# Malibu Lagoon Restoration and Enhancement Project

## Comprehensive Monitoring Report (Year 4)

August 2017

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# Malibu Lagoon Restoration and Enhancement Project

## Comprehensive Monitoring Report (Year 4)

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Photo: Malibu Lagoon Restoration Project at sunrise (27 December 2016; credit TBF).

# 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). Another subsequent year of monitoring (Year 5) will allow the post-restoration data to be evaluated against the 5-year project goals and success criteria, as well as identifying trends over time. California Rapid Assessment Method (CRAM) surveys continue to be a good indicator of the consistently increasing condition of the post-restoration wetland habitat areas. 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 74 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. Transects 1, 2, 4, and 5 showed stable cross section profiles, with no evidence of sediment deposition. Transect 3 had a slight shift in overall profile when estimating area changes; however, the thalweg remains stable, with no signs of sediment deposition. Slight shifts in the profiles are likely attributed to natural morphological variability due to tidal waters. Sediment appears to be moving in accordance with predicted tidal and closed berm water regimes.

***Water Quality – Automated Water Quality Monitoring:*** Year 4 post-restoration permanent sonde water quality dissolved oxygen data exceeded both of the success criteria at all stations. Data from the back channel sondes displayed an increase in the percentage of readings above dissolved oxygen thresholds, when compared to pre-restoration data from the back channel. 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.  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 variability in other physical or climatic factors.

Lastly, sonde probe failure and equipment malfunctions, primarily unexplained early shut-offs of the Hydrolab sondes, led to periods of missing data during the cooler closed bar conditions.  To address problems with probe failure and equipment malfunctions, data continue to be QAQC'ed monthly to analyze issues as soon as possible and more frequent checks of sonde status in the field have been conducted.  Additionally, failed sondes with unidentified problems were returned to the manufacturer and replaced.  There are no comparative pre-restoration data to the 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 events never fell below 11 mg/L in May 2014, 8 mg/L in May 2015, and 10 mg/L in May 2016.  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 subsequently, and consistent low concentrations of nutrients remained present through the Year 4 surveys (2016).  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 and another decrease in May 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 an expected trend. 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. Multiple large spikes for all nutrients were present in the pre-restoration September 2006 and April 2007 data which doubled the highest concentrations identified in post-restoration surveys. Post-restoration sediment nutrient data also displayed more uniform distributions and smaller total ranges. 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.

***Biological Monitoring – Benthic Invertebrates:*** The invertebrate survey data results have established a trend from a depauperate, pollution-tolerant invertebrate community (pre-restoration), to a healthier, diverse invertebrate community that included a higher percentage abundance of sensitive species and numbers of taxa (post-restoration). The current abundances and numbers of sensitive taxa are much higher than pre-restoration conditions and did not exhibit decreases across multiple years; thus, the benthic community is meeting the project success criteria. It will be important to continue to evaluate these data in the subsequent monitoring report (Year 5) across all five monitoring 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 the native fish species richness' and the overall native fish abundances are higher in all three of the post-restoration summer surveys than in the pre-restoration summer survey. Up to 12 native fish species have been documented in the lagoon, as compared to a pre-restoration species richness of five. Non-native fish abundances are lower, post-restoration, and the non-native species richness is the same. Tidewater gobies were observed in both the pre- and post-restoration surveys; however, the post-restoration gobies (and other fish species) have been identified in the back channels which were previously an anoxic dead zone.

***Biological Monitoring – Avian Community Surveys:*** Several patterns have emerged after four years of post-restoration bird monitoring, and while they have not been evaluated for statistical significance, they provide an indication of how the site's avifauna are responding to the restoration overall. Special-status species in Year 4 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 2016 included 11,736 individual birds identified, representing the highest count of birds recorded in any pre- or post-restoration years.

Intra-site usage provided an additional avenue of analysis. Since data were collected by region of the site (e.g., beach, western channels, main lagoon), a separate analysis of waterbirds was conducted showing increases in abundances and species richness, post-restoration, within the restoration channel habitats.

***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. 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. Conversely, post-restoration, a reduction in floating mat algae was observed during survey periods when compared to pre-restoration conditions. Instead of the algal mats, the post-restoration cover data were dominated by 'wrack', or floating, detached marine kelp species, and after four years, still remained well below a 10% grand mean total cover and well within the success criteria recommendations. Wrack does not cause eutrophication and often provides food and habitat for invertebrate species.

Additionally, wind-driven circulation in the post-restoration channels tended to disperse any algal blooms, thereby reducing any potential impacts from the algae becoming trapped in one location. Lastly, submerged aquatic vegetation (SAV) seagrasses are longer-living species which update and fix nutrients, reducing eutrophication. Living SAV was present in the form of *Ruppia sp.* and *Phyllospadix sp.* in several locations within the restoration area. SAV provides many benefits to the ecosystem, including filtering water and improving clarity, preventing erosion, sequestering carbon dioxide and respiring oxygen (contributing oxygen to the system), and preventing sediment resuspension during extreme tides or storm events.

***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 1.1% 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. Native cover in the most recent survey ranges from 51.8% to 81.7%.

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

***Conclusions:*** Year 4 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 wetland condition 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.  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 a period of five years.

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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 9 March 2017. During the Year 4 monitoring period, the Lagoon berm breached on 28 November 2016, and the 'open condition monitoring' occurred between the date of the breach and 9 March 2017 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 26 January 2017 with an open berm condition (credit: P. House, The Bay Foundation).


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, and post-restoration baseline data from Abramson et al. 2013, 2015, and 2016. 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*

Seven 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, 19 January 2016, and 27 December 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, 27 December 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 and Figure 5, with the pre-restoration data (2012) also included for comparison. The overall CRAM score increased from 50 pre-restoration to 74 based on the latest survey, with an additional increase in the hydrology, physical, and biotic attributes since the January 2016 survey. The hydroperiod metric improved largely due to a lack of artificial breaching occurring during the survey time period. The lagoon breached from a closed to open condition naturally in the appropriate location on 28 November 2016. The scores for topographic complexity and overall complexity of the Assessment Area also improved, with the addition of several new microtopographic patch types. The vegetation community was similar to last year, with additional establishment of a large plant layer, predominantly in the form of *Schoenoplectus californicus* (California bulrush).

While the overall CRAM score 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 slightly over time, due to increasing complexity and continued maturation in defined vegetation structure. Continued maintenance and monthly volunteer restoration events continue to contribute to the reduction in non-native vegetation across the site.

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 | 12/27/16 |
|---|---|---|---|---|---|---|---|---|
| Attribute 1: Buffer and Landscape Context | 38 | 38 | 38 | 38 | 53 | 53 | 53 | 53 |
| Attribute 2: Hydrology Attribute | 50 | 58 | 58 | 58 | 58 | 58 | 58 | 67 |
| Attribute 3: Physical Structure Attribute | 50 | 88 | 75 | 75 | 88 | 88 | 88 | 100 |
| Attribute 4: Biotic Structure Attribute | 61 | 39 | 56 | 53 | 64 | 64 | 72 | 75 |
| **Overall AA Score** | **50** | **56** | **57** | **56** | **66** | **66** | **68** | **74** |

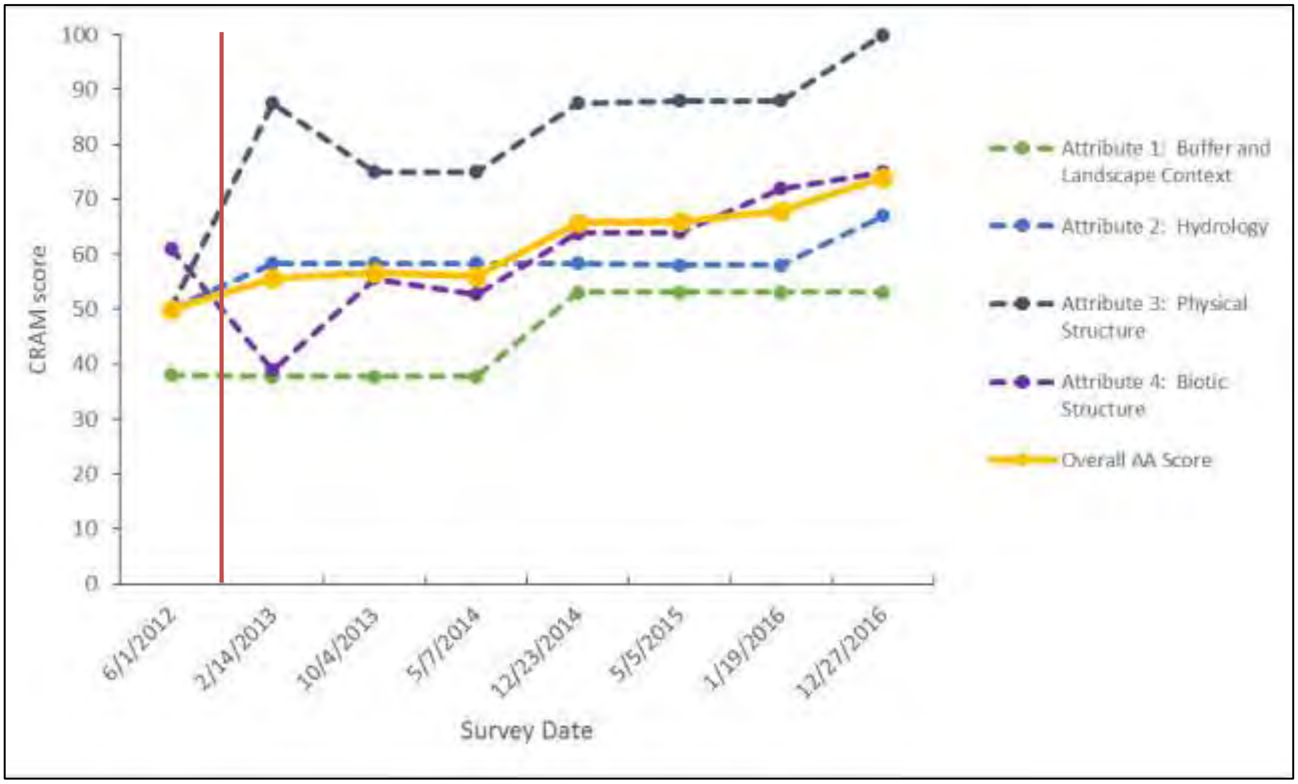



Figure 5. Graph of CRAM attribute and overall scores over time. Note: the 2012 survey date is pre-restoration.

### *Performance Evaluation*

Post-restoration surveys show a consistent increase in final CRAM scores over time, with the most recent scores indicating that the wetlands are in good condition, overall. As predicted, the biotic structure attribute continued to increase slightly as the vegetation community increased in overall cover and complexity over time. The hydrology score increased for the first time in several years due to a significant reduction in irrigation and a lack of artificial breaching occurring this year. The overall CRAM final score is also likely to remain consistently above the pre-restoration assessment final score. CRAM surveys will continue annually (at minimum) 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 four consecutive post-restoration years on 14 February 2013, 18 December 2014, 19 January 2016, and in December 2016 (21 and 27 December 2016) (Figures 6 and 7). Two survey days were needed in Year 4 to complete the monitoring. Horizontal and vertical locations of cross-section end-points were fixed by monuments. Sediment scour or deposition depths were calculated from the data.

Figure 6. Cross-channel elevation surveys at Malibu Lagoon, 27 December 2016.


Figure 7. Map of cross-channel elevation transect locations.

