented in the post-restoration surveys, including the small benthic cores (23 taxa) and the net sweep (10 taxa) invertebrate data (Table 14). Figures 28 and 29 display data from the 2006 and 2007 pre-restoration surveys, both of the 2014 post-restoration surveys, and the January 2016 survey (Year 3). Post-restoration abundances were dominated by oligochaetes, polychaetes, and ostracods.

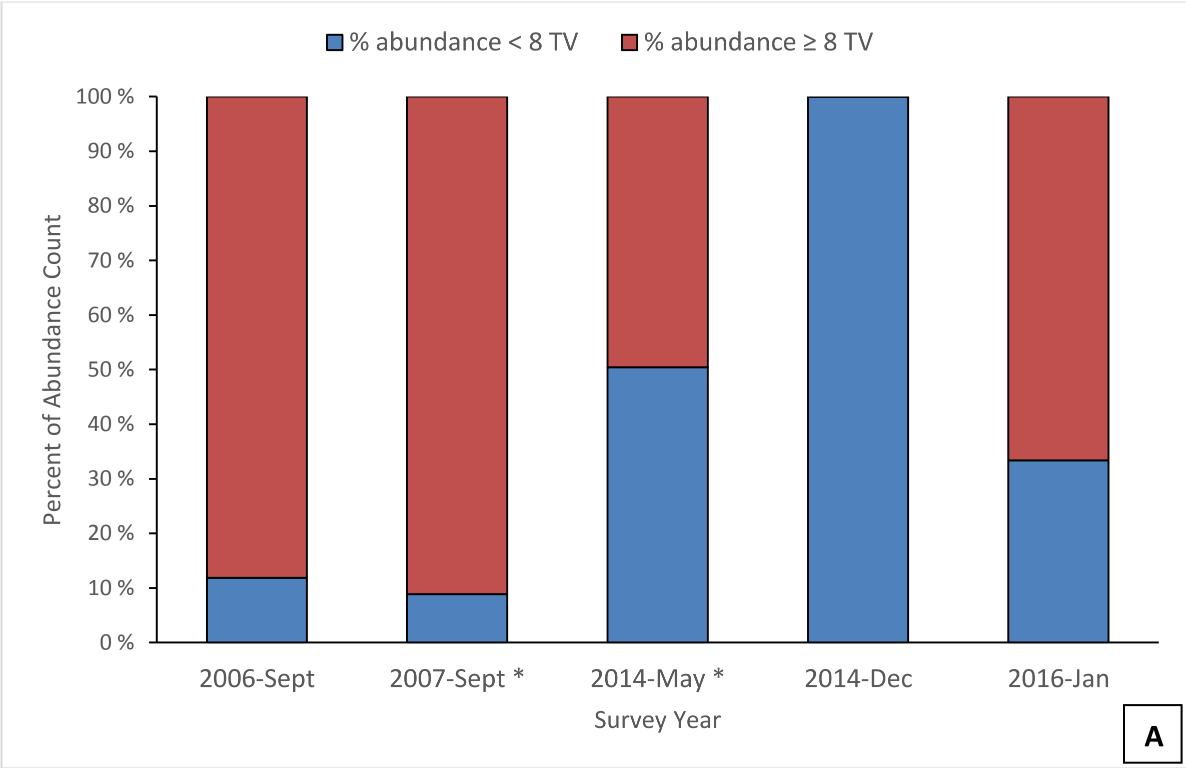
Data are reported using the pollution tolerance values established for freshwater invertebrate species (CAMLnet, CA Fish and Wildlife, 2003), and scores of 8-10 are considered to have high pollution tolerance. Both the benthic core and net sweep data indicated a rise in the percentage of sensitive taxa, or pollution-intolerant species, for the first two post-restoration years (e.g. from 8.9% in 2007 to 99.9% in December of 2014 for benthic core invertebrates) (Figures 28a and 29a), 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). However, during the third monitoring year, the benthic community shifted back to a predominantly pollution-tolerant one (33.4% sensitive taxa for benthic invertebrates and 8.2% sensitive for kick net invertebrates).

A similar trend, albeit less dramatic, was expressed by the percentages of the numbers of taxa, which showed a slight increase in sensitive (pollution-intolerant) species use of the site through December 2014 for both survey types, and a slight decrease in the percent of number of pollution tolerant taxa (Figures 28b and 29b). Both survey types were still above (i.e. benthic community), or approximately the same (i.e. kick net invertebrates) as the pre-restoration conditions.

For additional incidental invertebrate data collected during the fish seining events, see the Fish Community Survey chapter (below).

Table 14. Taxa presence list for all post-restoration surveys combined. Asterisks indicate a closed berm condition.

| Phylum | Class | Order | Family | Lowest Possible Taxon | Benthic Cores | | | Net Sweeps | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | * May 2014 | Dec 2014 | Jan 2016 | * May 2014 | Dec 2014 | Jan 2016 |
| Annelida | Oligochaeta | | | Oligochaeta | | | | X | X | X |
| Annelida | Oligochaeta | Haplotaxida | Tubicidae | Tubicidae | X | | | | | |
| Annelida | Oligochaeta | Haplotaxida | Tubificidae | Tubificidae | | X | X | | | |
| Annelida | Polychaeta | Sedentaria | Capitellidae | *Capitella capitata* cmplx | | X | 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 | Chronomini | X | X | 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 | | X |
| Arthropoda | Insecta | Hemiptera | Corixidae | *Trichocorixa sp.* | X | | | X | | |
| Arthropoda | Malacostraca | Amphipoda | Gammaridae | *Gammarus sp.* | | X | | | | |
| Arthropoda | Maxillopoda | Calanoida | | Calanoida | X | | X | | | |
| Arthropoda | Maxillopoda | Harpactacoida | | Harpactacoida | | | X | | | |
| Arthropoda | Ostracoda | | | Ostracoda | | | | | X | X |
| Arthropoda | Ostracoda | Podocopida | | Podocopida | X | X | X | X | | |
| Chordata | Osteichthys | | | Fish egg/larva | X | | | | | |
| Mollusca | Gastropoda | Opisthobranchia | Hermaeidae | *Alderia willowi* | X | | | | | |
| Nematoda | Adenophorea | Mermithida | Mermithidae | Mermithidae | X | X | X | | | |
| Nemertea | Anopla | Paleonemertea | | Paleonemertea | X | | | | | |
| Platyhelminthes | Turbellaria | Rhabdocoela | | Rhabdocoela | X | | | | | |



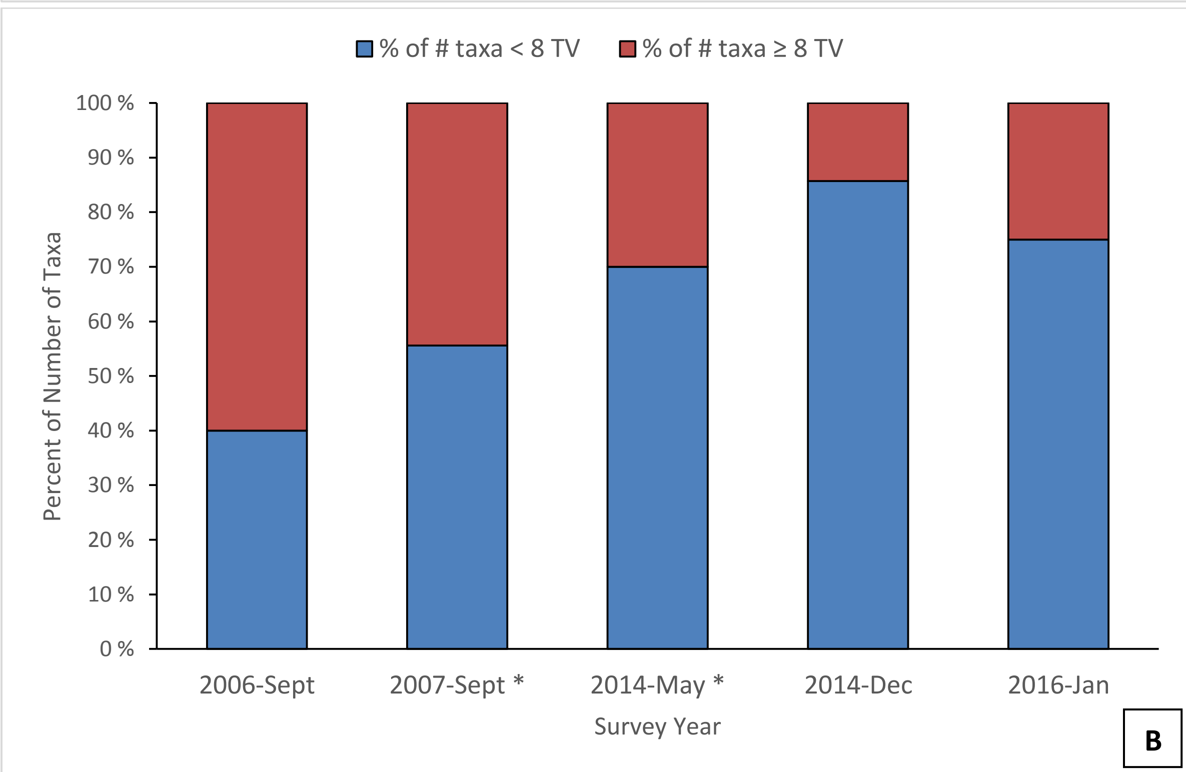




Figure 28. Benthic invertebrate core data results organized by (A) percent of abundance count data with pollution tolerance values (TV) below 8, and (B) percent of number of taxa with TV below 8. Asterisks indicate a closed berm condition.

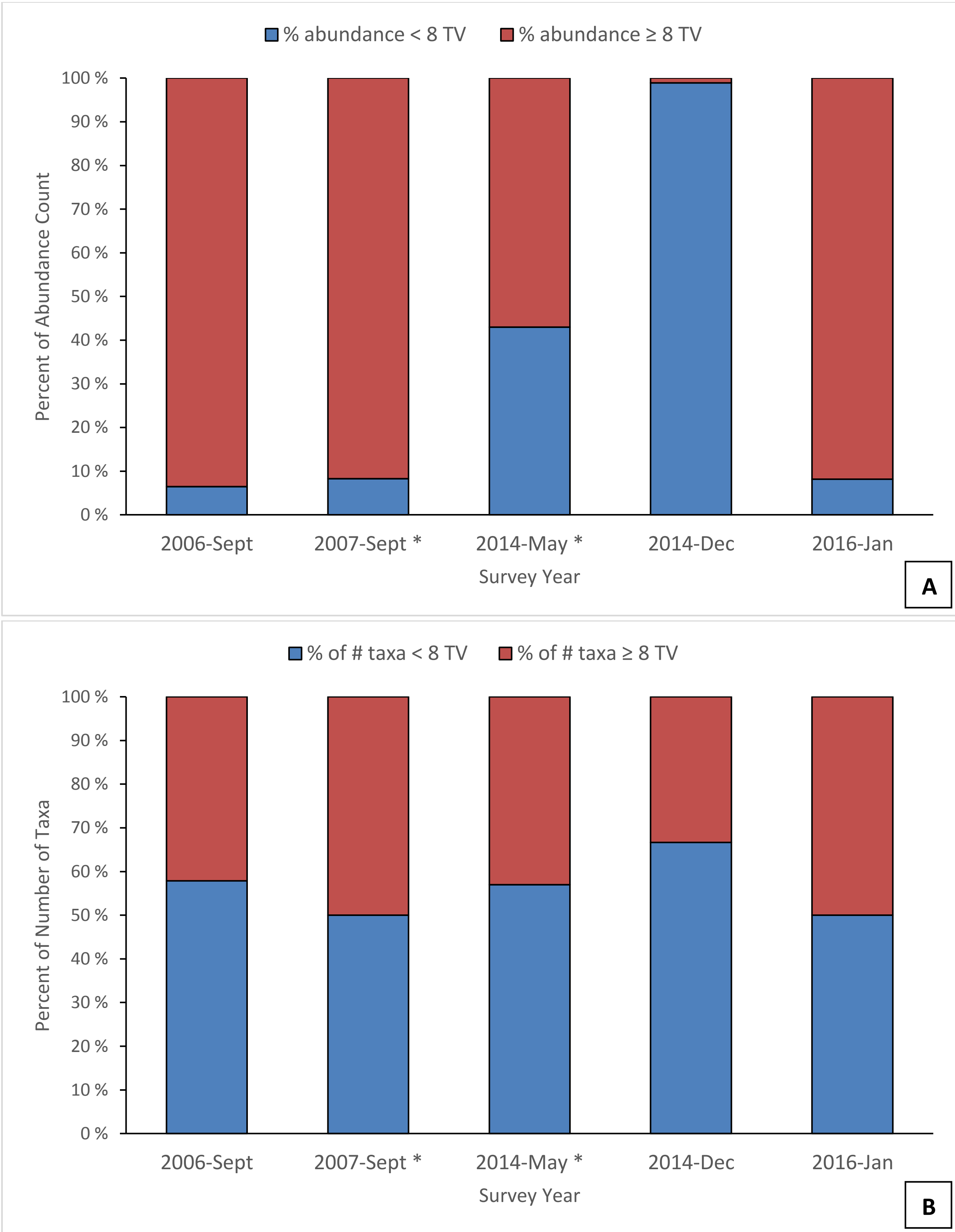



Figure 29. Net sweep invertebrate data results organized by (A) percent of abundance count data with pollution tolerance values (TV) below 8, and (B) percent of number of taxa with TV below 8. Asterisks indicate a closed berm condition.

### *Performance Evaluation*

The invertebrate survey data results initially established as a shift from a depauperate, pollution-tolerant invertebrate community, to a healthier, diverse invertebrate community that included a higher percentage abundance of sensitive species and numbers of taxa. This trend reversed to some degree in the January 2016 survey data results, indicating a decrease in sensitive taxa between December 2014 and January 2016. However, the overall community still currently has abundances and numbers of sensitive taxa that are higher than pre-restoration conditions and no decreases across multiple years; thus, the benthic community is still meeting the project success criteria. It will be important to evaluate these data in conjunction with the next several years to have a full evaluation of trends over time.

Another trend identified has been a shift in the invertebrate community to include more marine (oceanic water) species into the mix of freshwater invertebrate species. As the marine invertebrates are not able to be measured in the CAMLnet (freshwater) invertebrate index, they are not represented in the ‘pollution-tolerant’ analyses. This may weigh the evaluation during open conditions (e.g. January 2016) to appear less favorable to sensitive taxa.

As several other lagoons in Southern California experienced odd trends in conditions due to the effects of El Niño, significantly warmer oceanic waters, and extended berm closure events, it is unclear whether these data represent an accurate shift in the benthic community. Anecdotal sightings of shore crabs, mussels, barnacles, and the occasional sea hare that were not present before the restoration continue to support the robust nature of the benthic community. Additionally, 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. 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, 11 December 2014, 27 May 2015, and 12 January 2016 by a team led by the Resource Conservation District of the Santa Monica Mountains with assistance from CDPR. Pre-restoration surveys were conducted once on 20 June 2005, seven years before the restoration. Due to the continued increases in extremely deep unconsolidated fine grained sediment and anoxic conditions throughout the lagoon between 2005 and the restoration, pre-construction surveys were not possible prior to the start of work in June 2012 and it is likely that the fish community continued to deteriorate after the 2005 surveys were completed due to a lack of appropriate conditions and water quality on site.

Six permanent sites (Figures 30 and 31) were seined to depletion and spot surveying was conducted at three places along the banks of the Main Lagoon. 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.

In May 2015, the survey protocol for the six restoration sites was modified slightly because there were too many fish present to seine all the way to depletion. After repetitive seines with subsequently fewer fish in each seine, the site was considered representatively complete, although the exact abundances were likely slightly higher than the final numbers included in this report.

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 surveyed again (similarly to the second year surveys) to comply with monitoring plan requirements. The lagoon (berm) was closed to the ocean for the May 2015 survey, but it was open for the January 2016 survey.


Figure 30. Map of the six permanent fish monitoring Sites.

Figure 31. Representative photograph of fish surveys being conducted at Site 1 on 12 January 2016 (photo: RCDSMM).

### *Results*

For detailed water quality parameter measurements and fish species counts for each survey, see Appendices 1 and 2 and the first and second-year post-restoration baseline reports (Abramson et al. 2013, 2015). Table 15 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 15. 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 | * May 2015 | Jan 2016 |
|---|---|---|---|---|---|---|---|
| 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 | | X | |
| Northern anchovy | *Engraulis mordax* | | X | | X | | X |
| Opaleye | *Girella nigricans* | X | | | | | |
| Staghorn sculpin | *Leptocottus armatus* | | X | X | | | X |
| Striped mullet | *Mugil cephalus* | | | X | X | X | X |
| Tidewater goby | *Eucyclogobius newberryi* | X | X | X | | X | |
| Topsmelt | *Atherinops sp.* | X | X | X | X | X | X |
| Topsmelt larva (< 5 cm) | *Atherinops sp.* | | | X | | X | X |
| Unidentified fish larva (< 5 cm) | ---- | | | X | | X | |
| Unidentified smelt larva (< 5 cm) | *Atherinops sp.* | | | X | | X | X |
| **Non-Native Fish** | | | | | | | |
| Mississippi silversides | *Menidia berylina* | | X | | X | X | X |
| Mosquitofish | *Gambusia affinis* | X | X | X | X | X | X |
| Carp | *Cyprinus carpio* | X | | X | | | |
| **Invertebrates** | | | | | | | |
| Oriental shrimp | ---- | X | X | X | X | X | X |
| Shore crab | *Hemigrapsus sp.* | | X | X | 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 (January 2013, Table 15) reflect the winter, marine influenced conditions, as compared to the five native species observed in the

June pre-construction survey of 2005. Tidewater gobies (*Eucyclogobius newberryi*) were observed in both the pre- and post-construction surveys. No opaleye (*Girella nigricans*) or long-jawed mudsuckers (*Gillichthys mirabilis*) 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 15). 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. Only a single non-native mosquitofish was captured, compared to thousands of native fish larva, with topsmelt and gobies dominant in number.