### *Results*

Results were calculated for all five post-restoration cross-section transects comparatively across all survey dates (Figures 8-12). 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 8-12). 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 13). Cross section diagrams and area calculations continue to show no significant evidence of sediment deposition. Transects 1, 2, 4, and 5 showed a consistent estimated area, with no evidence of sediment deposition. Transect 3 had a slight increase in estimated area, not significant enough to indicate a problem with sediment deposition, but more likely attributed to natural morphological variability due to lagoon tidal flow.

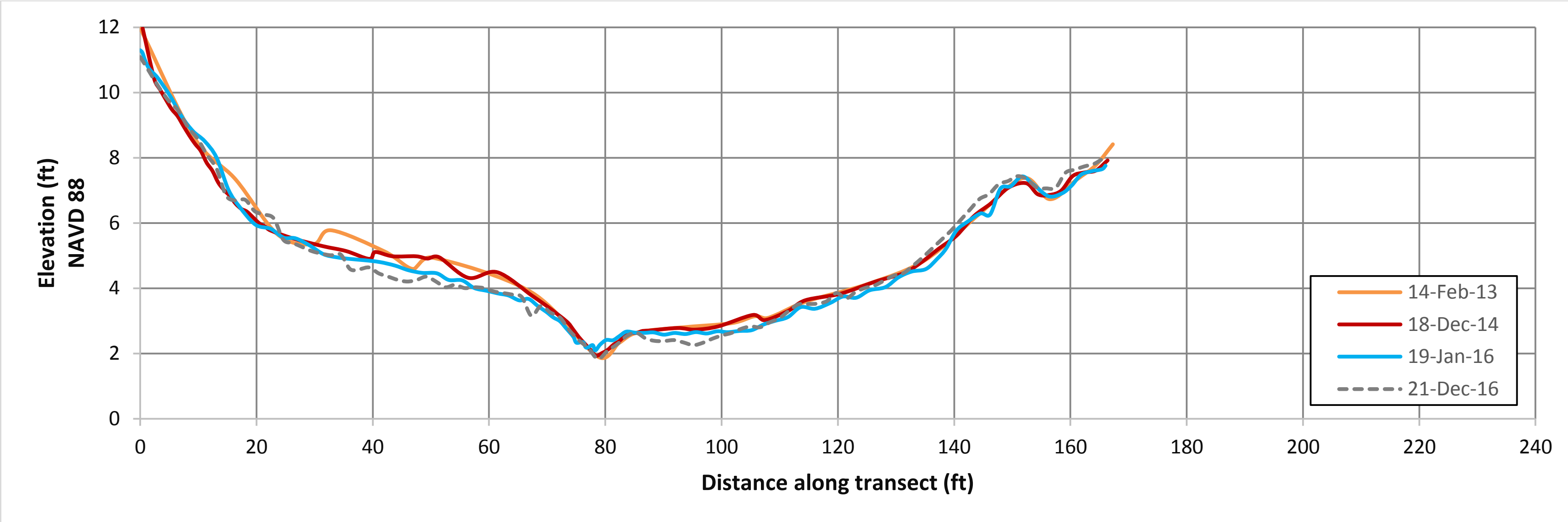



Figure 8. Channel Cross-section Transect 1.

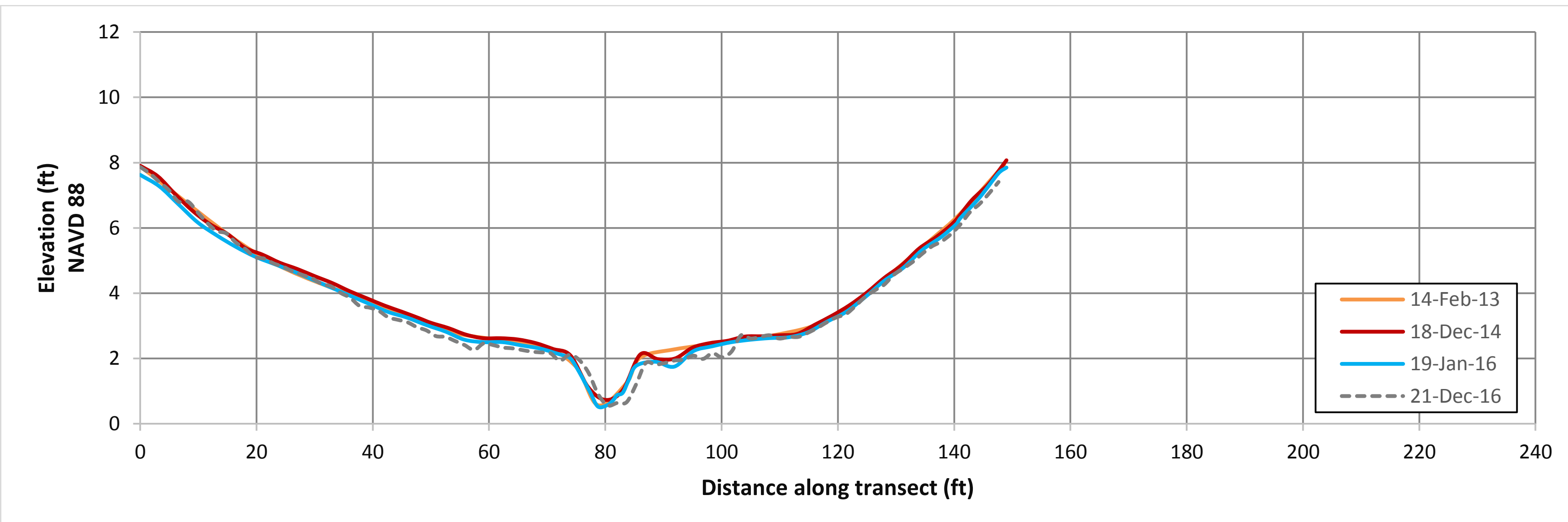



Figure 9. Channel Cross-section Transect 2.

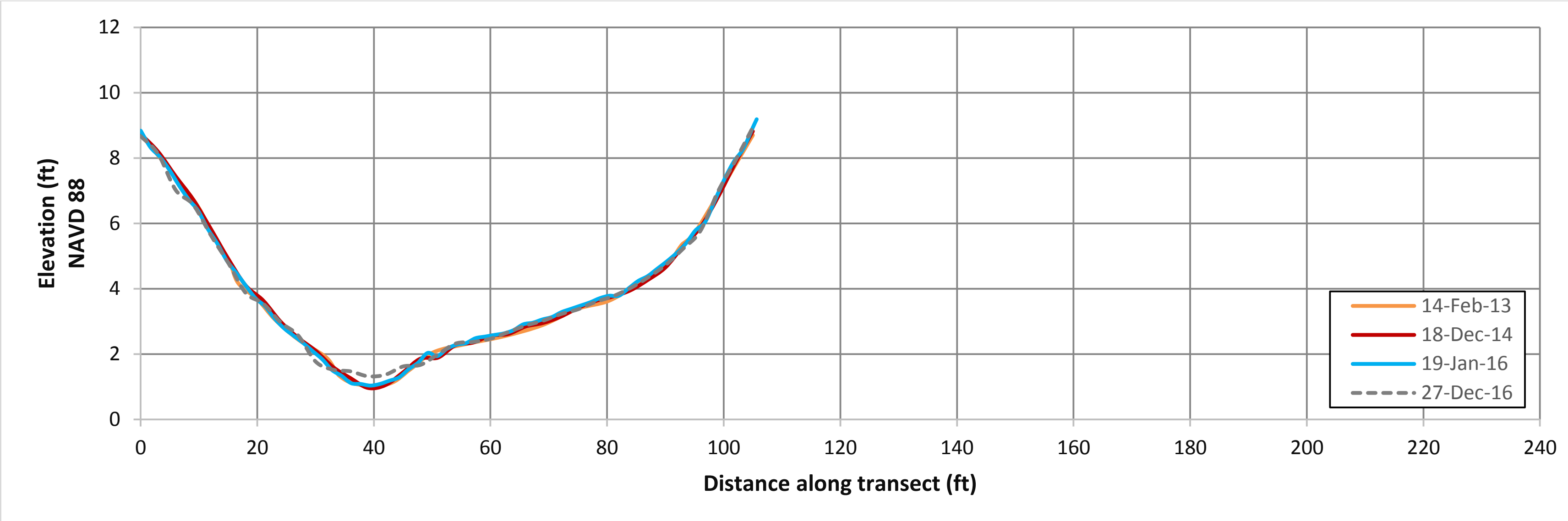



Figure 10. Channel Cross-section Transect 3.

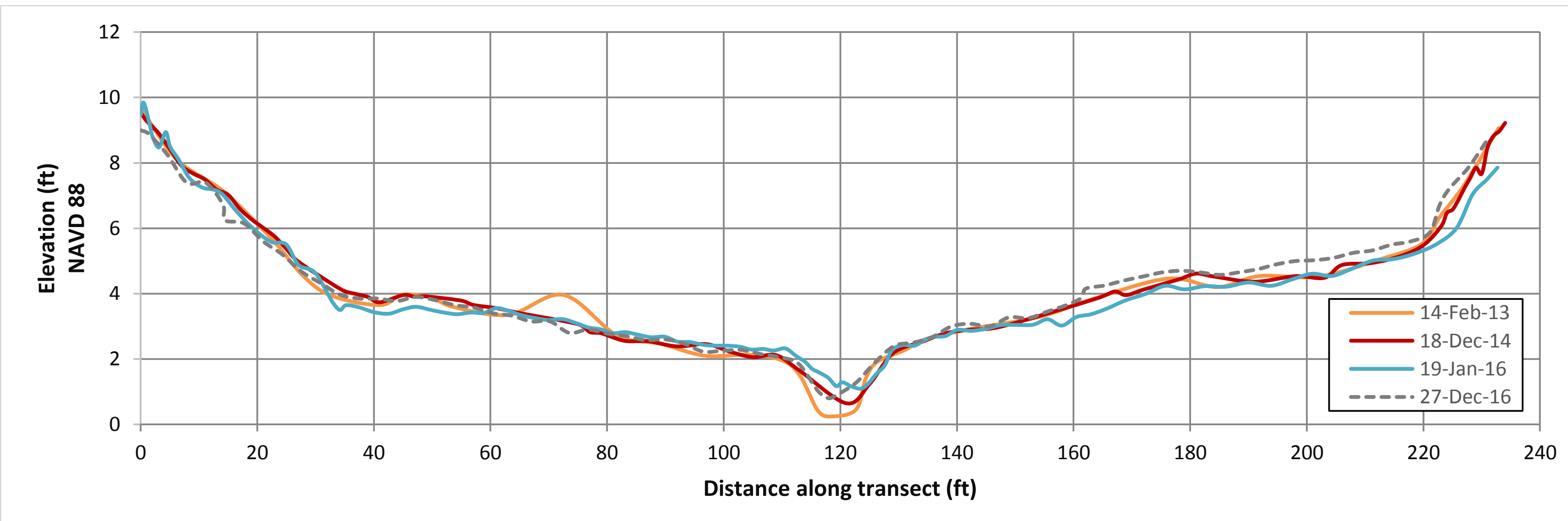



Figure 11. Channel Cross-section Transect 4.

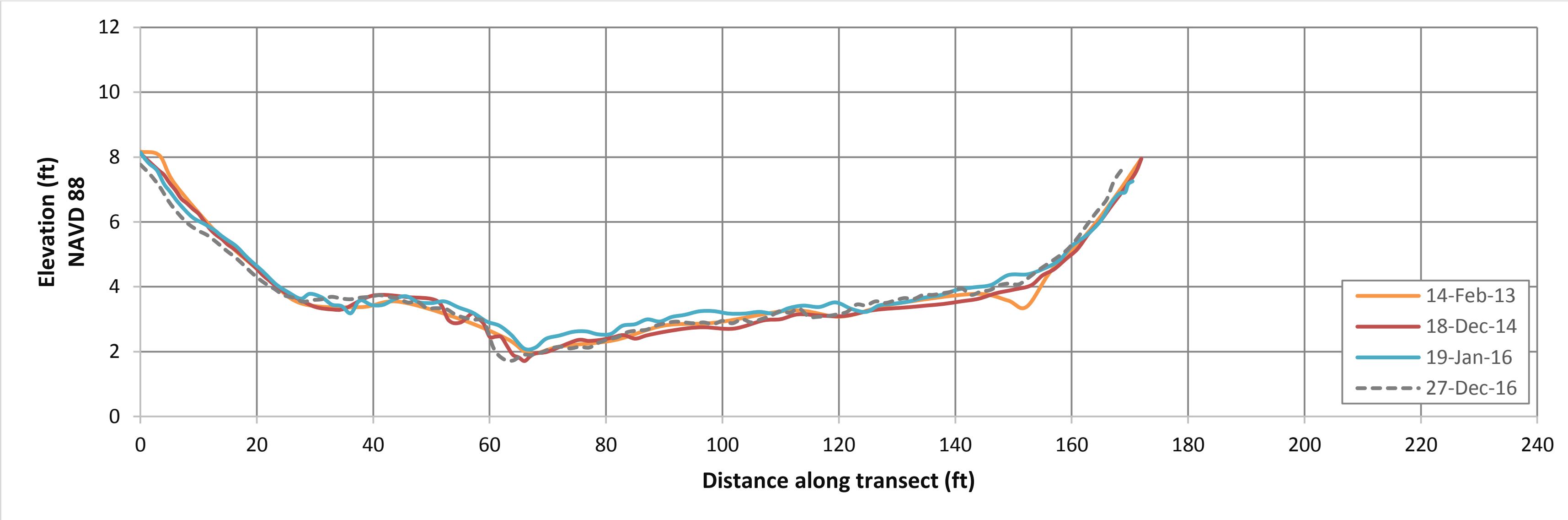



Figure 12. Channel Cross-section Transect 5.

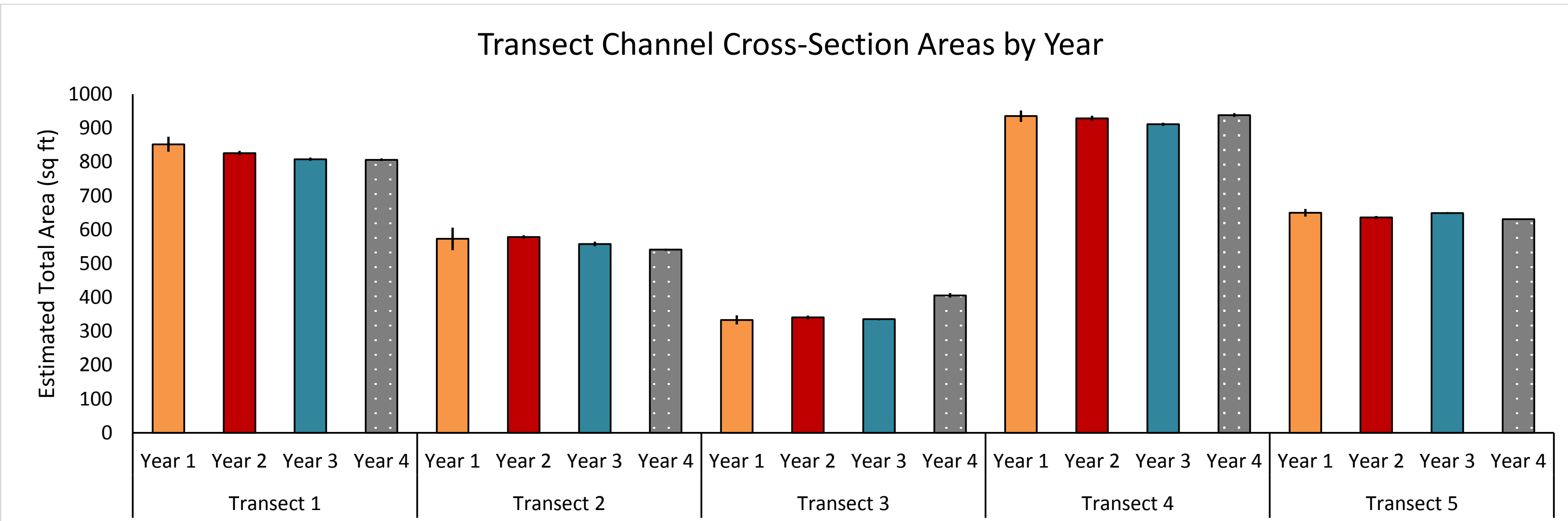



Figure 13. Transect channel cross-section areas by year.

### *Performance Evaluation*

A primary restoration target involved increasing tidal energy to suspend and scour fine grain sediments to limit sedimentation during open lagoon conditions. This would prevent the pre-restoration conditions which included a slowly sedimenting (filling) wetland over time. 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, and the project success criteria were met. This demonstrates that one of the key goals of the restoration is also being met, as sediments move through the system and out of the system as designed, rather than slowly accreting and filling wetland habitats with anoxic sediments, which was happening prior to the implementation of the restoration.

## 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 Hydrolab DS5X and Yellow Springs Instruments (YSI) 600XLM multi-parameter data loggers. The YSI 600XLM data loggers were phased out and replaced with Hydrolab DS5X data loggers; and in mid-2016 the last YSI 600XLM data logger was retired. Currently all deployed data-loggers are Hydrolab DS5X models. 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 2016 at three permanent post-restoration stations. Dates of deployment varied by station due to probe malfunctions, servicing, or calibration glitches (Table 3). Post-restoration monitoring stations were located within the western Lagoon's main channel (Station 2) and within the western Lagoon's back channels (Stations 5 and 8) (Figure 14). When possible, data were compared to pre-restoration data collected from hydrologically similar back channels (ML2 and ML6) (Figure 15). 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 16). 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 or replacement. Additionally, the last YSI data logger at Station 8 was replaced with new Hydrolab data loggers because of probe failure. Major data gaps in 2016 included sonde malfunctions and power failures, resulting in sondes being returned for maintenance and/or replaced by the manufacturer. During the fall of 2016, sonde housings were removed and cleaned due to significant biofouling (e.g.

barnacles). Biofouling inside and around the sonde housing can cause inaccurate and unreliable measurements due to suppressed water flow to sonde probes and direct uptake of oxygen by the organisms.

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

| Station | Start Gap | End Gap | Parameter | Reason |
|---|---|---|---|---|
| 2 | 1/1/2016 | 1/30/2016 | DO | Sensor malfunction |
| | 1/31/2016 | 3/2/2016 | All | Sonde malfunction, pulled for service |
| | 4/21/2016 | 5/17/2016 | All | Sonde malfunction - early shutoff |
| | 10/1/2016 | 10/7/2016 | All | Sonde malfunction – early shutoff |
| | 10/31/2016 | 12/1/2016 | All | Sonde data port damaged, pulled for service |
| 5 | 1/1/2016 | 5/10/2016 | Depth | Sensor calibration issue |
| | 1/30/2016 | 2/9/2016 | ALL | Sonde pulled for service |
| | 3/31/2016 | 4/4/2016 | ALL | Sonde pulled for calibration/service |
| | 5/10/2016 | 5/13/2016 | ALL | Battery dead |
| | 6/23/2016 | 7/25/2016 | Depth | Sensor calibration issue |
| | 10/1/2016 | 10/7/2016 | ALL | Sonde malfunction - early shutoff |
| | 10/22/2016 | 11/17/2016 | ALL | Sonde pulled for service |
| 8 | 1/1/2016 | 6/2/2016 | pH, ORP | Sensor malfunction |
| | 2/25/2016 | 3/4/2016 | All | Sensor malfunction |
| | 3/22/2016 | 4/5/2016 | All | Sensor malfunction |
| | 4/12/2016 | 4/21/2016 | All | Sensor malfunction |
| | 6/23/2016 | 7/25/2016 | Salinity, conductivity, depth | Sensor malfunction |
| | 8/25/2016 | 10/7/2016 | All | Sonde malfunction, pulled for service |
| | 11/29/2016 | 12/6/2016 | pH | Sensor malfunction |
| | 12/7/2016 | 12/30/2016 | All | Sonde malfunction, pulled for service |


Figure 14. 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 Hydrolab data sondes (in yellow).


Figure 15. Map of pre-restoration water quality monitoring stations. ML2 and ML6 are the locations of the pre-restoration permanently-deployed YSI data sondes.

Figure 16. In-field sonde calibration; 17 November 2016.

### *Results*

Graphs displaying data from post-construction monitoring at Stations 2, 5, and 8 are presented in Figures 17-19. Figures 17a, 18a, and 19a 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 17b, 18b, and 19b demonstrate the relationship between temperature (oC) 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 4 summarizes the overall percentage of dissolved oxygen readings above each specified threshold. Figures 17c, 18c, and 19c illustrate the relationship between pH and oxidation reduction potential (ORP). ORP and pH was not collected at Station 8 during the first half of 2016 due to a probe malfunction and failure to meet calibration standards.

Table 4. 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 | 93.69% | 90.49% | 81.04% | 63.79% |
| 5 | 84.46% | 79.36% | 63.31% | 43.27% |
| 8 | 95.93% | 93.14% | 84.90% | 70.14% |

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 15 and 6 consecutive 24-hour periods below 1 mg/L (25% time) for Station 5 and Station 8, respectively. Additionally, results displayed 5 and 6 consecutive 24-hour periods below 1.5 mg/L (50% time) for Station 5 and Station 8, respectively. Station 2 results displayed only four 24-hour periods below 1 mg/L (25% time) and 2 days below 1.5 mg/L (50% time).

Data from the back channel sondes displayed an increase in the percentage of readings above dissolved oxygen thresholds, when compared to pre-restoration data from the back channel. The post-restoration back channel sondes were above 1 mg/L dissolved oxygen during closed conditions approximately 84% (Station 5) and 96% (Station 8) of the time compared to approximately 83% (ML2) and 89% (ML6) during pre-restoration deployment (Table 5). The percentage of post-restoration closed condition readings above 1.5 mg/L dissolved oxygen were approximately 79% (Station 5) and 93% (Station 8), compared to 81% (ML2) and 86% (ML6) during pre-restoration conditions.