**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 15). 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.

**May 2015 Survey**

The dominant identifiable fish species captured in seine nets was topsmelt, which was present in at least three size classes (<5cm, <15cm, >15cm). The second and third dominant species were juvenile tidewater goby and long-jawed mudsuckers. Striped mullet (*Mugil cephalus*), and non-native mosquitofish and Mississippi silversides were also present.

Larval fish (<5cm) were the most abundant category sampled (n=3,235) but were not identifiable in the field due to their small size. Those species are described in Table 15 as 'unidentified fish larva' and 'unidentified smelt larva.' Voucher larval fish specimens indicate there are at least three distinct species present.

**January 2016 Survey**

The dominant identifiable fish species captured in seine nets during this survey was Northern anchovy (*Engraulis mondax*, n=180), although most were quite small (<5 cm). The second dominant species was larval smelt, with a few larger topsmelt (approximately 6-10 cm). A single juvenile staghorn sculpin was captured and released. Striped mullet were observed leaping throughout the lagoon. Although not numerous, non-natives mosquitofish (n=6) and Mississippi silversides (n=15) were also present.

### *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. Both the native fish species richness' and the overall native fish abundances are higher in both of the post-restoration summer surveys than in the pre-restoration summer survey. Non-native fish abundances are lower, post-restoration, and the non-native species richness is the same.

The native fish species documented in the January 2013, December 2014, and January 2016 post-construction surveys reflect the winter, marine influenced conditions, as compared to the native fish species observed in the May surveys. Overall fish species richness was found to be lower, relatively, in the winter surveys, 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. Tidewater gobies were observed in both the pre- and post-construction 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 native habitat diversity and additional wetland habitats would allow for more water-dependent 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 pre-restoration 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.

Twelve 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, 28-29 October 2014, 6-7 January 2015, 21 April 2015 (two surveys completed on this date), 9-10 July 2015, and 26-27 October 2015. Surveyors at Cooper Ecological Monitoring, Inc. surveyed the entire site in the morning or afternoon of consecutive or near-consecutive days to capture 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.

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.

### *Results*

The total number of individual birds recorded during each year of quarterly surveys pre-restoration was remarkably similar (i.e. 7563 and 8489 individuals) prior to 2015; this year, 11,299 individual birds were identified, representing a nearly 30% increase over the prior years' average. Species richness dropped in the first two years post-restoration and rebounded in 2015 (i.e. 117 species in 2005 and 2006 prior to restoration, 87-88 species in 2013 and 2014, and 99 species in 2015). However, comparison of sheer numbers (abundances) and species richness totals is of limited interpretive use, and these counts should not be treated as statistically significant, since they are based on only one or two visits each quarter. Rather, these data should be used to detect possible trends, which can be confirmed in subsequent survey years.

The presence of all landbird and waterbird guild species recorded on all pre- and post-restoration site-wide avifauna surveys are presented in Tables 16 and 17. Quantities and additional details for each identified species can be found in Appendix 3. Several additional years of monitoring will be necessary to confirm these trends.

**Landbird results**

Addressing each ecological guild separately, counts of open country species surged in 2015 (112% over 2014), and showed levels nearly double those during the pre-restoration years. Counts of scrub / woodland species also increased from those in 2014 (and in 2013), but more modestly (11%), and were still short of pre-restoration counts (276 in 2005-06 vs. 129 in 2015); still, species richness within this guild was found to be double that of the first year post-restoration (8 spp. in 2013 vs. 16 spp. in 2015). Urban birds declined in Years 1 and 2 post-restoration, and their numbers have remained below pre-restoration levels, though increasing slightly in Year 3 (320 birds in 2005-06 vs. 67 in 2015).

**Waterbird results**

Fish-eating waterbirds (e.g., Ruddy Duck) showed relatively dramatic increases, presumably due to a richer and more predictable fish fauna – and more room to forage – in the expanded, post-restoration lagoon. Scrub and woodland birds continued to increase in Year 3, probably owing to the continued re-growth of scrub at the site. Counts of large waders (herons/egrets) and waterfowl show no clear trend overall; however, many species in these groups continue to use the site heavily. Urban-associated species and those associated with freshwater marsh showed the steepest initial (Year 1) declines, due to the near-total lack of their preferred habitats at the site when all hardscape and freshwater marsh vegetation was removed and replaced with new native plantings. Birds associated with freshwater marsh habitat surged in numbers over 2014 (347% increase), with two species found that had not been recorded on the survey since the pre-restoration years (Marsh Wren and Red-winged Blackbird). Counts of shorebirds overall have continued to decline into Year 3 (20% of the 2005-06 abundances), though species richness remains similar to pre-restoration levels.

Table 16. Presence of landbird species recorded during all pre- and post-restoration surveys by guild (see footnotes in Appendix 3 regarding species omissions).

| | | Pre-restoration | Post-restoration | | |
|---|---|---|---|---|---|
| **Guild** | **Species** | **2005-06** | **2013 (Year 1)** | **2014 (Year 2)** | **2015 (Year 3)** |
| Open country | American Pipit | X | X | | X |
| | Killdeer | X | X | X | X |
| | Savannah Sparrow | X | X | X | X |
| | Say's Phoebe | X | X | X | X |
| | Western Kingbird | X | | | X |
| | Western Meadowlark | | X | X | X |
| Scrub/Woodland | Allen's Hummingbird | X | X | X | X |
| | American Robin | | X | | |
| | Anna's Hummingbird | X | | X | X |
| | Bewick's Wren | X | X | X | X |
| | Bushtit | X | X | X | X |
| | California Towhee | X | X | X | X |
| | Cedar Waxwing | X | | | |
| | Hermit Thrush | | | X | X |
| | House Wren | X | X | X | X |
| | Lincoln's Sparrow | X | | X | X |
| | Orange-crowned Warbler | X | | X | X |
| | Ruby-crowned Kinglet | X | X | X | X |
| | Song Sparrow | X | X | X | X |
| | Spotted Towhee | X | | X | X |
| | Wilson's Warbler | X | | | X |
| | Yellow Warbler | X | | | X |
| Urban | American Crow | X | X | X | X |
| | Black Phoebe | X | X | X | X |
| | Brewer's Blackbird | X | | | |
| | Brown-headed Cowbird | X | X | X | X |
| | European Starling | X | X | X | X |
| | Hooded Oriole | X | X | | |
| | House Finch | X | X | X | X |
| | Northern Mockingbird | X | X | X | X |
| | **TOTAL** | 27 | 20 | 22 | 26 |

Table 17. Presence of waterbird species recorded during all pre- and post-construction surveys by guild (see footnotes in Appendix 3 regarding species omissions). Asterisk indicates new species in 2015 surveys.

| | | Pre-restoration | Post-restoration | | |
|---|---|---|---|---|---|
| **Guild** | **Species** | **2005-06** | **2013 (Year 1)** | **2014 (Year 2)** | **2015 (Year 3)** |
| Freshwater Marsh | Common Yellowthroat | X | X | X | X |
| | Great-tailed Grackle | X | X | X | X |
| | Marsh Wren | X | | | X |
| | Red-winged Blackbird | X | | | X |
| | Sora | X | | | |
| | Virginia Rail | X | | | |
| Marine/Beach | Black Oystercatcher | X | X | | |
| | Bonaparte's Gull | X | X | X | X |
| | Brant | X | X | | X |
| | Brown Pelican | X | X | X | X |
| | Caspian Tern | X | X | X | X |
| | Double-crested Cormorant | X | X | X | X |
| | Elegant Tern | X | X | X | X |
| | Forster's Tern | X | X | | X |
| | Glaucous-winged Gull | X | X | X | X |
| | Heermann's Gull | X | X | X | X |
| | Herring Gull | X | X | X | X |
| | Horned Grebe | X | | | X |
| | Least Tern | X | | | X |
| | Mew Gull | X | | X | |
| | Red-breasted Merganser | X | X | X | X |
| | Red-throated Loon | | X | X | |
| | Royal Tern | | X | X | X |
| | Ruddy Turnstone | X | X | X | X |
| | Sanderling | X | X | X | X |
| | Snowy Plover | X | X | X | X |
| | Surfbird | | | X | |
| | Western Grebe | | X | X | X |
| | Western Gull | X | X | X | X |
| Shorebirds | American Avocet | X | X | | |
| | Black-bellied Plover | X | X | X | X |
| | Dunlin | X | X | X | |
| | Greater Yellowlegs | X | X | | |
| | Least Sandpiper | X | X | X | X |
| | Long-billed Curlew | X | | | |
| | Long-billed Dowitcher | X | | | X |
| | Marbled Godwit | X | X | X | X |

| | | Pre-restoration | Post-restoration | | |
|---|---|---|---|---|---|
| Guild | Species | 2005-06 | 2013 (Year 1) | 2014 (Year 2) | 2015 (Year 3) |
| | Semipalmated Plover | X | X | X | X |
| | Spotted Sandpiper | X | X | X | X |
| | Western Sandpiper | X | X | X | X |
| | Whimbrel | X | X | X | X |
| | Willet | X | X | X | X |
| Waders | Black-crowned Night Heron | X | X | X | X |
| | Great Blue Heron | X | X | X | X |
| | Great Egret | X | X | X | X |
| | Green Heron | X | | X | X |
| | Snowy Egret | X | X | X | X |
| Waterfowl | American Coot | X | X | X | X |
| | American Wigeon | X | X | X | X |
| | Blue-winged Teal | X | | | X |
| | Bufflehead | X | X | X | X |
| | Cinnamon Teal | X | | | X |
| | Gadwall | X | X | X | X |
| | Green-winged Teal | X | X | X | X |
| | Hooded Merganser * | | | | X |
| | Lesser Scaup | X | X | X | |
| | Mallard | X | X | X | X |
| | Northern Pintail | X | | X | X |
| | Northern Shoveler | X | X | X | X |
| | Pied-billed Grebe | X | X | X | X |
| | Ruddy Duck | X | X | X | X |
| | Snow Goose | X | | | X |
| Fish-eaters | Caspian Tern | X | X | X | X |
| | Double-crested Cormorant | X | X | X | X |
| | Eared Grebe | X | X | X | X |
| | Forster's Tern | X | X | | X |
| | California Brown Pelican | X | X | X | X |
| | Horned Grebe | X | | | X |
| | Least Tern | X | | | X |
| | Red-breasted Merganser | X | X | X | X |
| | Red-throated Loon | | X | X | |
| | Royal Tern | | X | X | X |
| | Western Grebe | | X | X | X |
| | Black-crowned Night Heron | X | X | X | X |
| | Great Blue Heron | X | X | X | X |
| | Great Egret | X | X | X | X |

| | | Pre-restoration | Post-restoration | | |
|---|---|---|---|---|---|
| **Guild** | **Species** | **2005-06** | **2013 (Year 1)** | **2014 (Year 2)** | **2015 (Year 3)** |
| | Green Heron | X | | X | |
| | Snowy Egret | X | X | X | X |
| | Eared Grebe | X | X | X | X |
| | Pied-billed Grebe | X | X | X | X |
| | Ruddy Duck | X | X | X | X |
| | **TOTAL** | 73 | 62 | 61 | 68 |

### *Performance Evaluation*

Several patterns have emerged after three years of post-restoration bird monitoring, and while none may be statistically significant, they may provide an indication of how the site's avifauna could be responding to the restoration. Additional monitoring will be necessary to confirm the data trends. Special-status species in Year 3 continue to make heavy use of the site, in particular the beach and lower lagoon area (e.g., Brown Pelican and Snowy Plover). The total number of individual birds recorded during 2015 included 11,299 individual birds identified, representing a nearly 30% increase over the prior years' total.

As no specific success criteria were 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.

The continued maturation and shift in vegetation assemblages may result in additional increased observations of individuals within several guilds (e.g. shorebirds, freshwater, 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. Several additional years of monitoring will be necessary to confirm trends identified throughout this chapter.

## 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, 23 December 2014, and 19 January 2016. Floating, mat, and attached submerged aquatic vegetation and macroalgae were monitored at eight stations (Figure 15). 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). All stations were subsequently averaged together to determine the grand mean total cover by year. In cases where deep water obscured visibility, that area was not surveyed and was subtracted from the total transect length.

### *Results*

All stations had a total average algal cover of approximately 11% or less, and several stations had less than 1% average cover for the most recent survey on 19 January 2016 (i.e. Stations 4 and 6) (Tables 18 and 19). The grand mean total algal and SAV cover for all surveys on 19 January 2016 ± SE was 3.81 ± 1.1. The category 'wrack' is an amalgamation of several types of unattached or floating kelp species, including those in the genera *Macrocystis, Phyllospadix, Dictyota, Egregia, Eisenia*, and woody debris. '*Cladophora* cover' is a small, attached, turf-like green alga. At several stations, the most recent survey also identified *Ruppia sp.*, which is an attached submerged aquatic vegetation species (Table 19).

Table 18. Algae data as station total percent cover ± standard error for the three post-restoration surveys.

| | 14 Feb 2013 | 23 Dec 2014 | 19 Jan 2016 |
|---|---|---|---|
| Station 1 | 2.98 ± 0.57 | 10.17 ± 3.8 | 6.63 ± 1.27 |
| Station 2 | 0.45 ± 0.27 | 7.68 ± 2.21 | 11.51 ± 2.18 |
| Station 3 | 0.87 ± 0.87 | 0.95 ± 0.53 | 2.74 ± 1.2 |
| Station 4 | 2.1 ± 0.1 | 1.28 ± 0.27 | 0.82 ± 0.35 |
| Station 5 | 0 ± 0 | 3.84 ± 1.5 | 3.64 ± 1.58 |
| Station 6 | 0 ± 0 | 0.23 ± 0.1 | 0.4 ± 0.13 |
| Station 7 | 0.46 ± 0.06 | 0.29 ± 0.11 | 2.19 ± 0.37 |
| Station 8 | 5.08 ± 2.01 | 0.25 ± 0.11 | 2.56 ± 1.73 |
| **Grand Mean** | **1.49 ± 0.49** | **3.09 ± 1.08** | **3.81 ± 1.1** |

Table 19. Algae data as station average wrack and *Cladophora* percent cover ± standard error for the three post-restoration surveys.

| | 14 Feb 2013 | | 23 Dec 2014 | | 19 Jan 2016 | | |
|---|---|---|---|---|---|---|---|
| | wrack | *Cladophora* | wrack | *Cladophora* | wrack | *Cladophora* | *Ruppia* |
| Station 1 | 2.93 ± 0.53 | 0.05 ± 0.05 | 9.86 ± 3.7 | 0.31 ± 0.21 | 4.06 ± 1.4 | 2.55 ± 0.28 | 0.02 ± 0.02 |
| Station 2 | 0.44 ± 0.28 | 0.01 ± 0.01 | 7.58 ± 2.12 | 0.1 ± 0.1 | 7.44 ± 0.98 | 4.07 ± 2.04 | 0 ± 0 |
| Station 3 | 0.2 ± 0.2 | 0.67 ± 0.67 | 0.95 ± 0.53 | 0 ± 0 | 1.32 ± 0.53 | 1.21 ± 1.01 | 0.21 ± 0.21 |
| Station 4 | 1.67 ± 0.33 | 0.43 ± 0.3 | 1.12 ± 0.29 | 0.17 ± 0.07 | 0.72 ± 0.4 | 0.1 ± 0.1 | 0 ± 0 |
| Station 5 | 0 ± 0 | 0 ± 0 | 3.84 ± 1.5 | 0 ± 0 | 0.06 ± 0.02 | 3.42 ± 1.48 | 0.16 ± 0.16 |
| Station 6 | 0 ± 0 | 0 ± 0 | 0.18 ± 0.05 | 0.05 ± 0.05 | 0.29 ± 0.03 | 0 ± 0 | 0.11 ± 0.11 |
| Station 7 | 0.36 ± 0.06 | 0.11 ± 0 | 0.29 ± 0.11 | 0 ± 0 | 0.31 ± 0.12 | 1.88 ± 0.29 | 0 ± 0 |
| Station 8 | 0.68 ± 0.52 | 4.4 ± 2.42 | 0.25 ± 0.11 | 0 ± 0 | 2.44 ± 1.8 | 0 ± 0 | 0.12 ± 0.08 |

### *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 well below a 10% grand mean total cover 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.

Submerged aquatic vegetation (SAV) seagrasses are longer-living species such as *Phyllospadix sp.* and ditch grasses such as *Ruppia 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 sp.* and *Ruppia sp.* cover was present on the most recent survey, 19 January 2016, 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). These criteria are discussed in the data sonde section of the water quality chapter and the associated performance evaluation.

## 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*

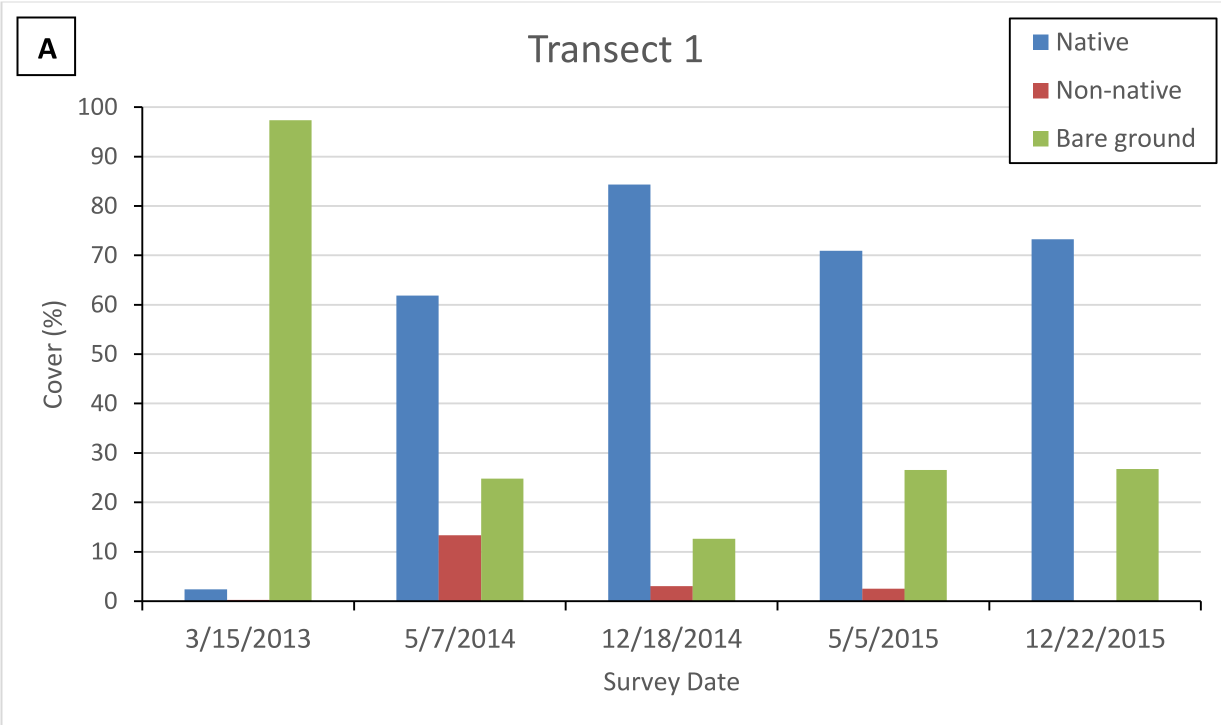
Data for absolute percent cover of native/nonnative vegetation species were collected along three, 50-meter transects (Figure 32) using the line-intercept method on 15 March 2013, 7 May 2014, 18 December 2014, 5 May 2015, and 22 December 2015. These data were combined to provide a comprehensive set of post-restoration vegetation surveys to evaluate native and non-native relative vegetation cover over time.

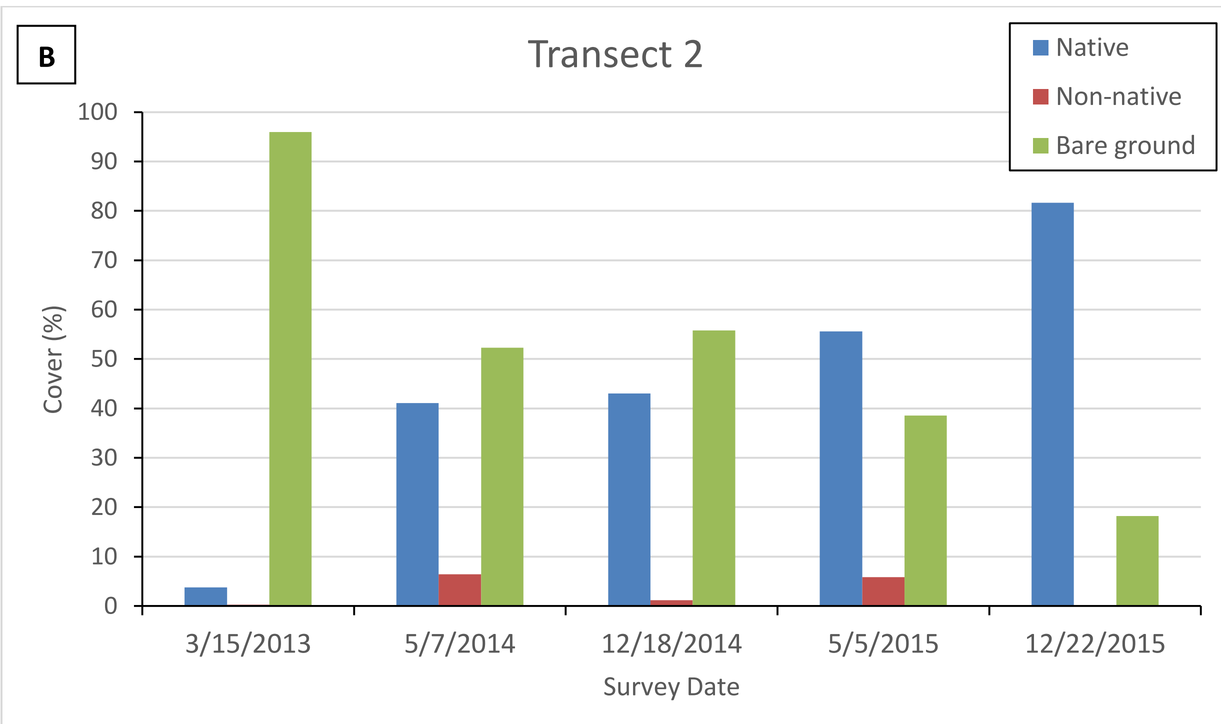
Each transect location was recorded with a submeter global positioning system (GPS) unit and photographed at each end. Absolute cover data were calculated based on the total distance for each species within each transect. Species data were collected to an accuracy of 0.01 m along each 50-meter transect. 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 32. Map of vegetation transect locations and start/end points.

### *Results*

After three years, cover for native vegetation species along an individual transect in the most recent survey was the highest on Transect 2, at 81.7% and lowest on Transect 3 at 30.9% (Figure 33). All transects displayed a relative increase in native vegetation cover and a decrease in bare ground when analyzed by post-restoration year. Additionally, the non-native cover for Transects 2 and 3 was 0.0% and less than one percent for Transect 2, indicating a decrease in non-native vegetation over time.


A
Transect 1
Native
Non-native
Bare ground
Cover (%)
100
90
80
70
60
50
40
30
20
10
0
3/15/2013
5/7/2014
12/18/2014
5/5/2015
12/22/2015
Survey Date


B
Transect 2
Native
Non-native
Bare ground
Cover (%)
100
90
80
70
60
50
40
30
20
10
0
3/15/2013
5/7/2014
12/18/2014
5/5/2015
12/22/2015
Survey Date

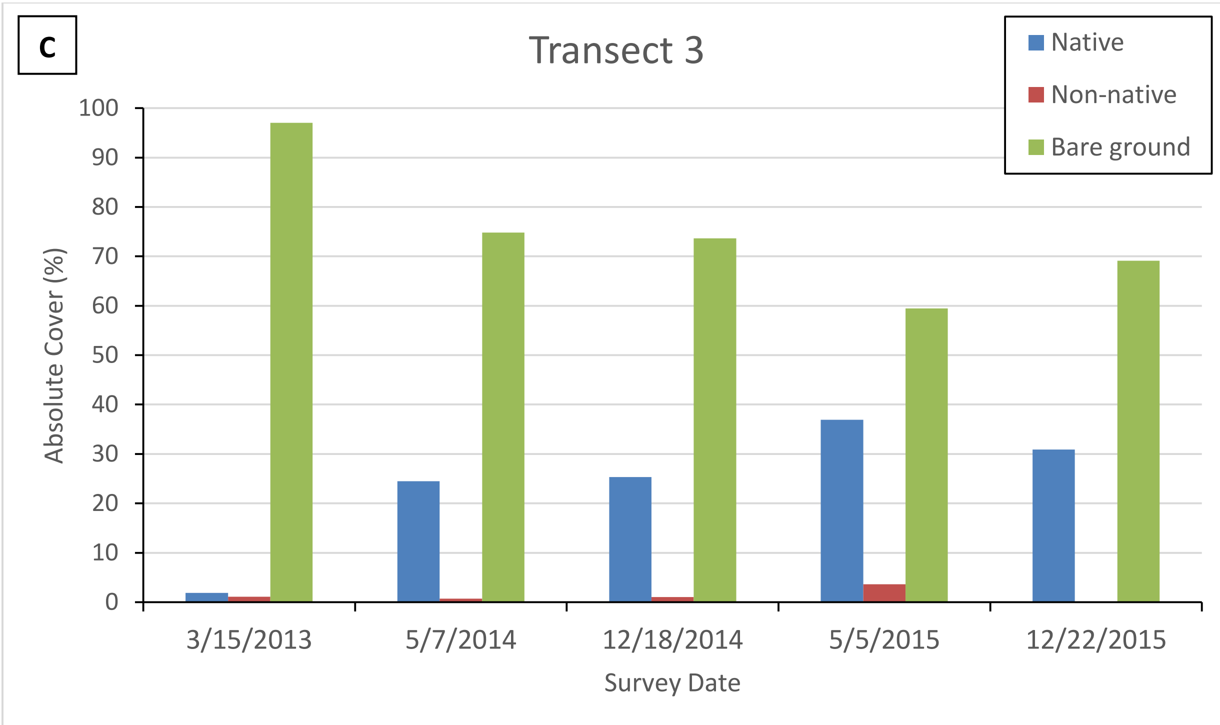



Figure 33. Graphs displaying absolute cover of vegetation across each Transect: (A) 1, (B) 2, and (C) 3.

### *Performance Evaluation*

Vegetation cover as assessed by these three transects has shown a relative increase over time, with a large increase after the initial post-restoration baseline survey. Vegetation cover is predicted to continue to develop and become more complex over time as mature plants have a chance to grow and spread. Non-native species on each transect represented between zero and one percent 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.

All transects have already met the non-native success criteria for Year 3 (i.e. < 10% cover) and Transects 1 and 2 are well above the native vegetation cover success criteria (i.e. > 50%); however, Transect 3 continues to establish and spread at a slower rate. Additionally, prolonged below average rainfall and drought in Southern California have continued to impact the site. However, the CRAM biotic metric continued increasing in Year 3, thus Transect 3 may not be representative of the average cover in the rest of the wetland habitat areas. Continued observation and monitoring is recommended, and future supplemental plantings may be recommended if drought conditions continue.

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. Post-restoration surveys indicated a range of 13 to 41 native plant species identified immediately adjacent to the transects (within approximately 10 meters), compared to an average of six dominant species pre-restoration. Plants that are able to handle higher salinities and soil compaction appear to be most successful.

# 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 20 and Figure 34) 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, 18 December 2014, 5 May 2015, and 22 December 2015 (Table 20). Approximate bearing is relative to the center of the photograph; detailed bearing ranges are included on the datasheets.

Table 20. GPS coordinates, bearings, and time of photo-point surveys.

| Date | Station | Approximate Bearing | Time | Number of Photos |
|---|---|---|---|---|
| 15 March 2013 | Photo Point 1 | 155° | 8:15 AM | 1 |
| | Photo Point 2 | 300°, 75° | 8:30 AM | 2 |
| | Photo Point 3 | 220°, 100° | 8:46 AM | 2 |
| 7 May 2014 | Photo Point 1 | 155° | 11:22 AM | 1 |
| | Photo Point 2 | 300°, 75° | 11:13 AM | 2 |
| | Photo Point 3 | 220°, 100° | 11:08 AM | 2 |
| 18 December 2014 | Photo Point 1 | 155° | 12:47 PM | 1 |
| | Photo Point 2 | 300°, 75° | 12:41 PM | 2 |
| | Photo Point 3 | 220°, 100° | 12:37 PM | 2 |
| 5 May 2015 | Photo Point 1 | 155° | 3:00 PM | 1 |
| | Photo Point 2 | 300°, 75° | 2:59 AM | 2 |
| | Photo Point 3 | 220°, 100° | 2:56 PM | 2 |
| 22 December 2015 | Photo Point 1 | 155° | 3:40 PM | 1 |
| | Photo Point 2 | 300°, 75° | 3:49 PM | 2 |
| | Photo Point 3 | 220°, 100° | 3:49 PM | 2 |

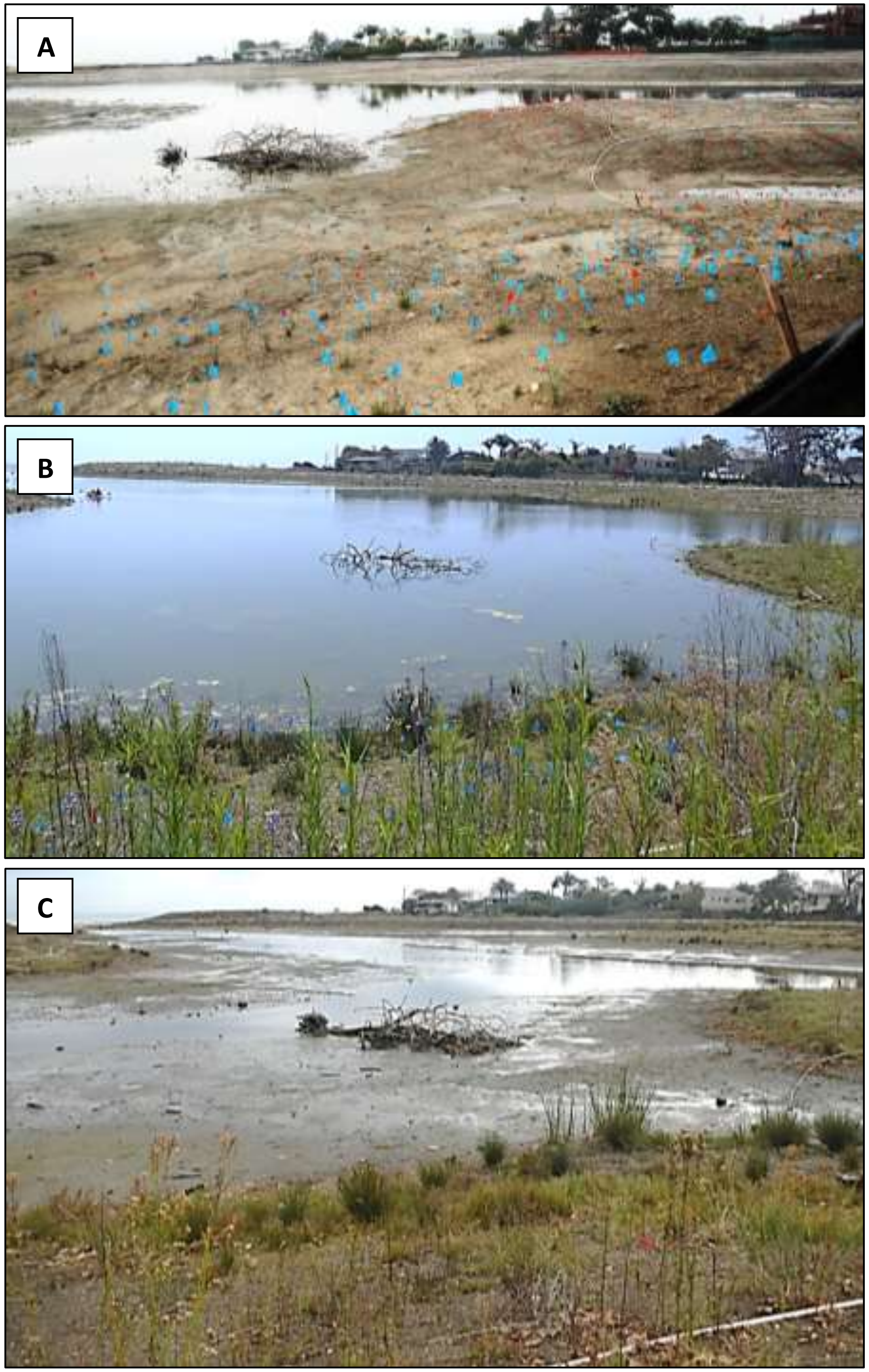
Figure 34. Map of photo-point locations and bearings for the surveys.

### *Results*

A total of five photos were taken at three locations to assess a range of habitat types across the restoration area. Figures 35 through 39 (A - E) display the photos from the five locations post-restoration on the three survey dates, respectively.

### *Performance Evaluation*

Consistent with the evaluation for plant cover transect monitoring and CRAM scores, 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. Unlike the prolific growth seen in the second and third photo point surveys (March 2014 and December 2014), the third year surveys (May 2015 and December 2015) showed more subtle variations. Gaps in vegetation seen in the December 2015 photos but not in the May 2015 shots were either from seasonal vegetation variation, post-restoration weed management, or slight shifts in the photographer's perspective.