Table 5. 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 (Year 4) | **Post-restoration average** |
|---|---|---|---|---|---|---|
| --- | --- | 8 | 95.76% | 53.35% | 95.93% | **85.58%** |
| ML2 | 82.79% | 5 | 96.97% | 74.05% | 84.46% | **87.88%** |
| ML6 | 89.50% | 2 | N/A* | 94.36% | 93.69% | **94.02%** |

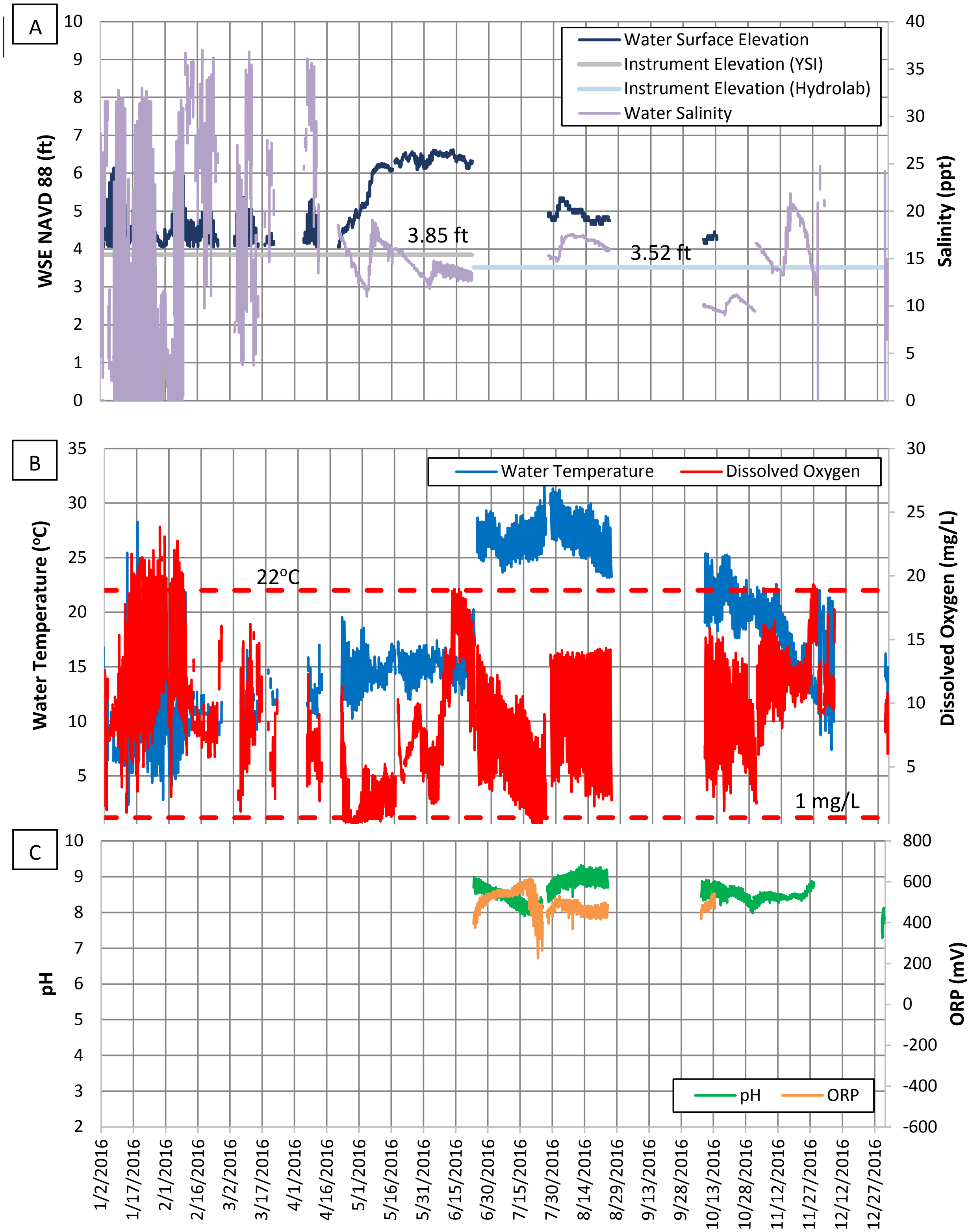



Figure 17. Graphs illustrating continuous water quality parameters from Station 8 (2016).

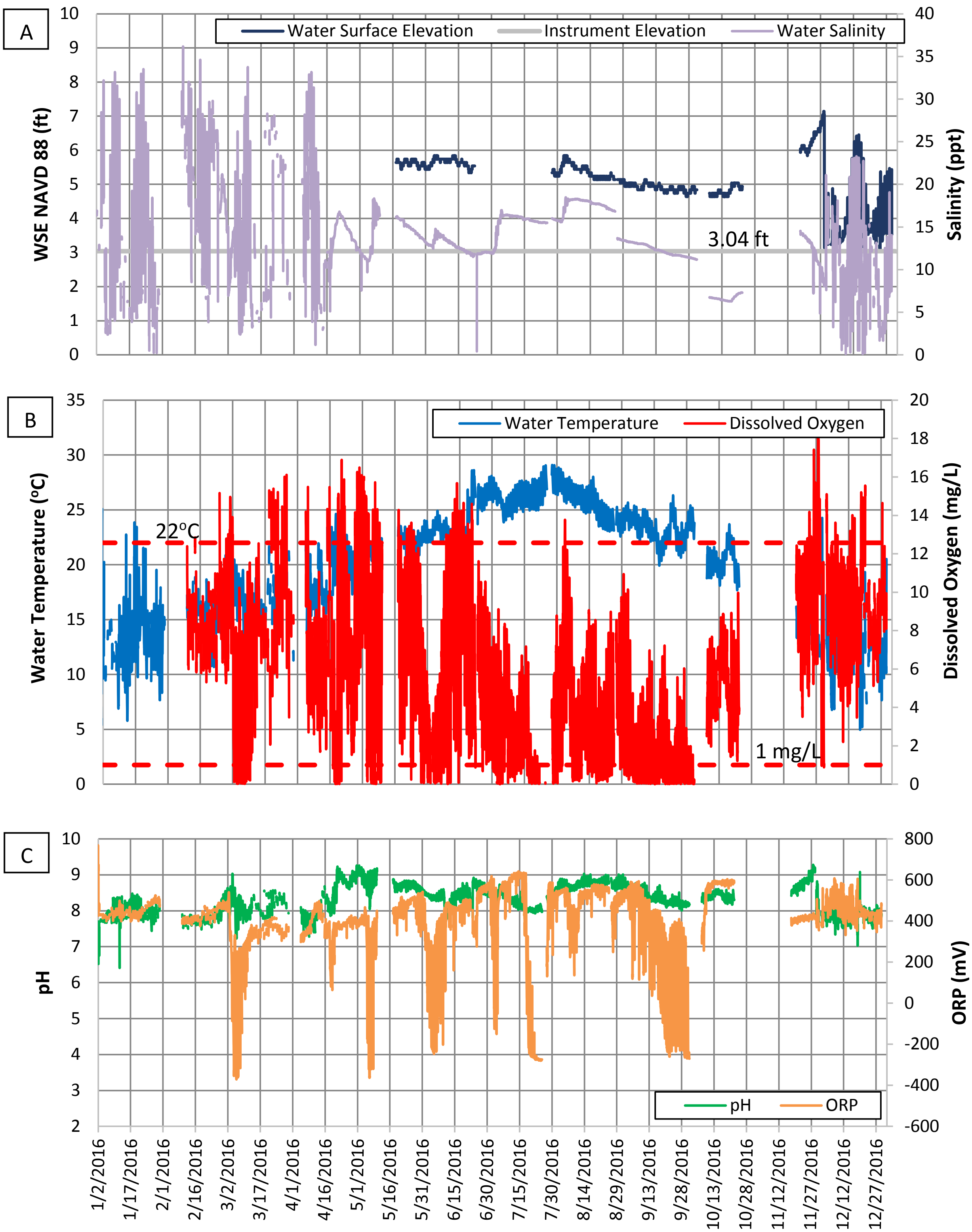



Figure 18. Graphs illustrating continuous water quality parameters from Station 5 (2016).

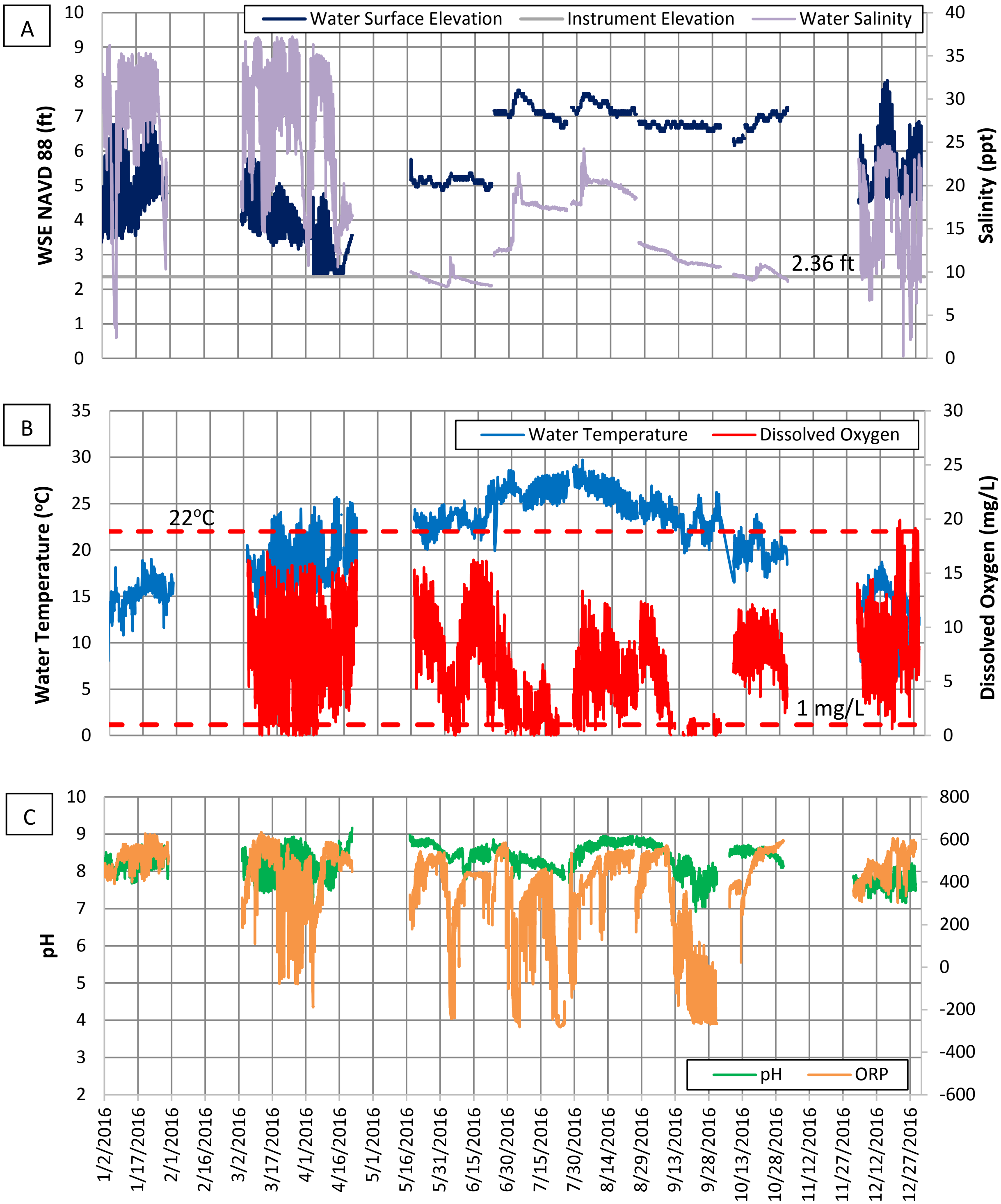



Figure 19. Graphs illustrating continuous water quality parameters from Station 2 (2016).

### *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. During Year 4, dissolved oxygen data exceeded all success criteria at all Stations during closed conditions.

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 only 15 and 6 consecutive 24-hour periods below 1 mg/L (25% time) for Station 5 and Station 8, respectively. Additionally, results displayed 5 and 6 consecutive 24-hour periods below 1.5 mg/L (50% time) for Station 5 and Station 8, respectively. Station 2 results displayed only four 24-hour period below 1 mg/L (25% time) and 2 days below 1.5 mg/L (50% time). Some of the readings may have been altered due to biofouling or cleaning/maintenance methods, thus they are likely to be conservative in their results (details below).

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 3 monitoring was high and contributed to lowering the overall post-restoration dissolved oxygen average. Year 4 results saw the data return to the post-restoration 'normal'. 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, primarily unexplained early shut-offs, led to periods of missing data during the cooler closed bar conditions. The sonde at Station 8 was replaced from a YSI 600XLM to a new Hydrolab DS5X after repeated probe and calibration issues with the pH and ORP sensors. Two of the three Hydrolab DS5X sondes repeatedly experienced unexplained power failures leading to early unplanned shut-offs. The manufacturer was unable to diagnose the problem and agreed to send temporary replacement sondes pending a no-cost replacement of a newer sonde model that is being released. The temporary sondes, also Hydrolab DS5X models, have not displayed power issues since deployment. Additionally, sondes tend to 'drift' prior to failure, where collected data encounter sporadic errors becoming more frequent with time. To address problems with probe failure and equipment malfunctions, data continue to be QAQC'ed monthly to analyze issues as soon as possible and more frequent checks of sonde status in the field have been conducted.

There are no comparative pre-restoration data to the 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; thus, the comparative estimates from post-restoration are likely to be conservative.

## 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 = 4) or closed condition (N = 3) using a YSI 600 XLM hand-held water quality instrument or equivalent (Table 6). 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.

Seven 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 14). The water temperature and pH parameters experienced sensor malfunctions on 27 January 2016; therefore, those data were subsequently omitted from analysis. The pH parameters also experienced sensor malfunctions on 12 May 2016 and 15 December 2016 and were subsequently omitted from analysis.

Table 6. 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 |
| 12 May 2016 | Closed | N/A |
| 15 Dec 2016 | Open | high spring; 6.9 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, 7 May 2015, and 12 May 2016), and cooler temperatures occurred during winter sampling events (14 February 2013, 23 December 2014, and 15 December 2016) (Figures 20a and 20b). 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 21a and 21b). During these times, the survey area was exposed to tidal influence. During the closed lagoon condition sampling events (5 May 2014, 7 May 2015, and 12 May 2016), 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 22a and 22b). The vertical profile dissolved oxygen levels never fell below 6 mg/L at any of the stations during all post-restoration sampling events. Dissolved oxygen levels during the closed berm condition sampling events never fell below 11 mg/L in May 2014, 8 mg/L in May 2015, and 10 mg/L in May 2016. 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 7 and 8).

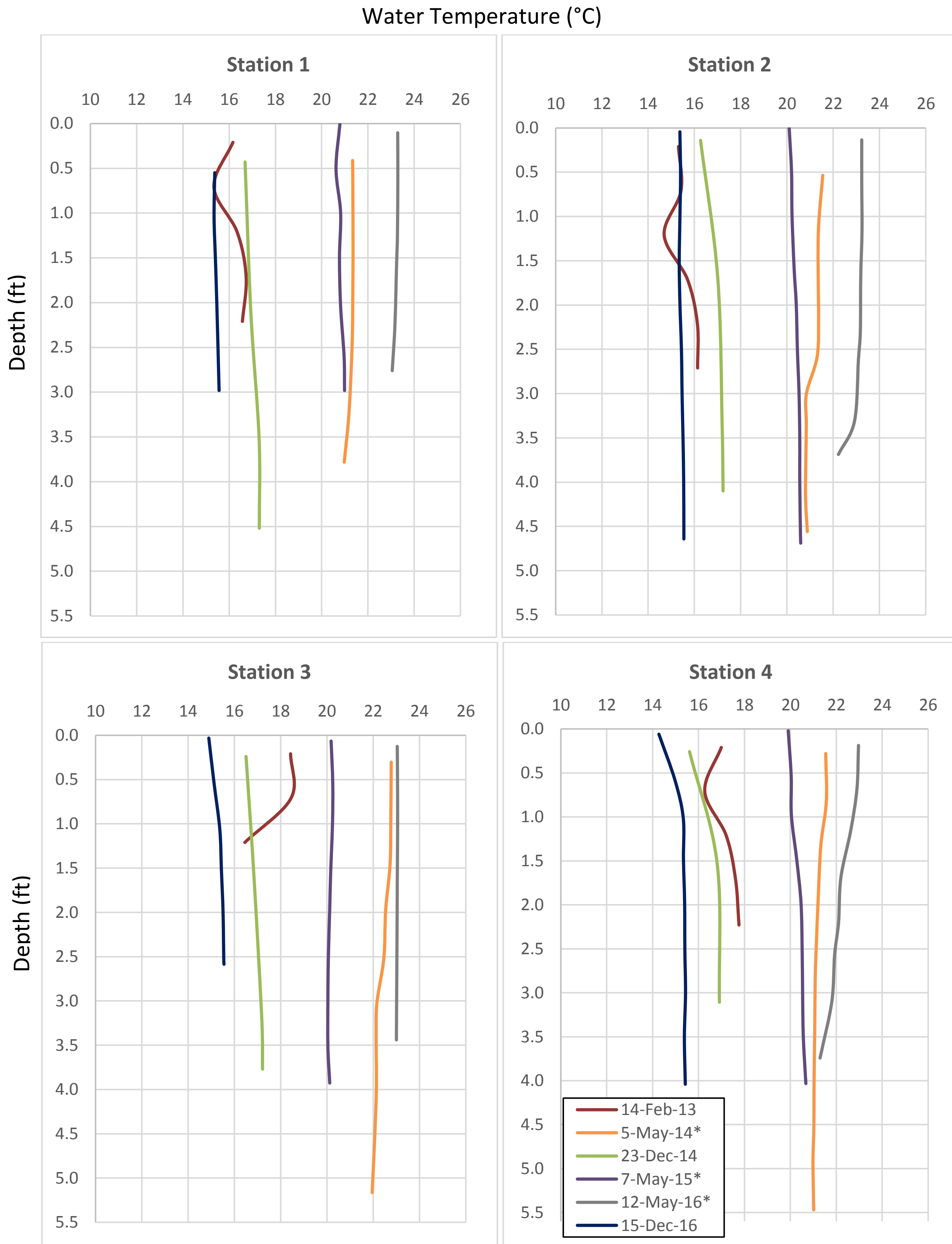



Figure 20a. Post-restoration temperature vertical water quality profiles at Stations 1-4. Asterisk indicates a closed berm condition.

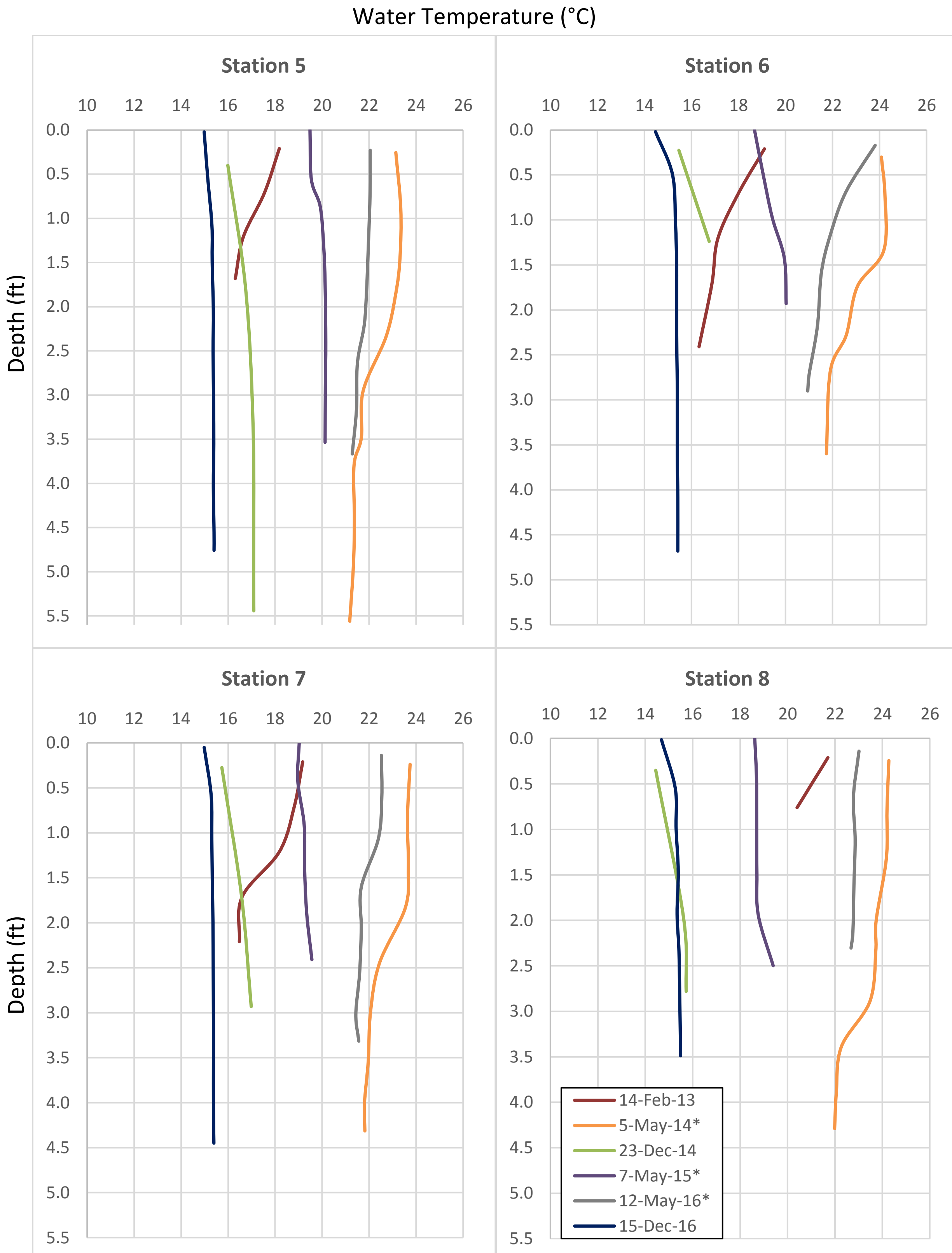



Figure 20b. Post-restoration temperature vertical water quality profiles at Stations 5-8. Asterisk indicates a closed berm condition.