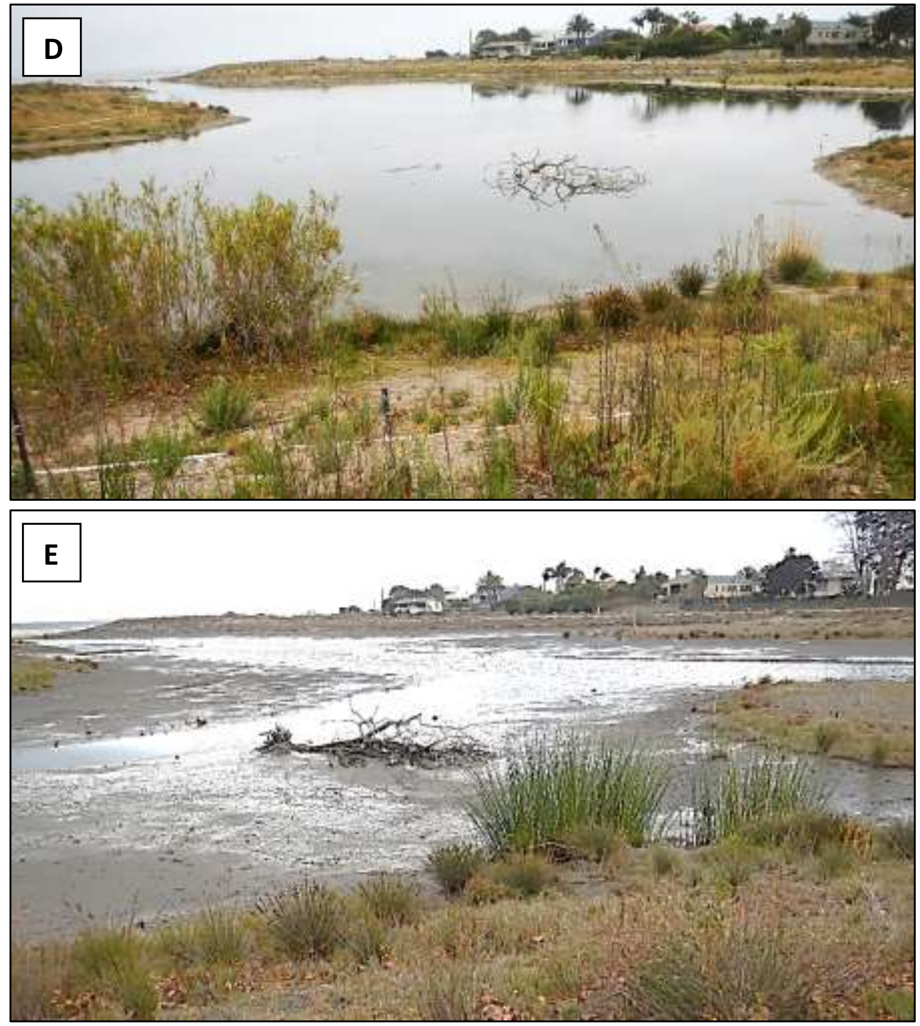




Figure 35. Photograph of Photo Point 1, bearing 155° on (A) 15 March 2013; (B) 7 May 2014; (C) 18 December 2014; (D) 5 May 2015; (E) 22 December 2015.


Figure 36. Photograph of Photo Point 2, bearing 300° on (A) 15 March 2013; (B) 7 May 2014; (C) 18 December 2014; (D) 5 May 2015; (E) 22 December 2015.


Figure 37. Photograph of Photo Point 2, bearing 75° on (A) 15 March 2013; (B) 7 May 2014; (C) 18 December 2014; (D) 5 May 2015; (E) 22 December 2015.

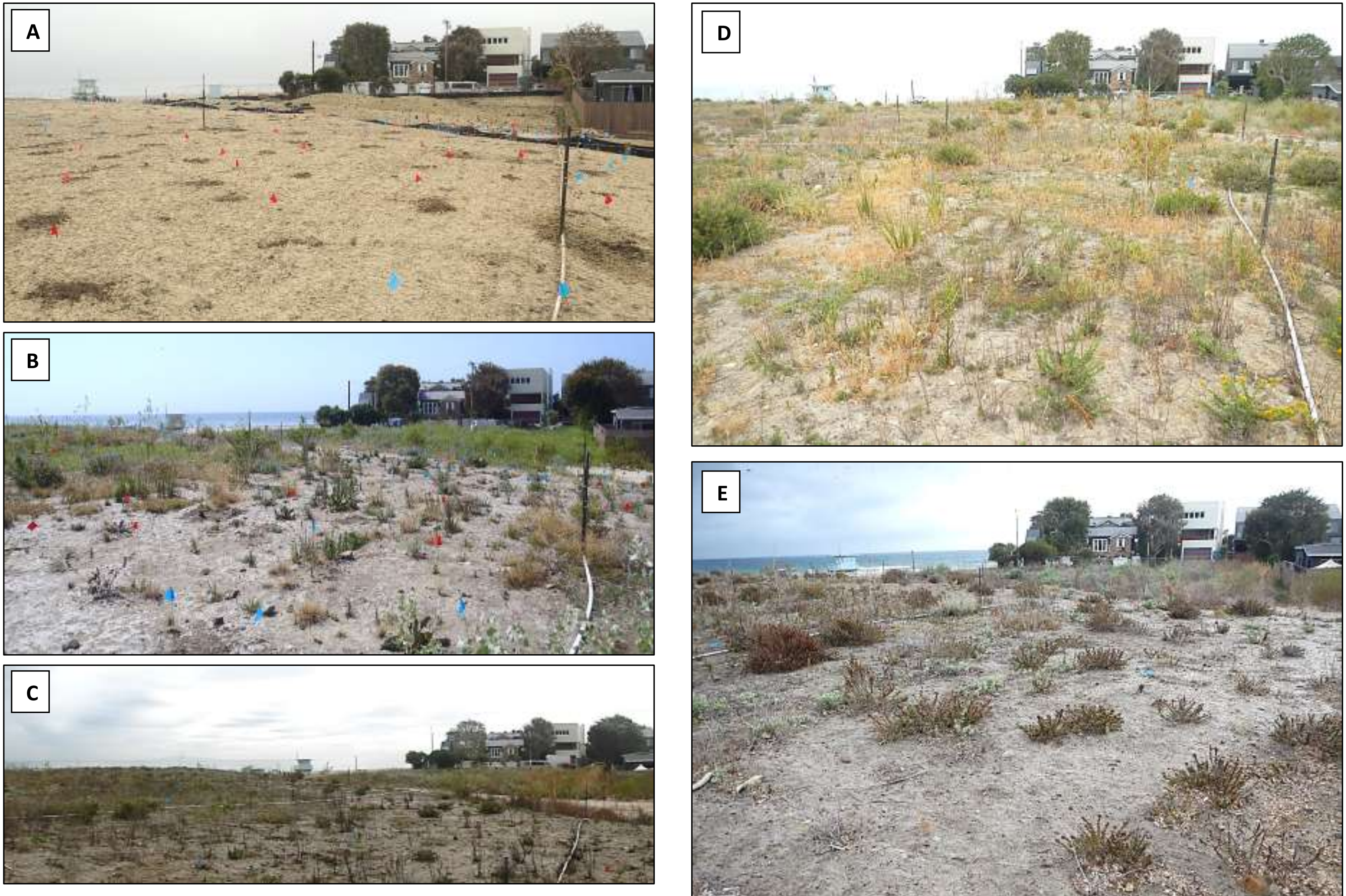
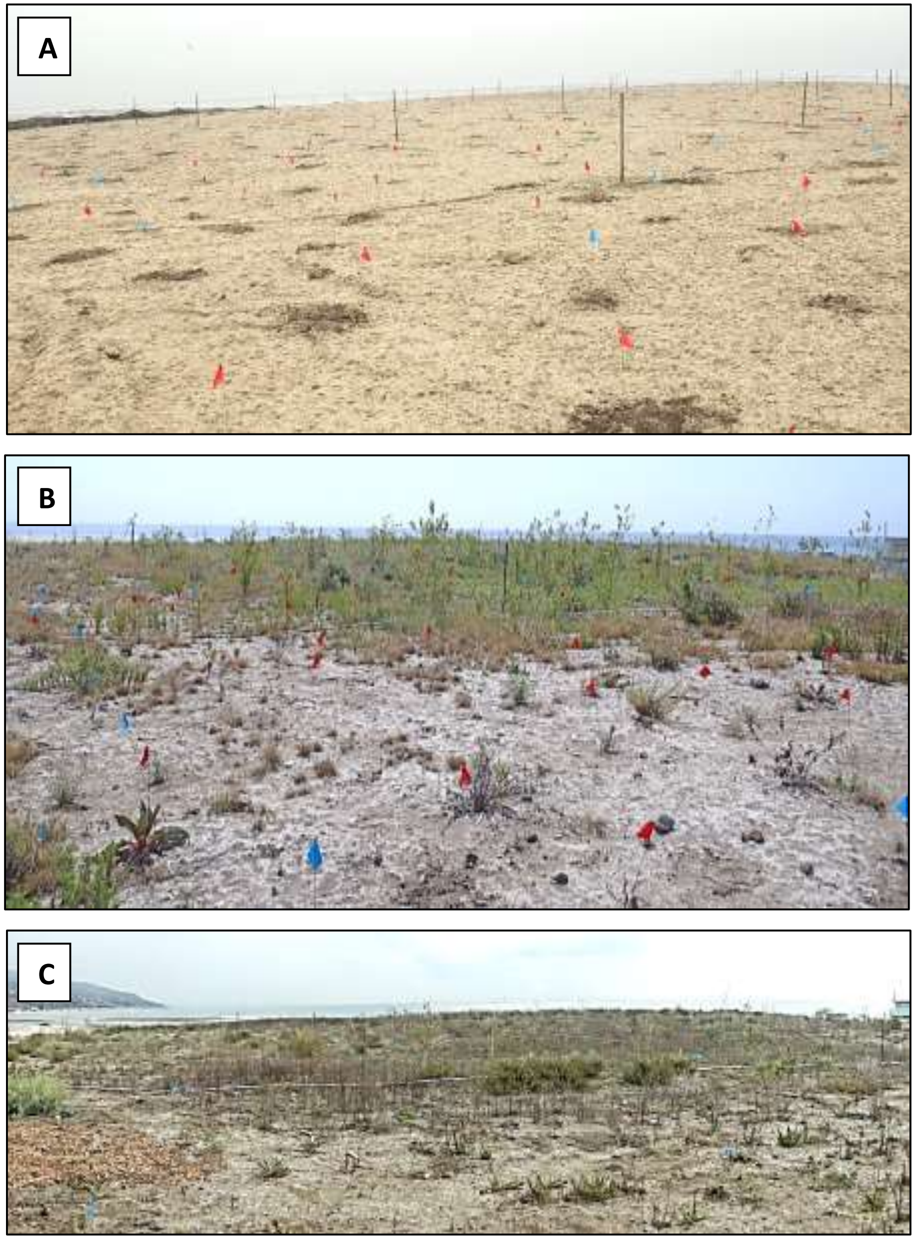



Figure 38. Photograph of Photo Point 3, bearing 220° on (A) 15 March 2013; (B) 7 May 2014; (C) 18 December 2014; (D) 5 May 2015; (E) 22 December 2015.



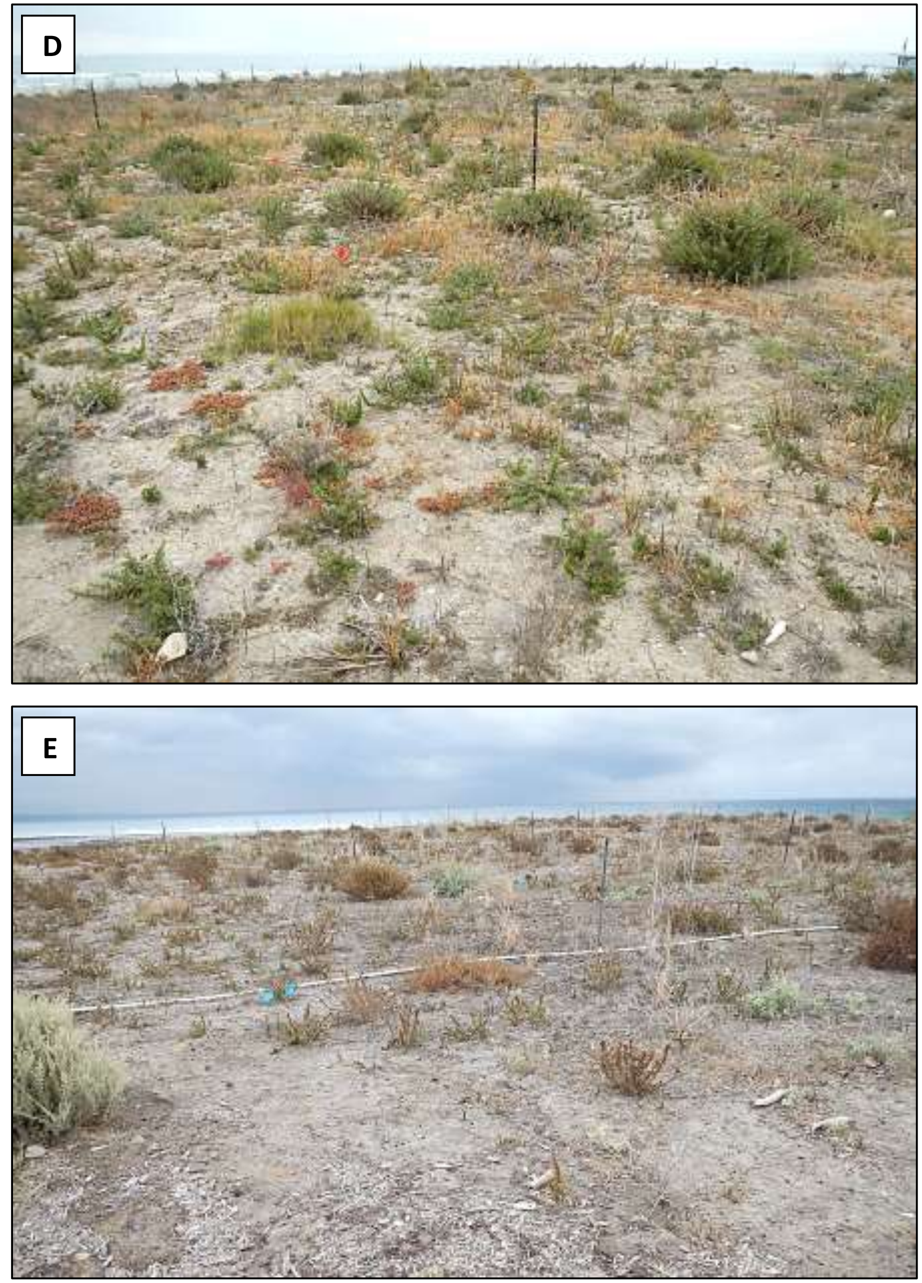




Figure 39. Photograph of Photo Point 3, bearing 100° on (A) 15 March 2013; (B) 7 May 2014; (C) 18 December 2014; (D) 5 May 2015; (E) 22 December 2015.

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Photo: Malibu Lagoon Restoration in a closed berm condition (R. Abbott, 15 December 2015).

# Appendix 1. Malibu Lagoon Post-construction Fish Survey Results: May 2015 (Prepared by R. Dagit)

# Malibu Lagoon
# Post Construction Fish Survey May 2015

**Prepared for:**
**Angeles District**
**California Department of Parks and Recreation**

**Prepared by:**
**Elizabeth Montgomery and Rosi Dagit**
**RCD of the Santa Monica Mountains**
**540 S. Topanga Canyon Blvd.**
**Topanga, CA 90290**

**May 2015**

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## EXECUTIVE SUMMARY

A post-construction fish survey of Malibu Lagoon was conducted on Wednesday, 27 May 2015 by a team from the RCD of the Santa Monica Mountains with assistance from CDPR and The Santa Monica Bay Restoration Foundation.

Malibu Lagoon was connected to the ocean between December 2014 and March 2015. The berm closed in early March, but breached for a short time between 21 March and 15 April before closing again. The lagoon was closed during the 27 May survey.

A total of six permanent sites were seined to depletion, or in the case of high (n>500) fish abundance, a total of 20 seine pulls. 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.

Federally endangered tidewater gobies (*Eucyclogobius newberryi)* were observed, steelhead trout (*Onchorhynchus mykiss)* were not.

Striped mullet (*Mugil cephalus*) were observed jumping throughout the lagoon, and one 11.4 cm individual was captured and retained as a voucher specimen. The dominant species surveyed and identified was topsmelt (*Atherinops affinis*, n=242), although small smelt and other unidentified larva were most abundant (n=3,235). Voucher specimens of larval fish and others were collected and will be reviewed at the Natural History Museum to confirm identification.