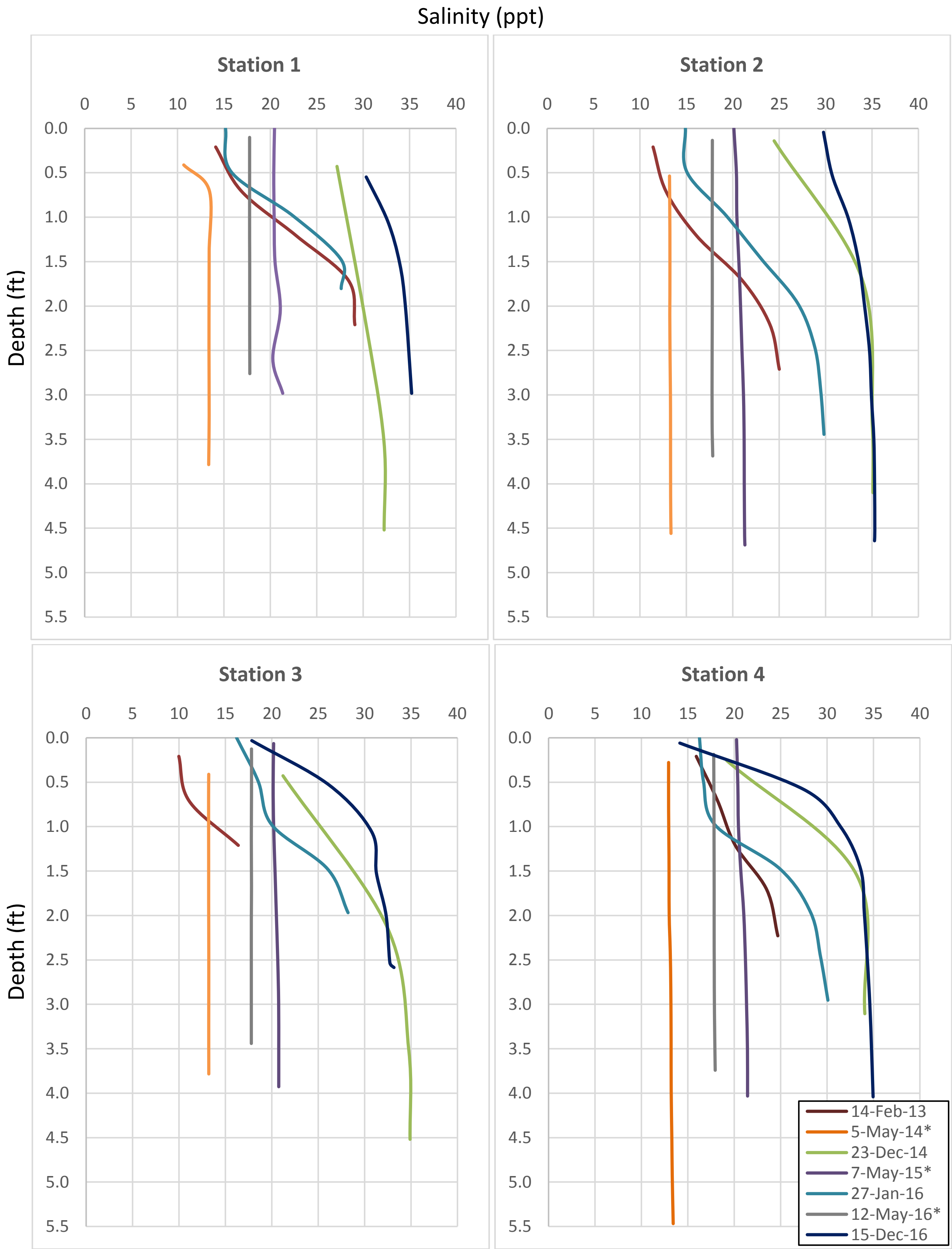



Figure 21a. Post-restoration salinity vertical water quality profiles at Stations 1-4. Asterisk indicates a closed berm condition.

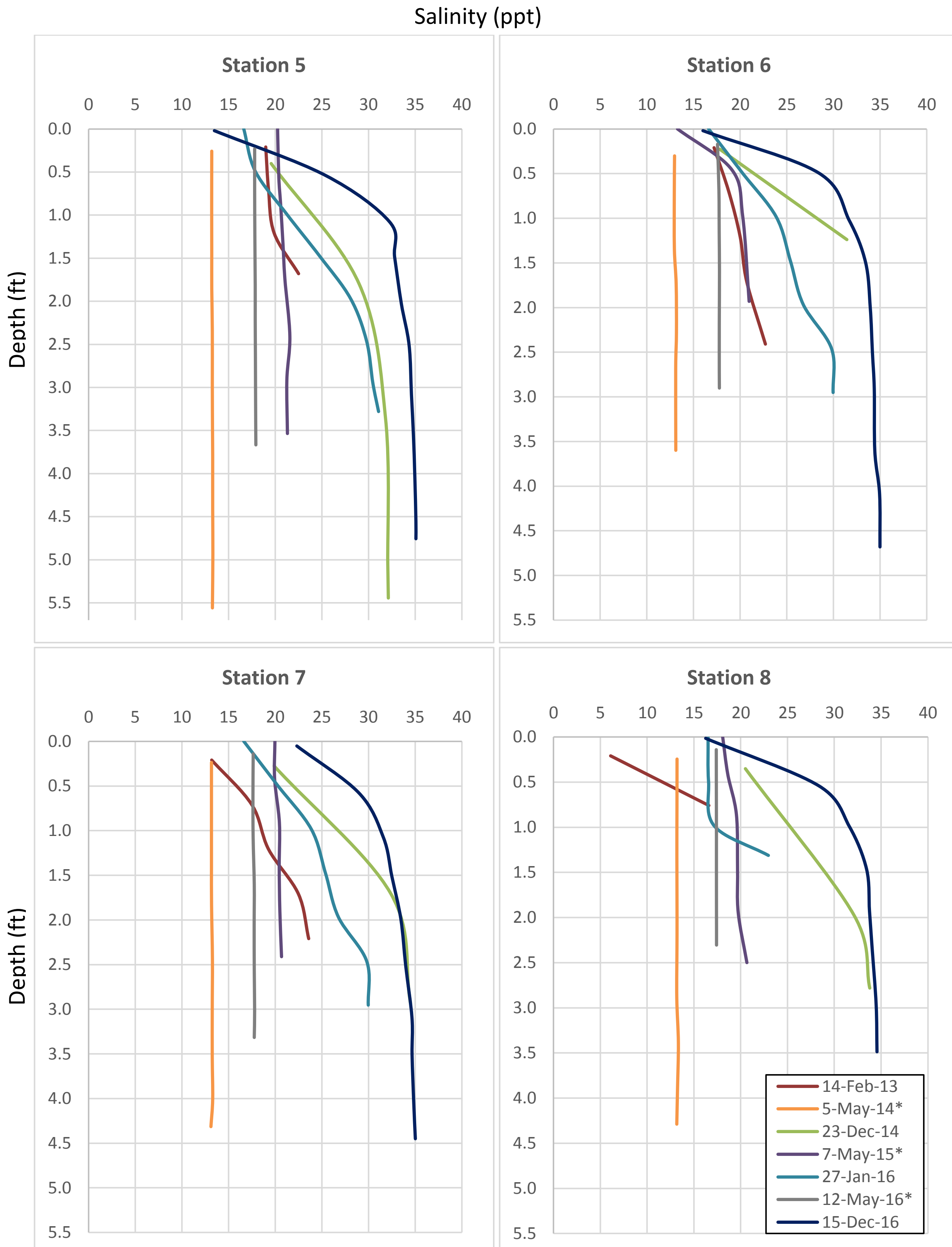



Figure 21b. Post-restoration salinity vertical water quality profiles at Stations 5-8. Asterisk indicates a closed berm condition.

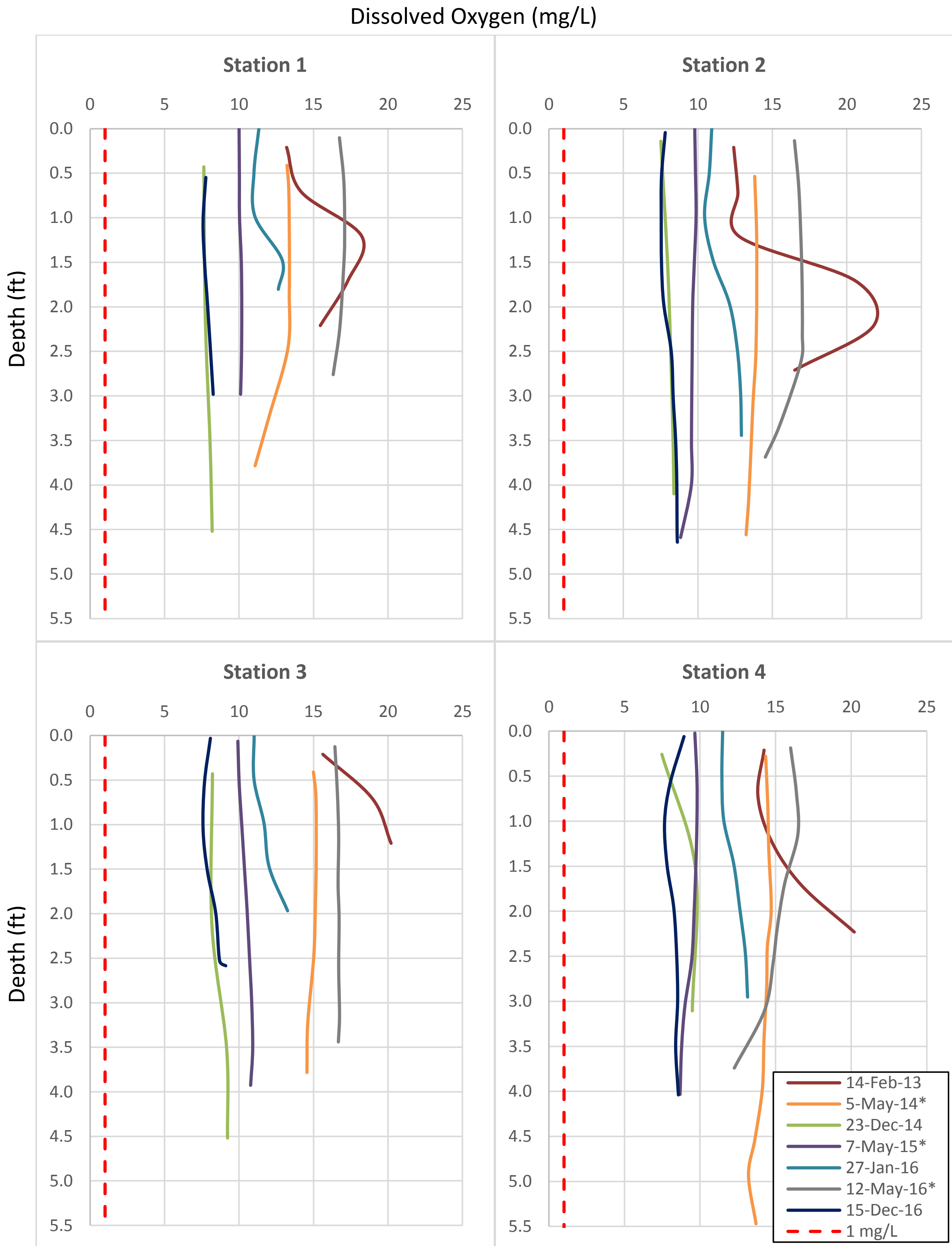



Figure 22a. Post-restoration dissolved oxygen vertical water quality profiles at Stations 1-4 (red line represents 1 mg/L threshold). Asterisk indicates a closed berm condition.