Species captured during the May 2015 survey include:

| | |
|---|---|
| **Native Fish Species** | |
| Tidewater goby | *Eucyclogobius newberryi* |
| Long-jawed Mudsucker | *Gillichthys mirabilis* |
| Topsmelt | *Atherinops affinis* |
| Striped mullet | *Mugil cephalus* |
| Unidentified fish larva | |
| **Non-Native Fish Species** | |
| Mosquitofish | *Gambusia affinis* |
| Mississippi silversides | *Menida audens* |
| **Invertebrates** | |
| Oriental shrimp | *Palaemonetes sp.* |
| Hemigraspus crab | *Hemigraspus sp.* |
| Snails | Gastropoda |
| Water scavenger beetle larva | Hydrophilidae |

## 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 Dayana Doroteo to help with the seining.

Rod Abbott and Erik Sode from The Santa Monica Bay Restoration Foundation also assisted with seining efforts.

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
Krista Adamek, Biologist
Andre Sanchez, Watershed Steward
Dane van Tamelen, Stream Team Volunteer

## PURPOSE OF SURVEY

The Malibu Lagoon restoration was completed in Fall 2012. A total of six post-construction monitoring locations were identified by the Malibu Lagoon Restoration and Enhancement Hydrologic and Biological Project Monitoring Plan (Abramson 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.

### SUMMARY OF POST CONSTRUCTION SURVEY EVENTS

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.

The 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.

This fourth survey took place on 27 May 2015. The weather was cloudy in the morning, and clear skies in the afternoon. The lagoon berm was closed during the survey, but had breached for short periods in both March and April, with a longer sustained breach between December 2014 - March 2015. Water level was noted at 6.8 feet.

## METHODS

A. Blocking Net Sampling Method for Permanent Stations

A meter tape was laid out along the shoreline at the waters edge extending for 10 meters. Two 10 m x 2 m 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 3 m x 1.25 m seines walked carefully to the apex of the triangle and pulled from the shore to the apex, from the apex towards the shore and randomly throughout the blocked area. 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, photographed and Fork Length measured, then they were released outside of the blocked area. Seining pulls continued until three consecutive pulls were empty, or until a total of 20 seines had been pulled.

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:

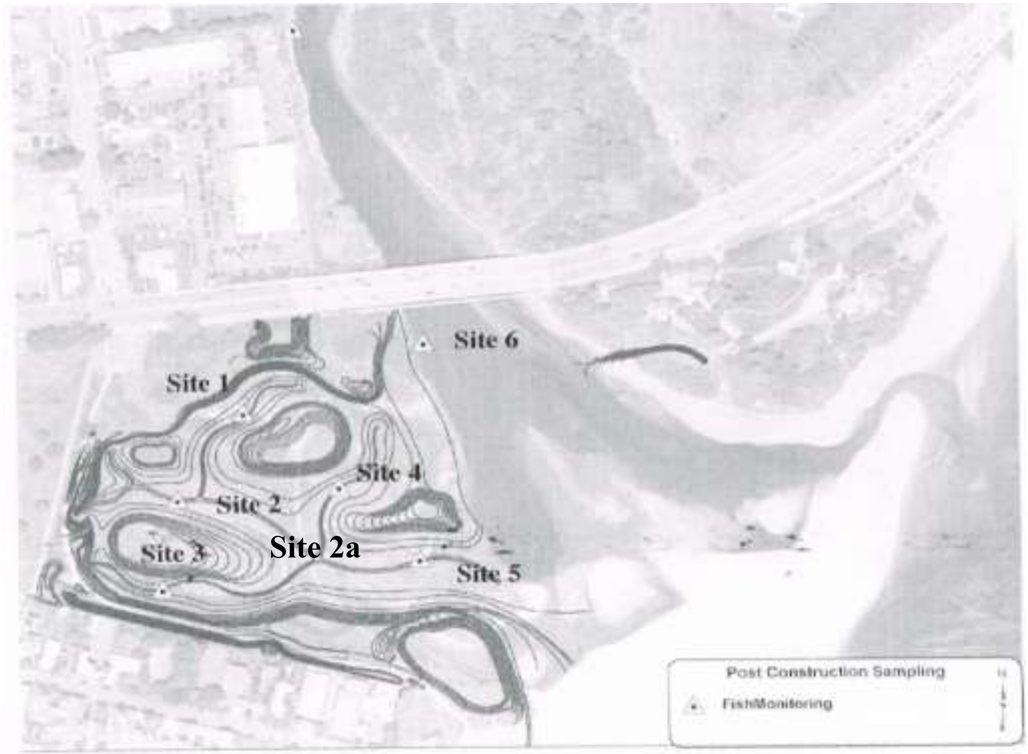
- WQ testing Kit (calibrated)
- 2 10m x 2m blocking nets
- 3m x 1.25 m seines (2)
- buckets (8)
- 30 m tape
- data sheets
- ice chest for voucher specimens

-ziplock baggies
- fish measuring boards (2)
- 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 27 May 2015

| Variable | Site 1 | Site 2 | Site 2a | Site 3 | Site 5 | Site 6 |
|---|---|---|---|---|---|---|
| Avg depth (cm) | 40 | 100 | 20 | 120 | 75 | 35 |
| Water T°C | 21.5 | 23.4 | 24.0 | 23.6 | 26.1 | 21.8 |
| Air T°C | 28.0 | 25.0 | 29.0 | 33.0 | 26.5 | NR |
| Salinity ppt | 18 | 16 | 17 | 16 | 17 | 14 |
| DO mg/l | 14.2 | 15.5 | 15.45 | 17.5 | 18.2 | 7.07 |
| pH | 9.18 | 9.23 | 9.25 | 9.3 | 9.34 | 9.04 |
| Conductivity | 1940 | Over range | Over range | Over range | Over range | Over range |
| % Floating algae cover | 40 | 0 | 80 | 50 | 100 | 40 |
| % Submerged/ Attached algae cover | 40 | 75 | 50 | 50 | 50 | 80 |
| % emergent vegetation bank cover | 75 | 80 | 0 | 90 | 60 | 80 |
| Emergent vegetation type | Jaumea, distichlis, salicornia | Jaumea, distichlis, salicornia | NA | Jaumea, distichlis | Jaumea, salicornia | Distichlis, salicornia |
| Time start | 12:20 | 14:00 | 13:35 | 15:00 | 16:05 | 09:30 |

The dominant identifiable fish species captured in seine nets was topsmelt (*Atherinops affinis,* n=242), which was present in at least three size classes (<5cm, <15cm, >15cm). The second and third dominant species were juvenile tidewater goby (*Eucyclogobius newberryi*, n=41) and long-jawed mudsuckers (*Gillichthys mirabilis*, n=25). Striped mullet (*Mugil cephalus*, n=1), and non-natives mosquitofish (*Gambusia affinis,* n=16) and Mississippi silversides (*Menida audens,* n=9) were also present.

Larval fish (<5cm) were the most abundant category sampled (n=3,235) but were not identifiable in the field due to their small size. Until their identification is confirmed, we have described those species in Table 3 as 'unidentified fish larva' and 'unidentified smelt larva.' Voucher larval fish specimens indicate there are at least three distinct species present. Identification of all these will be confirmed from voucher specimens by the Natural History Museum in 2015.

Table 3. Summary of Fish and Invertebrates captured/observed 27 May 2015

| **Lagoon-ocean connection conditions** | **Closed** | **Site 1** | **Site 2** | **Site 2a** | **Site 3** | **Site 5** | **Site 6** | **TOTAL** |
|---|---|---|---|---|---|---|---|---|
| **Seine pull total to depletions** | | 20 | 20 | 20 | 20 | 20 | 20 | |
| **Native Fish Species** | | | | | | | | |
| Tidewater goby (<5 cm) | *Eucyclogobius newberryi* | 5 | 1 | | 5 | 3 | 27 | 41 |
| Long-jawed mudsucker (<5 cm) | *Gillichthys mirabilis* | 1 | 2 | | | | | 3 |
| Long-jawed mudsucker (5-10 cm) | *Gillichthys mirabilis* | 4 | 3 | | 5 | 2 | 8 | 22 |
| Topsmelt larva (<5 cm) | *Atherinops affinis* | 7 | 99 | | 35 | 8 | 27 | 176 |
| Topsmelt juvenile (6-15 cm) | *Atherinops affinis* | | 52 | 1 | 1 | | 6 | 60 |
| Topsmelt adult (>15 cm) | *Atherinops affinis* | | 3 | | 3 | | | 6 |
| Unidentified smelt larva (<5 cm) | *Atherinops sp* | 474 | 266 | 413 | 246 | 96 | 749 | 2244 |
| Striped mullet | *Mugil cephalus* | | | | 1 | | | 1 |
| Unidentified larva (<1cm) | | 32 | 90 | | 160 | 47 | 662 | 991 |
| **Non-Native Fish Species** | | | | | | | | 0 |
| Mosquitofish juveniles (<5cm) | *Gambusia affinis* | 2 | | | | 3 | 8 | 13 |
| Mosquitofish adults (5-10 cm) | *Gambusia affinis* | 2 | | | | | 1 | 3 |
| Carp | *Cyprinus carpio* | | | | | | | 0 |
| Mississippi silversides | *Menida audens* | 1 | 1 | | | | 7 | 9 |
| **Invertebrates** | | | | | | | | 0 |
| Oriental shrimp | *Palaemonetes sp.* | | 4 | | 1 | | 5 | 10 |
| Hemigraspus crabs | | 3 | 10 | | 1 | 6 | | 20 |
| Gastropoda | | 1 | | | 1 | 2 | | 4 |
| Coleoptera larva | Hydrophilidae | | | | | | 1 | 1 |

**SUMMARY**

The May 2015 post-construction fish survey was completed in one day with a team of 10 people.

Table 4 provides a summary comparing abundance of species documented in Malibu Lagoon prior to restoration (2005), species relocated during restoration (2012), and four post-construction surveys (2013-2015).

Overall fish diversity and abundance post-construction was higher in May 2015 than December 2014. However, compared to May 2014, a few changes in surveyed species composition were observed. Tidewater gobies in several size classes were observed throughout the lagoon in May 2015. Steelhead trout (*Onchorhynchus mykiss*), staghorn sculpin (*Leptocottus armatus*), and California Killifish (*Fundulus parvipinnis*) observed in May 2014 were not observed in May 2015. Long-jawed mudsucker (*Gillichthys mirabilis*) seine captures increased from 5 to 25 individuals, and juvenile and adult topsmelt (>6cm) increased from 11 to 66 individuals. Seine captures of non-native Mississippi silversides (*Menida audens*) were down significantly from December 2014 from 801 to 9 individuals. Continued monitoring may reveal if this is an acute or seasonal trend. Mosquitofish (*Gambusia affinis*), a dominant species pre-restoration, continue to be present but in very low numbers (<20). Thousands of smelt and other fish larva were present both 2014 and 2015, indicating Malibu Lagoon's function as fish nursery habitat.

Diversity and abundance of invertebrates also shifted slightly from May 2014 to 2015. Seine captured non-native oriental shrimp (*Palaemonetes sp.*) declined from 207 to 10, and Hemigraspus crabs increased from 10 to 20. One water scavenger beetle larva (Hydrophilidae n.d., tolerance value 5) was captured in a seine net at site 6 in May 2015.

Table 4. Summary of Fish and Invertebrates captured/observed 2005 - 2015

| | | Survey Jun-05 open | Relocation Jun-12 open | Survey Jan-13 open | Survey May-14 closed | Survey Dec-14 open | Survey May-15 closed |
|---|---|---|---|---|---|---|---|
| **Native Fish Species** | | | | | | | |
| Steelhead trout | *O.mykiss* | | | | 1 observed | | |
| Unidentified goby larva (<5 cm) | | | 2 | | 500~ | | |
| Tidewater goby | *Eucyclogobius newberryi* | 473 | 8 | | 15 | | 41 |
| Arrow goby (<5 cm) | *Cleavlandia ios* | | | | 5 | | |
| Bay goby? | *Lepidogobius lepidus* | | | | 3 | | |
| CA killifish juveniles (<5cm) | *Fundulus parvipinnis* | | 306 | | 5 | | |
| CA killifish (5-10 cm) | *Fundulus parvipinnis* | 46 | 16 | | | | |
| Long-jawed mudsucker (<5 cm) | *Gillichthys mirabilis* | 1 | 8 | | 5 | | 3 |
| Long-jawed mudsucker (5-10 cm) | *Gillichthys mirabilis* | | 11 | | | | 22 |
| Topsmelt larva (<5 cm) | *Atherinops sp* | | 1 | 3 | | | 176 |
| Topsmelt juvenile (6 cm) | *Atherinops sp* | 244 | 0 | | 11 | 2 | 60 |
| Topsmelt adult (16 cm) | *Atherinops sp* | | 0 | | | | 6 |
| Unidentified smelt larva (<5 cm) | *Atherinops sp* | | 101 | | >15,000 | | 2244 |
| Staghorn sculpin (<5 cm) | *L. armatus* | | | 17 | 11 | | |
| Staghorn sculpin (5-10 cm) | *L.armatus* | | 3 | | | | |
| Diamond turbot | *H. guttulata* | | | 7 | 1 | | |
| Northern anchovy <5 cm | *Engraulis mordax* | | 5 | | | | |
| Striped mullet | *Mugil cephalus* | observed | | observed | observed | 6 | 1 |
| Unidentified fish larva | | | | | | | 991 |
| **Non-Native Fish Species** | | | | | | | |
| Mississippi silversides | *Menida audens* | | | 1 | | 801 | 9 |
| Mosquitofish | *Gambusia affinis* | 65 | 4072 | | 1 | 2 | 16 |
| Carp | *Cyprinus carpio* | 1 | 4072 | | observed | | |
| **Invertebrates** | | | | | | | |
| Oriental shrimp | *Palaemonetes sp.* | | | 37 | 207 | | 10 |
| Hemigraspus crabs | | | | | 10 | | 20 |
| Water boatman juveniles | | | 6 | | | | |
| Amphipods | | | 6,000+ | | | | |
| Isopods | | | 2500+ | | | | |
| Ctenophore sp (<2 cm) | | | 2500+ | 3 | | | |
| Salp sp (<2 cm) | | | | 3 | | | |
| Sea hare (5-10 cm) | *Aplysia californica* | | | 2 | | | |
| Segmented worm <2 cm) | | | | 3 | | | |
| Gastropoda | | | | | | | 4 |
| Water scavenger larva | Hydrophilidae | | | | | | 1 |

# Appendix A. Photographs of fish species


Tidewater goby


Topsmelt

Long-jawed mudsucker


Striped mullet juvenile

Smelt and unidentified fish larva

# 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: January 2016 (Prepared by R. Dagit)

# Malibu Lagoon
# Post Construction Fish Survey January 2016

**Prepared for:**
**Angeles District**
**California Department of Parks and Recreation**

**Prepared by:**
**Elizabeth Montgomery and Rosi Dagit**
**RCD of the Santa Monica Mountains**
**540 S. Topanga Canyon Blvd.**
**Topanga, CA 90290**

**January 2016**

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## EXECUTIVE SUMMARY

A post-construction fish survey of Malibu Lagoon was conducted on Tuesday, 12 January 2016 by a team from the RCD of the Santa Monica Mountains with assistance from CDPR staff.

Malibu Lagoon was closed to the ocean between March 2015 and 16 December 2015. The lagoon was open during the 12 January survey.

A total of six permanent sites were seined to depletion. Tidal surges associated with rising tide were encountered and due to tidal connection, depth at all sites was quite low. High tide was at 10:04 am. 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. In addition, we conducted spot surveys along the lagoon side of the beach berm and at several locations on the east lagoon bank from just above the PCH bridge to the beach.

Neither federally endangered tidewater gobies (*Eucyclogobius newberryi)* nor steelhead trout (*Onchorhynchus mykiss)* were observed.

Striped mullet (*Mugil cephalus*) were observed jumping throughout the lagoon. The dominant species surveyed and identified was Northern anchovy (*Engraulis mondax*, n=180), although small smelt (n=64) and a few other species were observed. Overall, catch numbers were quite low. Voucher specimens of larval fish and others were collected and will be reviewed at the Natural History Museum to confirm identification.

Species captured or observed during the January 2016 survey include:

| | |
|---|---|
| **Native Fish Species** | |
| Topsmelt | *Atherinops affinis* |
| Northern Anchovy | *Engraulis mondax* |
| Staghorn sculpin | *Leptocottus armatus* |
| Striped mullet | *Mugil cephalus* |
| Unidentified fish larva | |
| | |
| **Non-Native Fish Species** | |
| Mosquitofish | *Gambusia affinis* |
| Mississippi silversides | *Menida audens* |
| | |
| **Invertebrates** | |
| Oriental shrimp | *Palaemonetes sp.* |
| Hemigraspus crab | *Hemigraspus sp.* |

## 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 Nick Chang, Allison Doran, and John Lukar to help with the seining.

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
Krista Adamek, Biologist
Elizabeth Montgomery, Biologist
Alex Balcerzack, Field Assistant
Ben Chuback, Field Assistant
Dylan Hofflander, Watershed Steward

## PURPOSE OF SURVEY

The Malibu Lagoon restoration was completed in Fall 2012. A total of six post-construction monitoring locations were identified by the Malibu Lagoon Restoration and Enhancement Hydrologic and Biological Project Monitoring Plan (Abramson 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. Due to the closed condition in fall 2015, we postponed the survey until January 2016 to allow the lagoon to reconnect to the ocean.

### SUMMARY OF POST CONSTRUCTION SURVEY EVENTS

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.

The 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.

The fourth survey took place on 27 May 2015. The weather was cloudy in the morning, and clear skies in the afternoon. The lagoon berm was closed during the survey, but had breached for short periods in both March and April, with a longer sustained breach between December 2014 - March 2015. Water level was noted at 6.8 feet.

This fifth survey took place on 12 January 2016 following the breach on 16 December 2015. The all day survey started with low tide conditions (0357, 1.8’) exposing large areas of the mudflats that gradually were covered as the tide rose (high tide 1004, 6.0’). Weather was clear with gentle winds. The lagoon breach was mid-beach, approximately 30 meters wide and up to 100 cm deep.

## METHODS

A. Blocking Net Sampling Method for Permanent Stations

A meter tape was laid out along the shoreline at the waters edge extending for 10 meters. Two 10 m x 2 m 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 2 m x 1 m seines walked carefully to the apex of the triangle and pulled from the shore to the apex, from the apex towards the shore and randomly throughout the blocked area. 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, photographed and Fork Length measured, then they were released outside of the blocked area. Seining pulls continued until three consecutive pulls were empty, or until a total of 20 seines had been pulled.

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 1.25 m seines, 2 teams pulled parallel to shoreline along beach bank, from west to east, as well as parallel to the east bank of the lagoon from just upstream of PCH Bridge to the beach.

Equipment needed:

- WQ testing Kit (calibrated)
- 2 10m x 2m blocking nets
- 2m x 1.25 m seines (2)
- buckets (8)
- 30 m tape
- data sheets
- ice chest for voucher specimens

-ziplock baggies
- fish measuring boards (2)
- 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 |

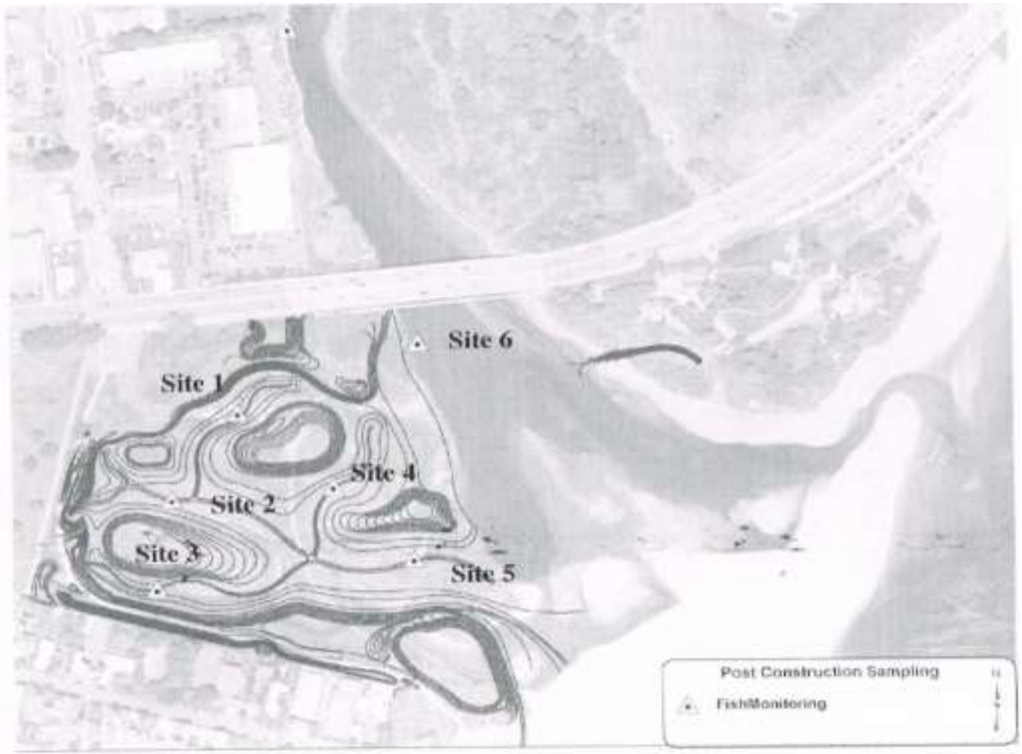



**Figure 1. Map of the Permanent Monitoring Sites, Malibu Lagoon Restoration (Established in January 2013 and revised in May 2014)**


**Figure 2. Locations of spot surveys 12 January 2016**

# RESULTS

Table 2. Water Quality and site conditions at the permanent monitoring sites 12 January 2016

| Variable | Site 1 | Site 2 | Site 2a | Site 3 | Site 5 | Site 6 |
|---|---|---|---|---|---|---|
| Avg depth (cm) | 40 | 60 | 10 | 80 | 60 | 25 |
| Water T°C | 11 | 10.3 | 9.9 | 11.2 | 12.9 | 12.5 |
| Air T°C | ND | ND | ND | ND | ND | ND |
| Salinity ppt | 18 | 15 | 15 | 15 | 20 | 23 |
| DO mg/l | 7.65 | 6.83 | 6.85 | 5.75 | 8.33 | 76.46 |
| pH | 8.57 | 8.5 | 8.53 | 8.52 | 8.46 | 8.45 |
| Conductivity | Over range | Over range | Over range | Over range | Over range | Over range |
| % Floating Algae cover | 0 | 0 | 0 | 0 | 0 | 0 |
| % Submerged/ Attached Algae cover | 0 | 0 | 0 | 0 | 0 | 0 |
| % emergent vegetation bank cover | 100 | 30 | 0 | 100 | 80 | 50 |
| Emergent Vegetation type | Jaumea, Distichlis. Salicornia | Distichlis. Salicornia | NA | Distichlis, Salicornia | Jaumea, Distichlis. Salicornia | Jaumea, Distichlis. Salicornia |
| Dominant Substrate | sand | silt | sand | Silt/muck | Gravel/sand | Sand/gravel |
| Time start | 09:35 | 09:45 | 10:02 | 11:00 | 10:35 | 09:30 |

*ND= no data collected

The dominant identifiable fish species captured in seine nets was Northern anchovy (*Engraulis mondax* n=180),although all quite small (<5 cm). The second dominant species was larval smelt, with just a few topsmelt between 6-10 cm). A single juvenile staghorn sculpin was captured and released. Striped mullet (*Mugil cephalus)* were observed leaping throughout the lagoon. Although not numerous, non-natives mosquitofish (*Gambusia affinis,* n=6) and Mississippi silversides (*Menida audens,* n=15) were also present.

Table 3. Summary of Fish and Invertebrates captured/observed 12 January 2016

| **Lagoon-ocean connection conditions** | **OPEN** | **Site 1** | **Site 2** | **Site 2a** | **Site 3** | **Site 5** | **Site 6** | **Spot E1** | **Spot E2** | **Spot E3** | **Spot B1/2** | **Spot B3** | **TOTALS** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Seine pull total to depletions** | | 5 | 7 | 5 | 5 | 4 | 12 | 2 | 2 | 2 | 4 | 2 | |
| **Native Fish Species** | | 0 | | | | | | | | | | | |
| Topsmelt larva (<5 cm) | *Atherinops affinis* | | | | | | | | | | 5 | | 5 |
| Topsmelt juvenile (6-15 cm) | *Atherinops affinis* | | | | | 2 | | | | | | 4 | 6 |
| Unidentified smelt larva (<5 cm) | *Atherinops sp* | | 2 | | | | | | 55 | 7 | | | 64 |
| Staghorn sculpin (<5 cm) | *Leptocottus armatus* | | | | 1 | | | | | | | | 1 |
| Northern anchovy <5 cm | *Engraulis mordax* | | 1 | | 142 | 9 | 8 | 10 | 8 | 1 | | 1 | 180 |
| striped mullet | *Mugil cephalus* | | | | | | | | | | | | 0 |
| Unidentified larva (<1cm) | | | | | | | | | | | | | 0 |
| **Non-Native Fish Species** | | 0 | | | | | | | | | | | 0 |
| Mosquitofish juveniles (<5cm) | *Gambusia affinis* | | | | 1 | 3 | | | 1 | | | 1 | 6 |
| Mississippi silversides | *Menida audens* | | 1 | 2 | 1 | | | 5 | 2 | | | 4 | 15 |
| **Invertebrates** | | 0 | | | | | | | | | | | 0 |
| Oriental shrimp | *Shrimp sp.* | | 1 | | | | | | 2 | | | 2 | 5 |
| Hemigraspus crabs | | | | | | | | | 1 | | | | 1 |
| Barnacles | | | | | | 1 | | | | | | | 1 |

**SUMMARY**

The January 2016 post-construction fish survey was completed in one day with a team of 10 people.

Table 4 provides a summary comparing abundance of species documented in Malibu Lagoon prior to restoration (2005), species relocated during restoration (2012), and five post-construction surveys (2013-2016).

Overall fish diversity and abundance in January 2016 was low. Continued monitoring may reveal if this is an acute or seasonal trend. Mosquitofish (*Gambusia affinis*), a dominant species pre-restoration, continue to be present but in very low numbers (<20). Thousands of smelt and other fish larva were present both 2014 and 2015, indicating Malibu Lagoon's function as fish nursery habitat.

One of the target species for recovery was tidewater goby. The post-restoration abundance of this species remains low, with only a few scattered individuals observed since restoration. Despite the increase of more than two acres of potential breeding habitat, reproduction has not been observed. Distribution of gobies has been restricted to the area below the PCH bridge on both east and west banks. Few individuals have been observed in the restored area.

It is important to note that the first confirmed observation of southern steelhead trout in Malibu lagoon occurred post-restoration.

Stripped mullet and topsmelt are the most abundant fish species currently observed.

Although numbers of tidewater gobies and California Killifish have not increased, other native species such as topsmelt, northern anchovy and long-jawed mudscuker have increased consistently.

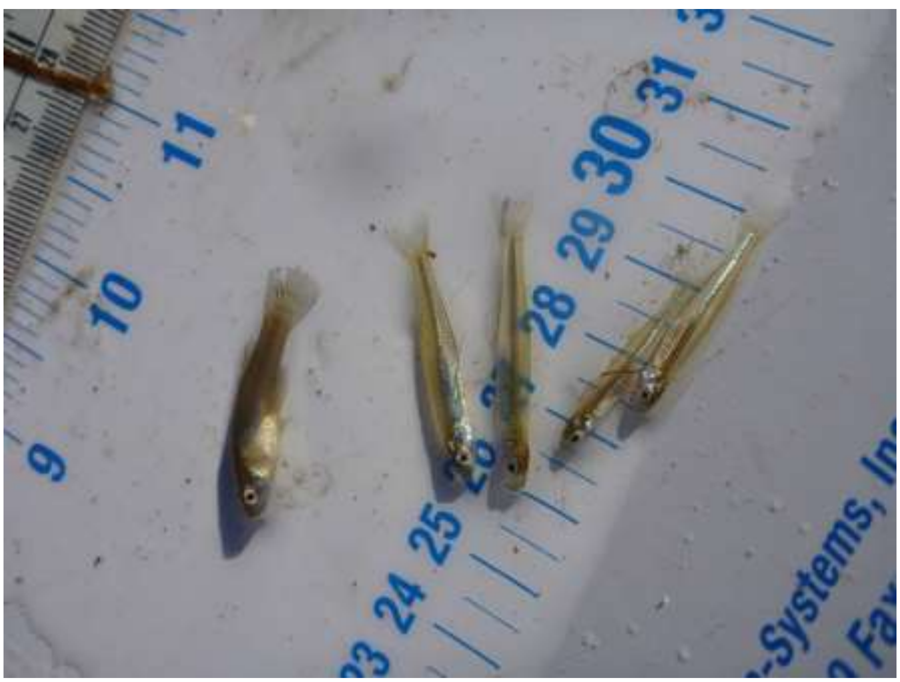
Most importantly, the numbers of non-native mosquitofish and carp have decreased severely.

Table 4. Summary of Fish Species     Pre-restoration     Post-restoration

| Native Fish Species | | Jun-05 open | Jun-12 open | Jan-13 open | May-14 closed | Dec-14 open | May-15 closed | Jan-16 open |
|---|---|---|---|---|---|---|---|---|
| Steelhead trout | *O.mykiss* | | | | 1 observed | | | |
| Unidentified goby larva (<5 cm) | | | 2 | | 500~ | | | |
| Tidewater goby | *Eucyclogobius newberryi* | 473 | 8 | | 15 | | 41 | |
| Arrow goby (<5 cm) | *Cleavlandia ios* | | | | 5 | | | |
| Bay goby? | *Lepidogobius lepidus* | | | | 3 | | | |
| CA killifish juveniles (<5cm) | *Fundulus parvipinnis* | | 306 | | 5 | | | |
| CA killifish (5-10 cm) | *Fundulus parvipinnis* | 46 | 16 | | | | | |
| Long-jawed mudsucker (<5 cm) | *Gillichthys mirabilis* | 1 | 8 | | 5 | | 3 | |
| Long-jawed mudsucker (5-10 cm) | *Gillichthys mirabilis* | | 11 | | | | 22 | |
| Topsmelt larva (<5 cm) | *Atherinops sp* | | 1 | 3 | | | 176 | 5 |
| Topsmelt juvenile (6 cm) | *Atherinops sp* | 244 | 0 | | 11 | 2 | 60 | 6 |
| Topsmelt adult (16 cm) | *Atherinops sp* | | 0 | | | | 6 | |
| Unidentified smelt larva (<5 cm) | *Atherinops sp* | | 101 | | >15,000 | | 2244 | 64 |
| Staghorn sculpin (<5 cm) | *L. armatus* | | | 17 | 11 | | | 1 |
| Staghorn sculpin (5-10 cm) | *L.armatus* | | 3 | | | | | |
| Diamond turbot | *H. guttulata* | | | 7 | 1 | | | |
| Northern anchovy <5 cm | *Engraulis mordax* | | 5 | | | | | 180 |
| Striped mullet | *Mugil cephalus* | observed | | observed | observed | 6 | 1 | |
| Unidentified fish larva | | | | | | | 991 | |
| **Non-Native Fish Species** | | | | | | | | |
| Mississippi silversides | *Menida audens* | | | 1 | | 801 | 9 | 15 |
| Mosquitofish | *Gambusia affinis* | 65 | 4072 | | 1 | 2 | 16 | 6 |
| Carp | *Cyprinus carpio* | 1 | 4072 | | observed | | | |
| **Invertebrates** | | | | | | | | |
| Oriental shrimp | *Palaemonetes sp.* | | | 37 | 207 | | 10 | 5 |
| Hemigraspus crabs | | | | | 10 | | 20 | 1 |
| Water boatman juveniles | | | 6 | | | | | |
| Amphipods | | | 6,000+ | | | | | |
| Isopods | | | 2500+ | | | | | |
| Ctenophore sp (<2 cm) | | | 2500+ | 3 | | | | |
| Salp sp (<2 cm) | | | | 3 | | | | |
| Sea hare (5-10 cm) | *Aplysia californica* | | | 2 | | | | |
| Segmented worm <2 cm) | | | | 3 | | | | |
| Gastropoda | | | | | | | 4 | |
| Water scavenger larva | Hydrophilidae | | | | | | 1 | |

# Appendix A. Photographs of fish species


Topsmelt



Gambusia and Mississippi silverside juveniles

# 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 3 (2015) (Prepared by D. Cooper)

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# Avian Usage of Post-restoration Malibu Lagoon Year 3 (2015)

## Malibu Lagoon State Beach

## Malibu, California

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November 5, 2015

**Summary**

Several patterns have emerged after three 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. Special-status species in year 3 continue to make heavy use of the site, in particular the beach and lower lagoon area (e.g., Brown Pelican and Snowy Plover)[1].

Fish-eating waterbirds (e.g., Ruddy Duck) showed relatively dramatic increases, presumably due to a richer and more predictable fish fauna – and more room to forage – in the expanded, post-restoration lagoon. Scrub and woodland birds continue to increase in year 3, probably owing to the continued re-growth of scrub at the site, which had been essentially denuded and replanted as part of the restoration to a more native habitat palette. Counts of large waders (herons/egrets) and waterfowl show no clear trend overall; however, many species in these groups continue to use the site heavily. Urban-associated species and those associated with freshwater marsh showed the steepest initial (year 1) declines, due to the near-total lack of their preferred habitats at the site when all hardscape and freshwater marsh vegetation was removed and replaced with new native plantings. However, counts of freshwater marsh species like Marsh Wren and Red-winged Blackbird in 2015 suggest they may be returning to the site. Urban birds declined in years 1 and 2 post-restoration, and their numbers have remained below pre-restoration levels, though increasing slightly in year 3. Counts of shorebirds overall have continued to decline into year 3, though species richness remains similar to pre-restoration levels. Several additional years of monitoring will be necessary to confirm these trends.

**Introduction and Methods**

The reconfiguration of Malibu Lagoon, completed in spring 2013, began in mid-2012 when the entire western portion was transformed into 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, vegetated 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), who 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 four years of data, each with four quarterly

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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.

surveys: pre-restoration (2005-06) and post-restoration (2013, 2014, and 2015), conducted on the following dates[3]:

Pre-restoration dates:

- 28-29 October 2005
- 09 and 11 January 2006
- 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
- 6-7 January 2015
- 21 April 2015 (both surveys done on this day)
- 9-10 July 2015
- 26-27 October 2015

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, so finding that 20 species were present in grassland and 22 in oak woodland

[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.