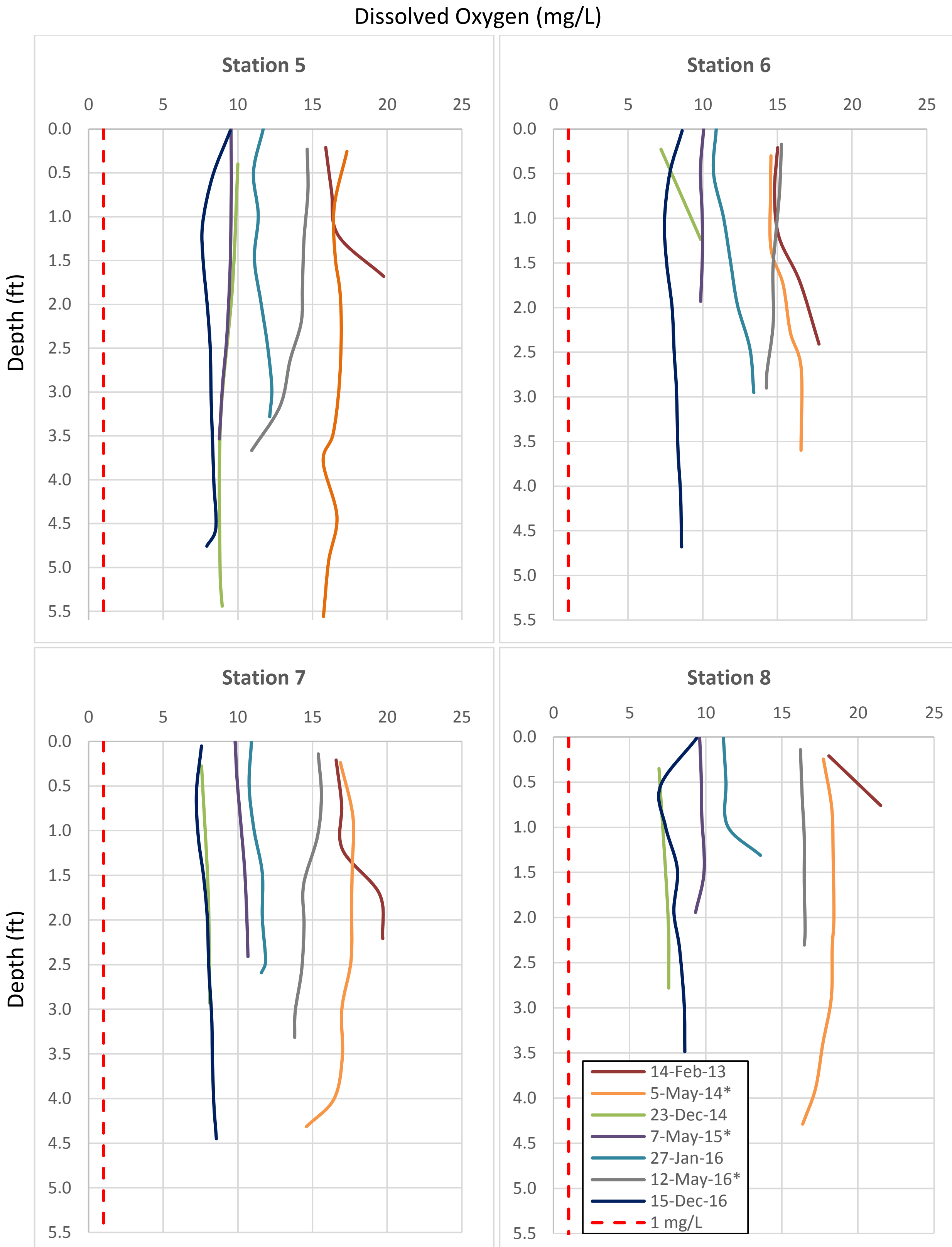



Figure 22b. Post-restoration dissolved oxygen vertical water quality profiles at Stations 5-8 (red line represents 1 mg/L threshold). Asterisk indicates a closed berm condition.

Table 7. 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 * | 18.62 | 20.99 | 13.28 | 20.21 | 8.68 | 10.92 | 7.79 | 8.86 |
| 27-Jan-16 | N/A | N/A | 14.88 | 31.09 | 10.45 | 13.59 | N/A | N/A |
| 12-May-16 * | 20.94 | 23.81 | 17.39 | 17.94 | 10.93 | 17.09 | N/A | N/A |
| 15-Dec-16 | 14.27 | 15.57 | 13.48 | 35.30 | 7.02 | 9.48 | N/A | N/A |

Table 8. Average parameter values and standard error (SE) by date and station. Asterisk indicates a closed berm condition.

| Date | Station | Average Temp (°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-14* | 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 | 0.00 |
| | 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 | 0.00 |
| | 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 | - | - |
| 12-May-2016* | 1 | 23.22 | 0.04 | 17.78 | 0.00 | 16.83 | 0.12 | - | - |
| | 2 | 23.04 | 1.22 | 17.78 | 0.01 | 16.39 | 0.32 | - | - |
| | 3 | 23.03 | 0.01 | 17.80 | 0.00 | 16.65 | 0.04 | - | - |
| | 4 | 22.23 | 0.20 | 17.85 | 0.01 | 15.11 | 0.49 | - | - |
| | 5 | 21.75 | 0.11 | 17.85 | 0.02 | 13.70 | 0.46 | - | - |
| | 6 | 21.87 | 0.39 | 17.75 | 0.03 | 14.76 | 0.14 | - | - |
| | 7 | 21.93 | 0.17 | 17.71 | 0.02 | 14.63 | 0.25 | - | - |
| | 8 | 22.81 | 0.05 | 17.41 | 0.00 | 16.42 | 0.05 | - | - |
| 15-Dec-2016 | 1 | 15.43 | 0.03 | 32.83 | 0.86 | 7.83 | 0.10 | - | - |
| | 2 | 15.45 | 0.02 | 33.76 | 0.59 | 8.10 | 0.01 | - | - |
| | 3 | 15.35 | 0.09 | 29.19 | 2.08 | 8.21 | 0.21 | - | - |
| | 4 | 15.21 | 0.13 | 31.06 | 2.26 | 8.29 | 0.13 | - | - |
| | 5 | 15.31 | 0.04 | 31.49 | 1.99 | 8.23 | 0.15 | - | - |
| | 6 | 15.27 | 0.09 | 31.64 | 1.85 | 8.11 | 0.13 | - | - |
| | 7 | 15.32 | 0.04 | 32.21 | 1.25 | 7.94 | 0.14 | - | - |
| | 8 | 15.29 | 0.09 | 30.82 | 2.20 | 8.16 | 0.27 | - | - |

### *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. Dissolved oxygen levels during the closed berm condition sampling events never fell below 11 mg/L in May 2014, 8 mg/L in May 2015, and 10 mg/L in May 2016. 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 4 semi-annual surface water and bottom water samples were collected at the eight vertical profile Stations (Figure 14) on 10 May 2016 and 15 December 2016, as described in the Monitoring Plan. May 2016 and December 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 2008-2016 (data accessed 6 August 2017).

### *Results*

Graphs displaying data from pre- and post-construction monitoring at all Stations are presented in Figures 23 (bottom) and 24 (surface). The yellow circles with the red crosses on all the right-hand graphs represent the most recent Year 4 survey results (15 December 2016). Figures 23a, 23b, 24a, and 24b display the values of nitrate plus nitrite as N concentrations for pre- and post-restoration surveys. Figures 23c, 23d, 24c, and 24d display the values of Total Kjeldahl nitrogen (TKN) concentrations for pre- and post-restoration surveys. Figures 23e, 23f, 24e, and 24f display the values of total phosphorous (TP) concentrations for pre- and post-restoration surveys. Figures 23g, 23h, 24g, and 24h display the values for orthophosphate concentrations for pre- and post-restoration surveys. Figures 23i, 23j, 24i, and 24j display the values for ammonia concentrations for pre- and post-restoration surveys. Figures 24k and 24l 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 23b, 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) or 2016 (Year 4) surveys. In fact, many of the 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 on-site 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 an overall decrease in Total Maximum Daily Load (TMDL) exceedances, post-restoration (Table 9), especially as compared to the highest exceedance years (i.e. 2011, 2008, and 2009). The Heal the Bay data for "grade" (AB 411) also received better "grades" post-restoration (i.e. B, B, A, and A, respectively) than the years preceding the restoration (D, C, B, and F, respectively). It should be noted, when the data were accessed for the Year 3 report, the Beach Report Card reported a 2015 TMDL Exceedance of 11, but Heal the Bay staff subsequently updated to the number to 53 after the Year 3 report was submitted. Thus, Table 9 reflects the most currently available data accessed on 6 August 2017. The restoration was completed in May 2013, so the data from 2013-2016 represent "post-restoration years", though a portion of the 2013 data was collected during the restoration activities.

Table 9. Summary annual grade from the bacteria Beach Report Card Heal the Bay data (accessed 6 August 2017). Note: the gray 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 | 53 |
| 2016 | A | 45 |

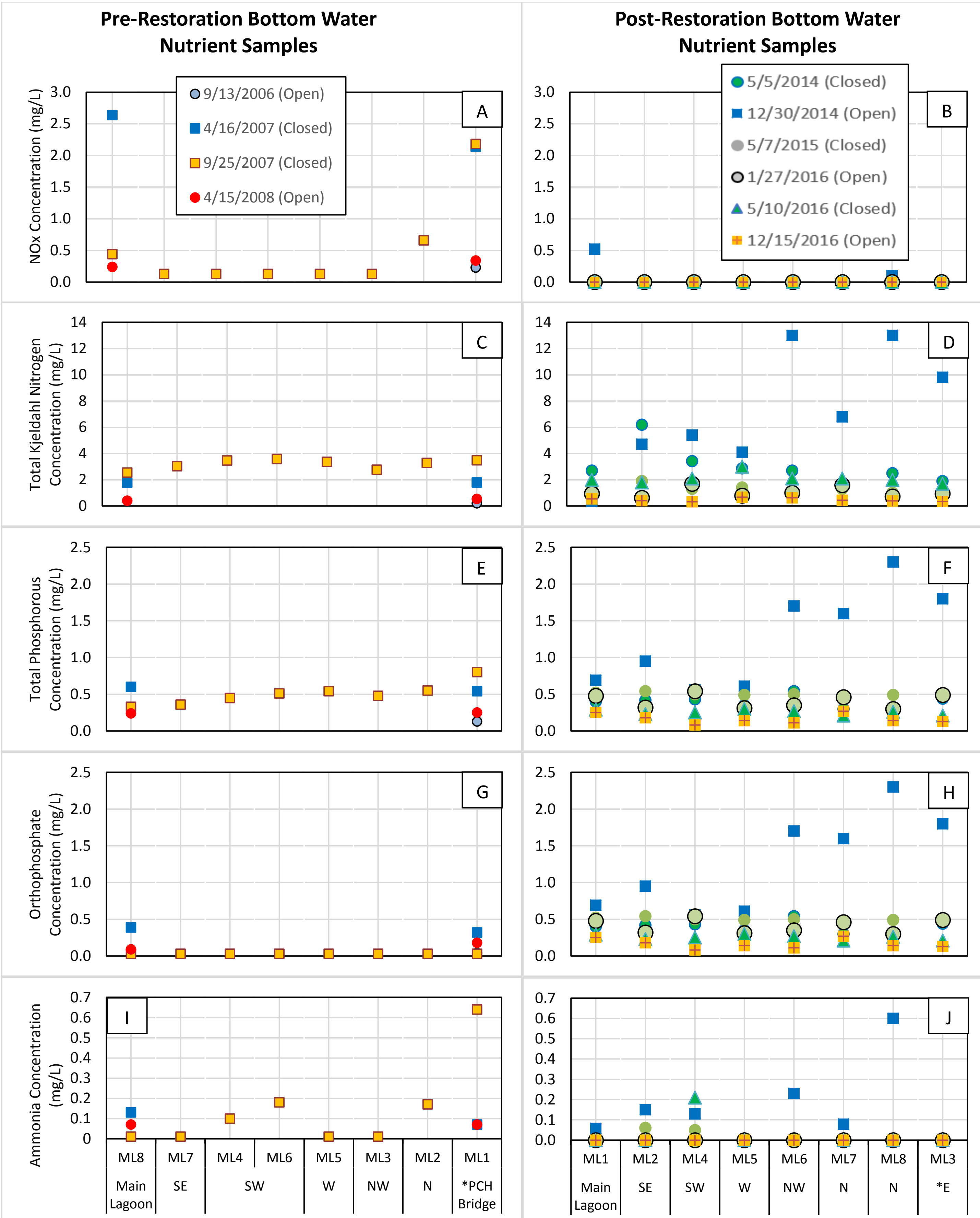
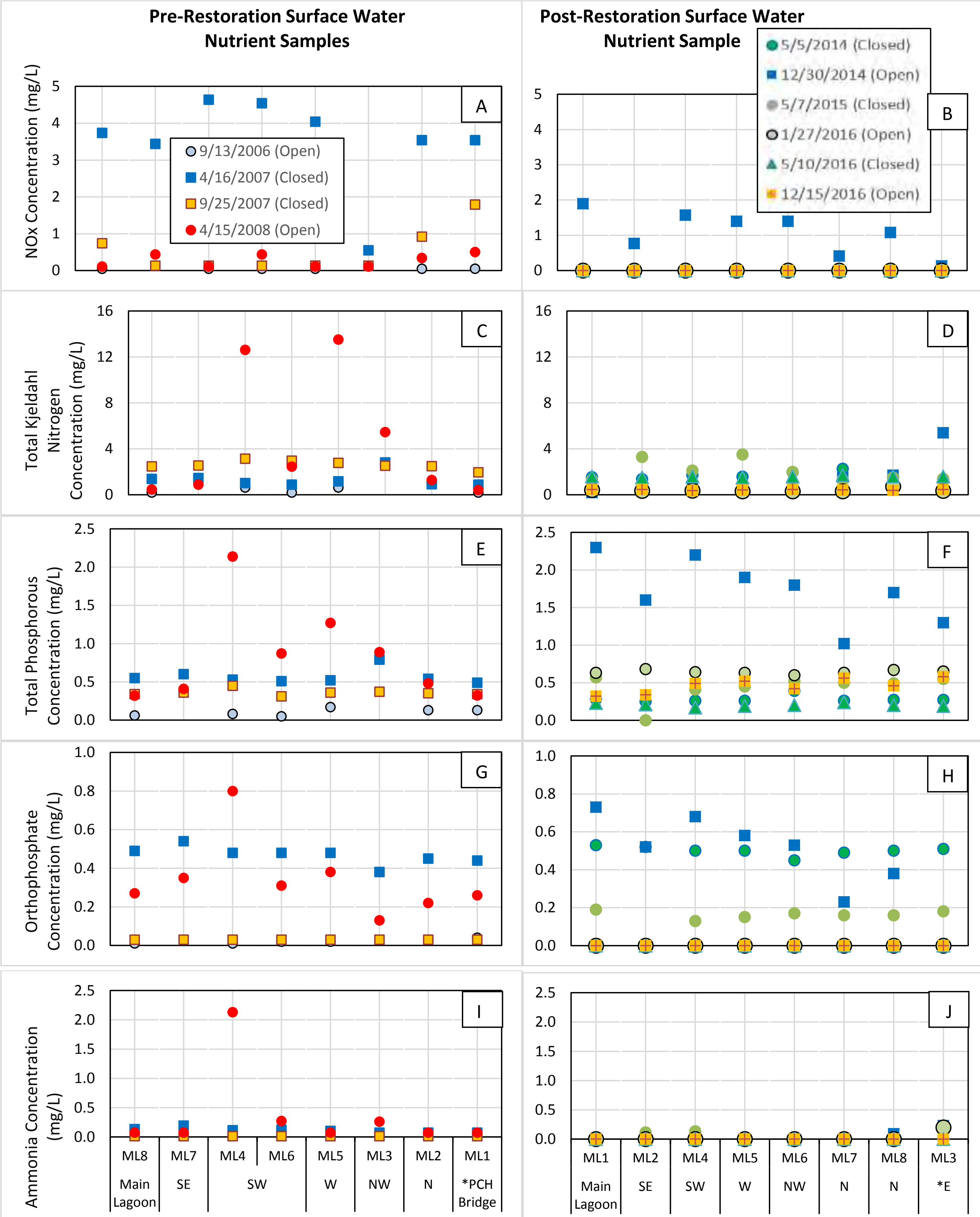