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 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 habitats, 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].

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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, single Peregrine Falcons in January and April 2014, and a Red-shouldered Hawk in October 2015.

[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.

**Results**

The total number of individual birds recorded during each year of quarterly surveys pre- and post-restoration was remarkably similar (7563-8489 individuals) prior to 2015; this year, the 11,299 individual birds estimated represents a nearly 30% increase over the prior years' average[6]. The cumulative number of species and identifiable subspecies detected in all four years stands at 146, with six species new for 2015[7]. Species richness, which dropped in the first two years post-restoration, appears to have rebounded somewhat by 2015 (117 species detected in late 2005 and 2006 prior to restoration, then 87-88 species in 2013 and 2014, to 99 species in 2015). 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.

Landbirds

Tables 1 and 2 summarize counts of selected groupings by ecological guilds of species from 2005 (pre-restoration) to 2015 (post-restoration). Treating landbirds first, I 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.

Now that we have data from three post-restoration years to analyze, for 2015 I assess the change in the number of individuals/species recorded in each of the species groups over that of the prior year (i.e., 2015 vs. 2014), as well as the change from the current year (2015) to the pre-restoration count in 2005-06. This hopefully provides a clearer picture of actual changes taking place in the avifauna of the site year-to-year. Addressing each ecological guild separately, counts of open country species surged in 2015 (112% over 2014), and showed levels nearly double those during the pre-restoration years. Counts of scrub/woodland species also increased from those in 2014 (and in 2013), but more modestly (11%), and were still well short of pre-restoration counts (276 in 2005-06 vs. 129 in 2015); still, species richness within this guild was found to be double that of the first year post-restoration (8 spp. in 2013 vs. 16 spp. in 2015). For urban species, after two straight years of declines, numbers began to increase in 2015, but were still found to be far lower than pre-restoration levels (320 birds in 2005-06 vs. 67 in 2015).

These observations may be compared to a much larger database of birders' reports to the eBird database (www.ebird.org); Figure 1 presents a graph of counts of one representative scrub-dwelling species, the Song Sparrow, at the site from multiple observers since 2011,

[6] Note that this number includes the cumulative total over two consecutive days, for a total of eight survey days per year.

[7] New species for 2015 surveys include Black-necked Stilt, Hooded Merganser, Red-shouldered Hawk, Thayer's Gull, Townsend's Warbler, and Wilson's Phalarope. All had been recorded multiple times at the lagoon, just not on the quarterly surveys reported on here.

which shows a basically consistent pattern across all five years (2011-15)[8], with slightly higher average counts pre-restoration (2011 and 2012). This suggests that the species has been able to adapt well to the scrub plantings on the site year after year.

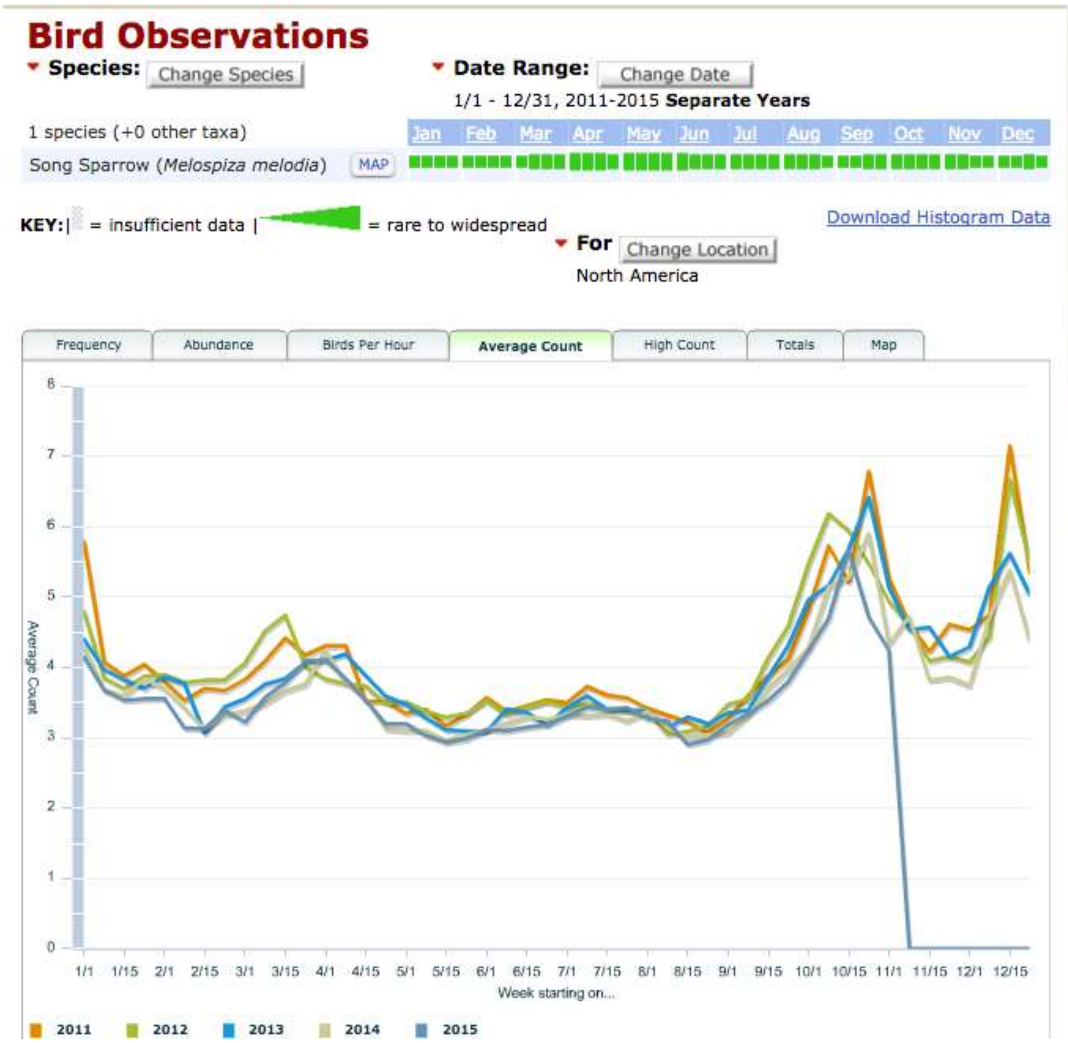


Figure 1. Counts of Song Sparrow at Malibu Lagoon, Jan. 2011 - Oct. 2015 (from eBird data).

8 Reasons for the consistent peaks in October and mid-December are hard to interpret, but be linked to an influx of fall migrants in October, and facultative movement of birds out of the Pacific Northwest following mid-winter rains and colder temperatures during December.

Waterbirds

For waterbirds, I identified six main groups, or guilds: freshwater marsh birds, marine/beach birds, shorebirds, waders, 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 associated with freshwater marsh (e.g., Cinnamon Teal), and many are fish-eaters.

A similar analysis as that for landbirds shows that birds associated with freshwater marsh habitat surged in numbers over 2014 (347% increase), with two species found that had not been recorded on the survey since the pre-restoration years (Marsh Wren and Red-winged Blackbird). By contrast, certain waterbird groups showed much clearer trends, including shorebirds (three straight years of double-digit declines, with 2015 counts just 20% of those in 2005-06), and much less dramatically, large waders such as herons and egrets, which showed declines of up to 13% each year. Figure 2 shows average counts of a typical shorebird, Least Sandpiper, which shows very high counts pre-restoration (2011), with much lower counts by 2014 and 2015.

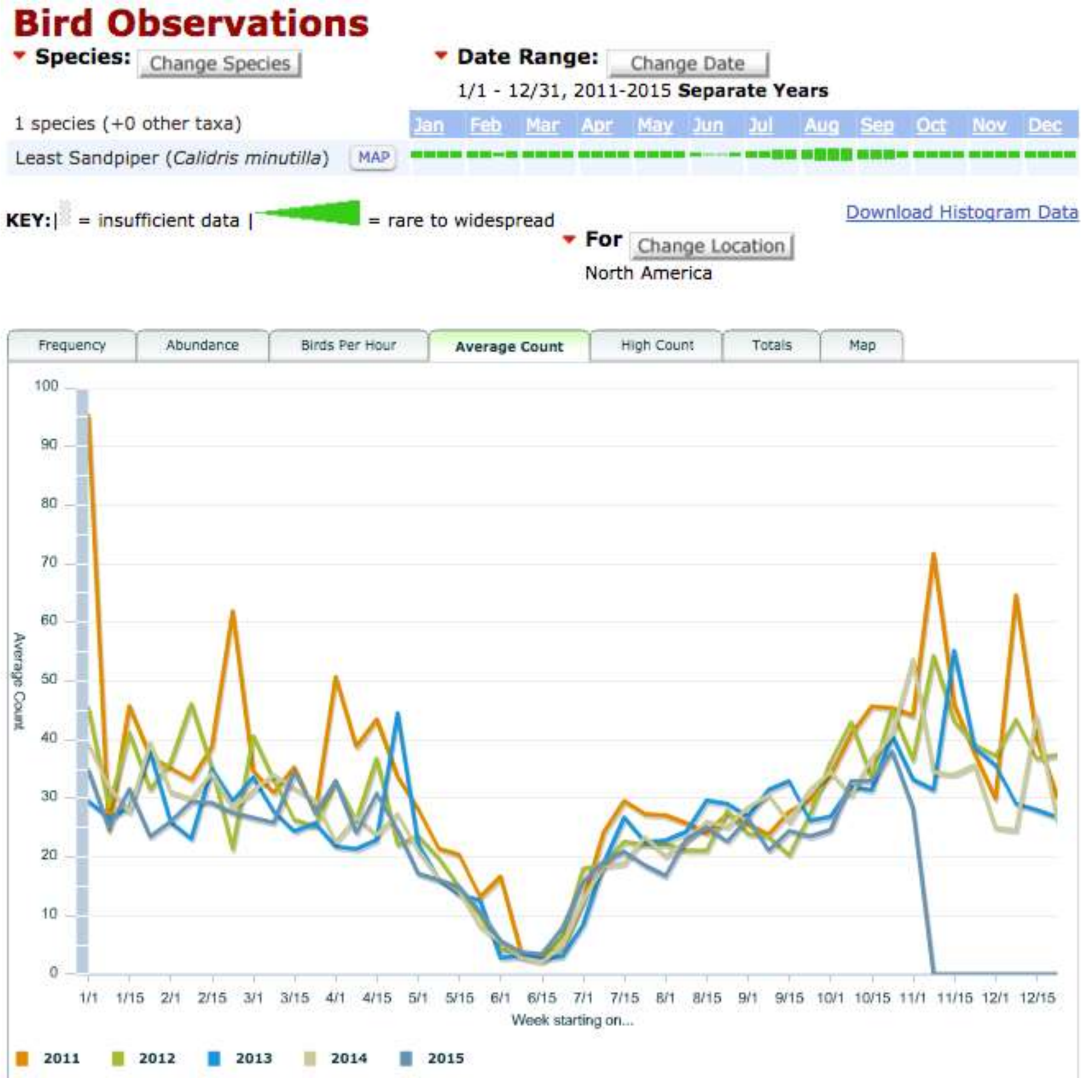


Figure 2. Counts of Least Sandpiper at Malibu Lagoon, Jan. 2011 - Oct. 2015 (from eBird data).

I found mixed trends for species typical of beach/marine habitat, and for waterfowl and fish-eaters, which showed post-restoration declines followed by increases (or vice-versa) over the past three years, and no clear pattern by year 3. Figure 3 shows a typical waterfowl species, Northern Shoveler, which showed relatively high counts prior to restoration (February and March 2011) but also very high counts during post-restoration years (e.g., January 2014).

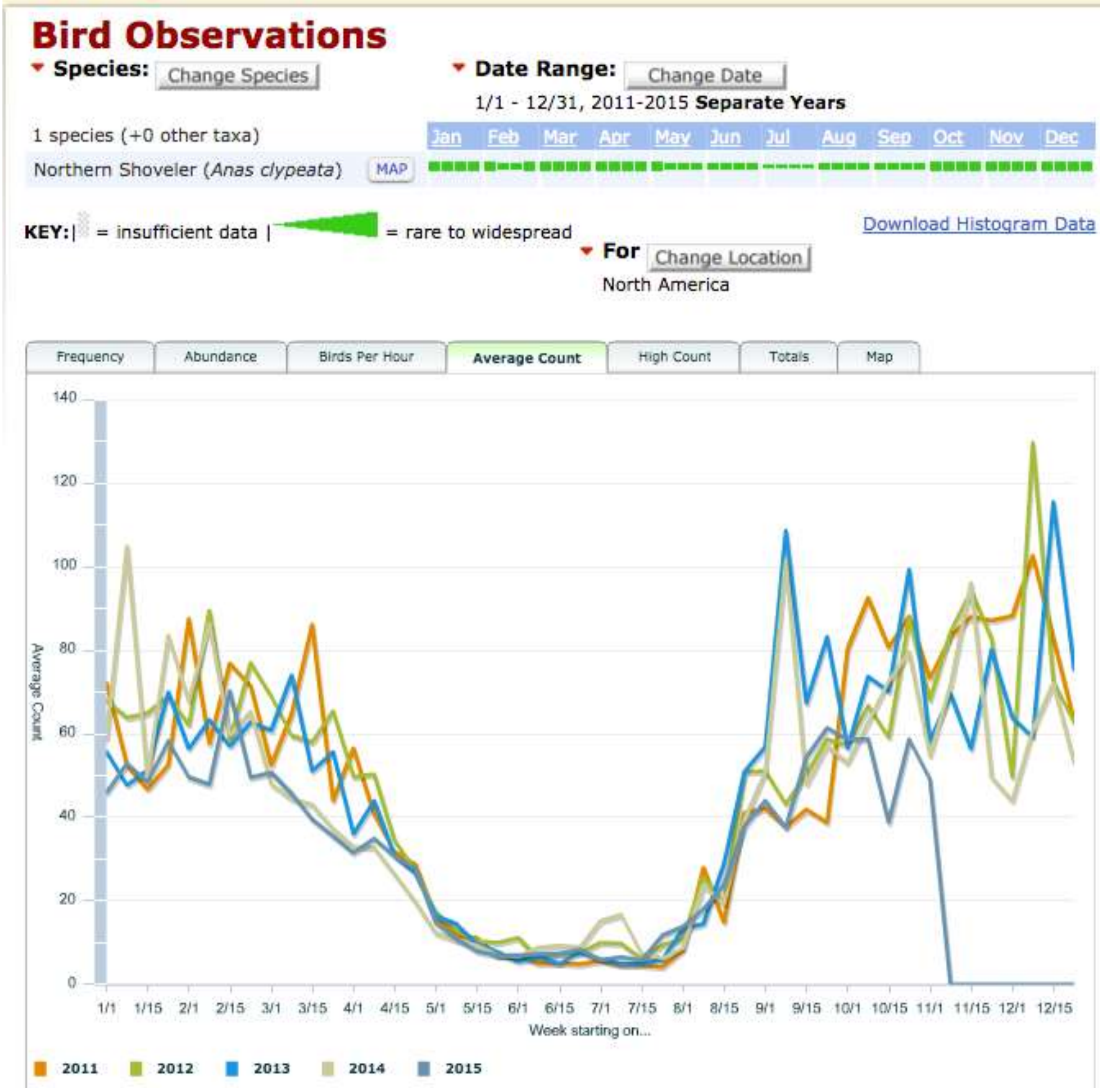


Figure 3. Counts of Northern Shoveler at Malibu Lagoon, Jan. 2011 - Oct. 2015 (from eBird data).

**Discussion**

The 30% increase in individual birds detected in the 2015 quarterly surveys was likely due to very large numbers of two species, Brown Pelican and California, which were observed roosting here in very large numbers. Brown Pelican numbers surged in spring (e.g., 2600 birds estimated here the afternoon of 21 April 2015), presumably as failed breeders returned early from nesting grounds off northwest Mexico, while California Gull numbers were highest in winter (4000+ birds roosting on the afternoon of 7 January 2015). High numbers of gulls may have had more to do with the changing configuration of the main lagoon and adjacent beach (birds counted on the beach have always been included in the count, since they tend to move freely back and forth between the lagoon and the beach). The expanded amount of open water likely favors roosting gulls, and in recent years (incl. 2015) low tide has exposed large areas of rocks jutting out from the beach that are used by large numbers of gulls and pelicans. Gull numbers may also be augmented by birds "commuting" from a nearby landfill in Calabasas to the north up Malibu Canyon (based on observations of gull flocks moving up and down the canyon, pers. obs.). To illuminate other patterns of avian usage that would be "swamped" by the thousands of gulls at the site, we have eliminated counts of most gulls from the analysis below.

Landbirds

The increase in open country birds, in particular the surge in 2015, is almost certainly due to the combination of the removal of high, brushy vegetation as part of the restoration, and the continued development of low, early-successional habitat favored by species like Savannah Sparrow and Western Meadowlark. These species have been particularly hard-hit in the region by a combination of outright habitat loss (through development), as well as the cessation of grazing and the consequent development of scrub, chaparral and woodland in formerly open habitats. The fact that their numbers are now nearly double pre-restoration counts suggests that the lagoon restoration had (and continues to have) a net-positive impact on this guild.

The more modest increase in birds of scrub and woodland also over prior years (though still roughly half pre-restoration levels) suggest that the scrub and riparian habitat planted as part of the restoration is "working", attracting (native) species that favor the willow thickets and goldenbush scrub that were once part of the natural landscape in the Malibu area. However, the fact that their numbers have yet to reach pre-restoration counts suggests that the prior vegetation at the site (i.e., during 2005-06), though strongly non-native, still likely functioned as an "ecological surrogate" for species like Hermit Thrush and California Towhee. It should be noted that very few scrub and woodland species at the site, then or now, are typical of undisturbed habitats in the region, but are the most widespread, adaptable representatives of this guild. For example, California Quail, California Thrasher, and Wrentit, which require large tracts of chaparral were probably always rare at Malibu Lagoon, yet are still fairly common in more extensive scrub habitat just north of Pacific Coast Highway, and no true riparian-obligate species, such as Yellow Warbler, have ever bred here (Cooper, unpubl. data). For this reason, the site will probably always be marginal for species in this guild.

The 2015 uptick in urban-adapted species was still well short of pre-restoration numbers, but as trees and shrubs grow back, their numbers will likely increase somewhat.

Waterbirds

The dramatic increase in freshwater marsh species is clearly due to the first emergence (in early 2015) of small stands of reeds at the edges of the "western channels" portion of the lagoon, which finally in 2015 were (re-)used by such characteristic species as Red-winged Blackbird (five at an afternoon roost in October 2015), Marsh Wren, and Common Yellowthroat. As these reeds expand and fill in, continued and increased usage by this guild will surely occur, and "lost" species such as Sora and Virginia Rail will likely move back into the site.

Shorebird usage at the site is complex, and these birds occur in several roles. The lagoon continues to provide high tide roosting habitat for species that feed in wet sand on beaches (e.g., Willet, Marbled Godwit). It provides limited shoreline habitat for foraging species like Western Sandpiper, which work the edges of channels and sand bars. Today, it provides very little reliable shallow-water/mudflat habitat (e.g., depth of <2") for flocking species such as "peeps" (Western/Least sandpipers), Dunlin, dowitchers, and others that were formerly more common here pre-restoration. The sharp decline of (non-marine) shorebirds appears largely driven by the reduction in number of two formerly common roosting species, the Black-bellied Plover and the Willet, with less severe declines noted for peeps and others. Many shorebird species continue to use the site (i.e., the species richness has not changed dramatically). It is likely the loss of shallow water and "roosting rocks" that were once located at the interface of the main lagoon and the western channels accounts for the sharp declines noted in at least Willet and Black-bellied Plover. And, the very shallow, "silted-in" channels that were dredged and widened as part of the restoration likely removed habitat for smaller species of shorebirds such as peeps, which had been regularly seen feeding in small flocks from the footbridges at the site prior to 2012 (pers. obs.).

These habitat features were also heavily used by both roosting and foraging large waders (herons/egrets), and it is possible that the declines in usage by this guild may be related to declines of smaller waders (owing to the former group's lower aggregate numbers in the region, the magnitude of its decline is likely reduced). For large waders, the loss of the broad, grassy expanses in the western channels (since removed and replaced by wider channels/more aquatic habitat) likely resulted in a reduction of roosting, as most local species were seen roosting in this habitat type essentially year-round. Today, small numbers of roosting waders are noted on the vegetated islands, but more often just one or two individuals of each species.

Changes in size and configuration of sand bars within the main lagoon may also have led to the decline of shorebird roosting since restoration; unless these low, broad islands – protected from human disturbance – form during winter, spring and fall when shorebirds are present, very little viable roosting habitat is available at the site. Often, sandbar habitat which develops is quickly submerged by ongoing releases from the upstream water treatment plan releases into Malibu Creek. However, it should be noted that the lagoon's avifauna is constantly in flux, and future years will undoubtedly see further changes in the patterns noted above.

Certain species of waterbirds can be hugely abundant – and variable in numbers – at the site and in the region generally from year to year (e.g., Brown Pelican, Elegant Tern and American Coot), which masks more subtle trends and makes it difficult to draw conclusions about diverse guilds. For example, for fish-eating birds, once we remove from the analysis the most variably abundant species that rarely forage at the site (i.e., Brown Pelican, Double-crested Cormorant) and Elegant Tern), abundance patterns do not conform to any recognizable trend. Many, if not most, of the individual pelicans, cormorants and terns at the lagoon are using the site for roosting/loafing, rather than for foraging, which is mainly done offshore. And, many are fairly nomadic through a given season, roosting on different beaches depending on local inshore marine fishing conditions and disturbance factors. So, a decline in their numbers at the lagoon would not necessarily suggest that fishing quality has declined or that the prey base is low at the site – it may simply be that there aren't enough fish offshore (prey base), or even that too many people are using the beach or that their favorite sand bar roosting site is now connected to land (human disturbance). So, while there were more marine-associated species and fish-eating birds counted at the lagoon in 2015 than in the pre-restoration surveys, the reasons may lie far offshore, or hundreds of miles to the south off Mexico (where many of them nest). Thus, one must balance generalizations for certain guilds with a more nuanced, species-by-species analysis that takes into account a complete understanding of the life history of the birds and their actual usage of the site and global numbers in a given year.

As noted in the year 2 study, many additional analyses could be conducted using the bird data from Malibu Lagoon, including 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?) Intra-site usage provides another avenue of analysis: since data were collected by region of the site (e.g., beach, western channels, main lagoon), are certain waterbirds showing increases in one area of the site but not in others? This could help clarify the role of the actual restoration activity across the site on a particular species or species group; of course, 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.

Sensitive species

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 2015, 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[9], it has not bred at the lagoon at any point in recorded history, but a calling pair was noted on the 9 July 2015 survey, after a summer in which as many as 11 were noted (on 17 June 2015; T. Linbo, eBird).

The State Threatened Belding's Savannah Sparrow presents an interesting case; while no historical populations is known from the site, dark-streaked individuals continue to be observed here (often foraging on sand), 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), and one photographed 2 Jan. 2015 (C. Warneke; eBird; likely continuing from 12 Dec. 2014, D.S. Cooper).

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.

[9] 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[10] and raptors). Yellow shading indicates species that appear to have unequivocally increased since 2005-06; the others have either declined at the site or show no clear trend.

| Guild | Species | 2005-06 | 2013 | 2014 | 2015 | % Change (# individuals) from year prior |
|---|---|---|---|---|---|---|
| OPEN COUNTRY[11] | | | | | | |
| | American Pipit | 10 | 3 | 0 | 5 | |
| | Killdeer | 48 | 31 | 14 | 36 | |
| | Savannah Sparrow | 2 | 3 | 5 | 8 | |
| | Say's Phoebe | 1 | 6 | 4 | 1 | |
| | Western Kingbird | 6 | 0 | 0 | 1 | |
| | Western Meadowlark | 0 | 5 | 27 | 55 | |
| Total open country (# species) | | 67 (5) | 48 (5) | 50 (5) | 106 (6) | -28%, +4%, +112% |
| SCRUB/WOODLAND[12] | | | | | | |
| | Allen's Hummingbird | 38 | 10 | 10 | 13 | |
| | American Robin | 0 | 3 | 0 | 0 | |
| | Anna's Hummingbird | 21 | 0 | 3 | 2 | |
| | Bewick's Wren | 15 | 1 | 1 | 1 | |
| | Bushtit | 70 | 22 | 35 | 24 | |
| | California Towhee | 18 | 9 | 7 | 6 | |
| | Cedar Waxwing | 14 | 0 | 0 | 0 | |
| | Hermit Thrush | 0 | 0 | 2 | 8 | |
| | House Wren | 5 | 2 | 3 | 4 | |
| | Lincoln's Sparrow | 5 | 0 | 2 | 2 | |
| | Oak Titmouse | 1 | 0 | 0 | 5 | |
| | Orange-crowned Warbler | 11 | 0 | 3 | 4 | |
| | Ruby-crowned Kinglet | 5 | 3 | 8 | 12 | |
| | Song Sparrow | 51 | 47 | 40 | 38 | |
| | Spotted Towhee | 15 | 0 | 2 | 1 | |
| | Townsend's Warbler | 0 | 0 | 0 | 4 | |
| | Wilson's Warbler | 3 | 0 | 0 | 2 | |
| | Yellow Warbler | 4 | 0 | 0 | 3 | |
| Total scrub/woodland (# species) | | 276 (15) | 97 (8) | 116 (12) | 129 (16) | -65%, +20%, +11% |
| URBAN | | | | | | |
| | American Crow | 49 | 16 | 6 | 8 | |
| | Black Phoebe | 28 | 17 | 11 | 7 | |
| | Brewer's Blackbird | 27 | 0 | 0 | 0 | |
| | Brown-headed Cowbird | 14 | 5 | 1 | 1 | |
| | European Starling | 123 | 1 | 2 | 28 | |
| | Hooded Oriole | 7 | 1 | 0 | 0 | |
| | House Finch | 65 | 11 | 17 | 19 | |
| | Northern Mockingbird | 7 | 3 | 5 | 4 | |
| Total urban (# species) | | 320 (8) | 54 (7) | 42 (6) | 67 (6) | -83%, -22%, +60% |

[10] 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.
[11] Cattle Egret had been included in prior years' analyses, but it is essentially a vagrant to the site and will be omitted from this and future ones.
[12] Mourning Dove and Lesser Goldfinch had been included in prior years' analyses, but they are more typical of weedy areas than woodland or scrub and so will be omitted from this and future ones.

Table 2. Waterbird guilds.

| Guild | Species | 2005-06 | 2013 | 2014 | 2015 | % Change (# individuals) from year prior |
|---|---|---|---|---|---|---|
| FRESHWATER MARSH | | | | | | |
| | Common Yellowthroat | 63 | 16 | 12 | 22 | |
| | Great-tailed Grackle | 20 | 41 | 5 | 43 | |
| | Marsh Wren | 3 | 0 | 0 | 6 | |
| | Red-winged Blackbird | 84 | 0 | 0 | 5 | |
| | Sora | 5 | 0 | 0 | 0 | |
| | Virginia Rail | 6 | 0 | 0 | 0 | |
| Total freshwater marsh (# species) | | 181 (6) | 57 (2) | 17 (2) | 76 (4) | -69%, -70%, +347% |
| MARINE/BEACH[13] | | | | | | |
| | Black Oystercatcher | 3 | 1 | 0 | 0 | |
| | Bonaparte's Gull | 1 | 2 | 11 | 9 | |
| | Brant | 4 | 6 | 0 | 6 | |
| | Brown Pelican | 862 | 167 | 4142 | 2821 | |
| | Caspian Tern | 83 | 13 | 26 | 19 | |
| | Double-cr. Cormorant | 109 | 310 | 142 | 193 | |
| | Elegant Tern | 258 | 219 | 310 | 781 | |
| | Forster's Tern | 2 | 6 | 0 | 4 | |
| | Glaucous-winged Gull | 1 | 2 | 4 | 10 | |
| | Heermann's Gull | 216 | 30 | 466 | 176 | |
| | Herring Gull | 1 | 4 | 2 | 18 | |
| | Horned Grebe | 3 | 0 | 0 | 2 | |
| | Least Tern | 30 | 0 | 0 | 2 | |
| | Mew Gull | 2 | 0 | 1 | 0 | |
| | Red-breasted Merganser | 7 | 8 | 4 | 12 | |
| | Red-throated Loon | 0 | 2 | 1 | 0 | |
| | Royal Tern | 0 | 7 | 12 | 26 | |
| | Ruddy Turnstone | 10 | 34 | 21 | 8 | |
| | Sanderling | 58 | 460 | 48 | 8 | |
| | Snowy Plover | 52 | 202 | 137 | 16 | |
| | Surfbird | 0 | 0 | 4 | 0 | |
| | Western Grebe | 0 | 3 | 16 | 9 | |
| | Western Gull | 608 | 576 | 325 | 284 | |
| Total marine/beach (# species) | | 2311 (19) | 2054 (21) | 5672 (18) | 4404 (19) | -11%, +176%, -22% |

[13] Brandt's Cormorant was eliminated; small sample size (0-1 individual each year recorded)

Table 2. (continued)

| Guild | Species | 2005-06 | 2013 | 2014 | 2015 | % Change (# individuals) from year prior |
|---|---|---|---|---|---|---|
| SHOREBIRDS[14] | | | | | | |
| | American Avocet | 9 | 6 | 0 | 0 | |
| | Black-bellied Plover | 287 | 224 | 169 | 73 | |
| | Black-necked Stilt | 0 | 0 | 0 | 4 | |
| | Dunlin | 5 | 2 | 1 | 0 | |
| | Greater Yellowlegs | 8 | 1 | 0 | 0 | |
| | Least Sandpiper | 71 | 33 | 4 | 1 | |
| | Long-billed Curlew | 2 | 0 | 0 | 0 | |
| | Long-b. Dowitcher | 14 | 0 | 0 | 1 | |
| | Marbled Godwit | 54 | 15 | 63 | 19 | |
| | Semipalmated Plover | 27 | 16 | 3 | 10 | |
| | Spotted Sandpiper | 11 | 6 | 7 | 8 | |
| | Western Sandpiper | 197 | 21 | 11 | 6 | |
| | Whimbrel | 20 | 27 | 9 | 21 | |
| | Willet | 212 | 47 | 15 | 38 | |
| | Wilson's Phalarope | 0 | 0 | 0 | 2 | |
| Total shorebirds (# species) | | 917 (13) | 398 (11) | 282 (9) | 183 (11) | -57%, -29%, -35% |
| WADERS | | | | | | |
| | Black-cr. Night-heron | 31 | 5 | 3 | 5 | |
| | Great Blue Heron | 24 | 26 | 9 | 17 | |
| | Great Egret | 13 | 13 | 5 | 8 | |
| | Green Heron | 1 | 0 | 1 | 1 | |
| | Snowy Egret | 55 | 77 | 87 | 66 | |
| Total waders (# species) | | 124 (5) | 121 (4) | 105 (5) | 97 (5) | -1%, -13%, -8% |
| WATERFOWL | | | | | | |
| | American Coot | 628 | 1096 | 562 | 239 | |
| | American Wigeon | 16 | 49 | 17 | 10 | |
| | Blue-winged Teal | 6 | 0 | 0 | 4 | |
| | Bufflehead | 46 | 26 | 10 | 4 | |
| | Cinnamon Teal | 16 | 0 | 0 | 3 | |
| | Eared Grebe | 10 | 27 | 74 | 29 | |
| | Gadwall | 94 | 164 | 107 | 143 | |
| | Green-winged Teal | 147 | 48 | 42 | 66 | |
| | Hooded Merganser | 0 | 0 | 0 | 2 | |
| | Lesser Scaup | 2 | 1 | 1 | 0 | |
| | Mallard | 170 | 98 | 28 | 99 | |
| | Northern Pintail | 8 | 0 | 2 | 2 | |
| | Northern Shoveler | 47 | 163 | 31 | 18 | |
| | Pied-billed Grebe | 14 | 28 | 12 | 13 | |
| | Ruddy Duck | 55 | 90 | 76 | 276 | |
| | Snow Goose | 8 | 0 | 0 | 1 | |
| Total waterfowl (# species) | | 1267 (15) | 1790 (11) | 962 (12) | 909 (15) | +30%, -46%, -6% |
| FISH-EATERS[15] | | | | | | |
| | Black-cr. Night-heron | 31 | 5 | 3 | 5 | |
| | Caspian Tern | 83 | 13 | 26 | 19 | |
| | Double-cr. Cormorant | 109 | 310 | 142 | 193 | |
| | Eared Grebe | 10 | 27 | 74 | 29 | |
| | Forster's Tern | 2 | 6 | 0 | 4 | |
| | Great Blue Heron | 24 | 26 | 9 | 17 | |
| | Great Egret | 13 | 13 | 5 | 8 | |

[14] Excludes marine-associated species such as Sanderling.
[15] Excludes Brown Pelican and Elegant Tern due to extreme variability in numbers due to global conditions (i.e., not local conditions as would be useful for this analysis) and the fact that both species use the lagoon primarily for roosting (i.e., not for foraging); also excludes Brandt's Cormorant (see above).

| | | | | | | |
|---|---|---|---|---|---|---|
| | Green Heron | 1 | 0 | 1 | 0 | |
| | Hooded Merganser | 0 | 0 | 0 | 2 | |
| | Horned Grebe | 3 | 0 | 0 | 2 | |
| | Least Tern | 30 | 0 | 0 | 2 | |
| | Pied-billed Grebe | 14 | 28 | 12 | 13 | |
| | Red-br. Merganser | 7 | 8 | 4 | 12 | |
| | Red-throated Loon | 0 | 2 | 1 | 0 | |
| | Royal Tern | 0 | 7 | 12 | 26 | |
| | Ruddy Duck | 55 | 90 | 76 | 276 | |
| | Snowy Egret | 55 | 77 | 87 | 66 | |
| | Western Grebe | 0 | 3 | 16 | 9 | |
| Total fish-eaters (# species) | | 437 (14) | 615 (14) | 468 (14) | 683 (15) | +40%, -24%, +46% |