Figure 23. Graphs displaying bottom water nutrients concentrations from pre- (left) and post-restoration (right) surveys.



Pre-Restoration Surface Water
Nutrient Samples
Post-Restoration Surface Water
Nutrient Sample
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)
5/10/2016 (Closed)
12/15/2016 (Open)
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)
ML8 ML7 ML4 ML6 ML5 ML3 ML2 ML1
Main Lagoon
SE
SW
W
NW
N
*PCH Bridge
ML1 ML2 ML4 ML5 ML6 ML7 ML8 ML3
Main Lagoon
SE
SW
W
NW
N
N
*E

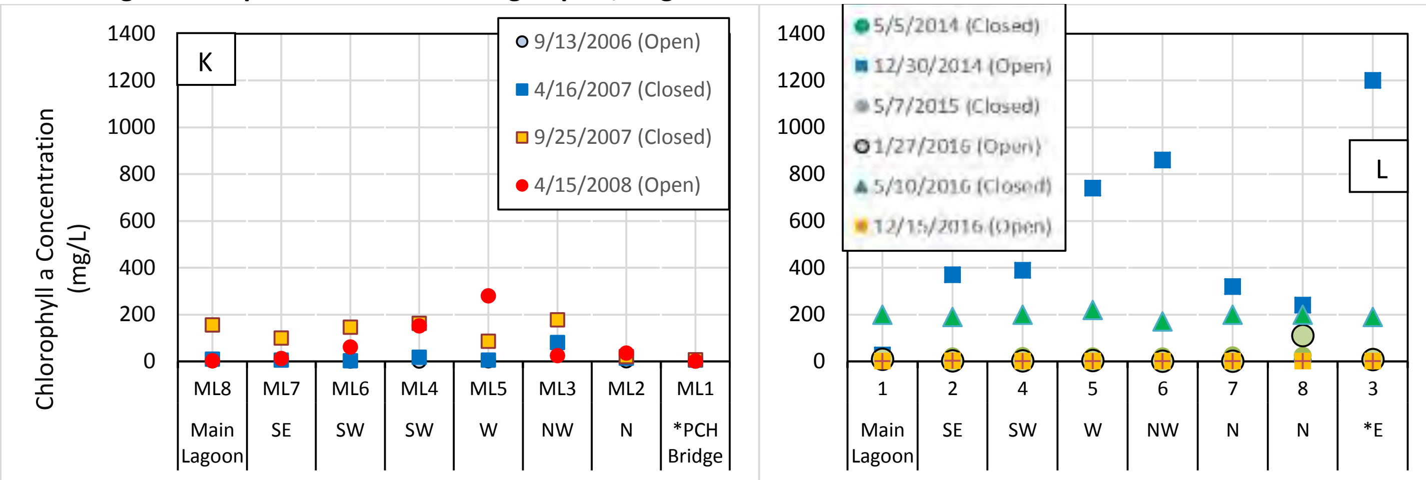



Figure 24. Graphs displaying surface water nutrients concentrations from pre- (left) and post-restoration (right) surveys.

### *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 have not been seen since, even within the Tapia discharge period, and consistent low concentrations of nutrients remained present through the Year 4 surveys. Several constituents (e.g. average ammonia as N, orthophosphate, and nitrate-nitrite) were found to be non-detects or effectively a zero reading for that constituent.

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. The winter of 2016 represented a wetter year than the previous four, and there were several rain events in the second half of Novmber that could have contributed to increased nutrient values. However, that trend was not seen, and the nutrient values remain consistently low for all constituents. Interestingly, the Surfrider location has not been identified 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 14) on 30 December 2014, 7 May 2015, 21 January 2016, 10 May 2016, and 9 March 2017. Year 4 samples taken on 10 May 2016 and 9 March 2017 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 2016 and March 2017 laboratory results reported median grain size. The 9 March 2017 samples were collected later on in the survey year due to significant rain events for several months during the wet season. The samples were not supposed to be collected subsequent to a rain event.

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 25). 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, January 2016, May 2016, and March 2017 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.

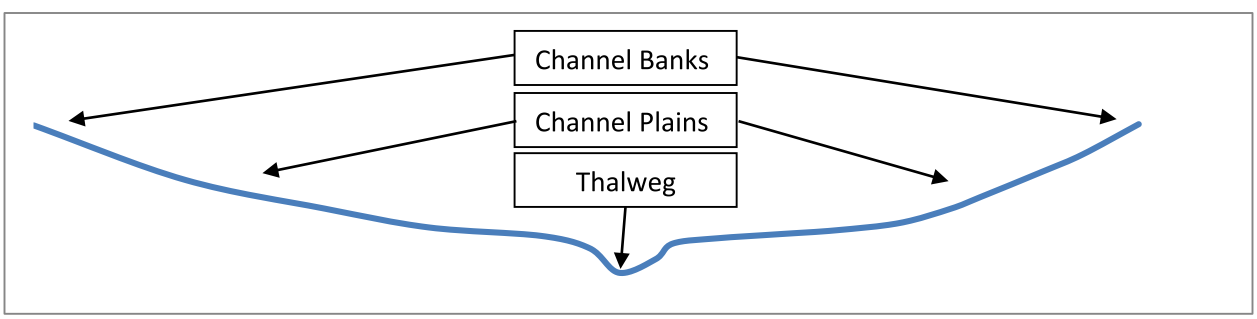



Figure 25. Representative channel cross section displaying the locations of sediment quality collection zones.

Sediment data were collected during pre-restoration conditions at four sampling locations (Figure 26) 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 26. 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, May 2016, and March 2017 surveys are summarized in Table 11. Overall, the thalweg sampling locations exhibited lower proportions of gravel than the channel plain and channel bank composite samples; moreover, the increased proportion of thalweg gravel shown at Stations 1 and 8 during the prior January 2016 survey was absent in Year 4 data. Station 3 showed an increase in thalweg gravel during the May 2016 survey but was not detected in the March 2017 survey results. Furthermore, fine-grained sediments (i.e., silts and clay) distributions showed normal seasonal variability with lower levels seen during open conditions and higher concentrations at close conditions.

Table 10. Sediment grain size analysis for all cross sections. 'Channel Banks' and 'Channel Plains' categories for May 2014, May 2015, January 2016, May 2016, and March 2017 surveys are each composited from the left and right sides of the channel (see Figure 25). '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.*

| | 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 2016 | 1 | Channel Banks | 0.13 | 99.87 | 0.00 | Fine |
| | | Channel Plains | 0.98 | 99.02 | 0.00 | Fine |
| | | Thalweg | 1.13 | 98.87 | 0.00 | Fine |
| | 2 | Channel Banks | 4.98 | 89.83 | 5.20 | Medium |
| | | Channel Plains | 5.23 | 71.89 | 22.88 | Medium |
| | | Thalweg | 27.88 | 66.51 | 5.60 | Fine |
| | 3 | Channel Banks | 12.50 | 83.68 | 3.83 | Medium |
| | | Channel Plains | 20.50 | 76.91 | 2.59 | Fine |
| | | Thalweg | 6.88 | 69.63 | 23.49 | Coarse |
| | 4 | Channel Banks | 11.29 | 88.24 | 0.47 | Fine |
| | | Channel Plains | 23.33 | 76.67 | 0.00 | Fine |
| | | Thalweg | 20.39 | 79.61 | 0.00 | Fine |
| | 5 | Channel Banks | 3.80 | 80.13 | 16.08 | Medium |
| | | Channel Plains | 14.74 | 84.28 | 0.97 | Fine |
| | | Thalweg | 24.81 | 75.19 | 0.00 | Fine |
| | 6 | Channel Banks | 46.36 | 52.90 | 0.75 | Fine |
| | | Channel Plains | 26.23 | 73.51 | 0.26 | Fine |
| | | Thalweg | 31.89 | 67.69 | 0.41 | Fine |
| | 7 | Channel Banks | 2.67 | 78.21 | 19.12 | Medium |
| | | Channel Plains | 20.75 | 65.20 | 14.07 | Medium |
| | | Thalweg | 30.86 | 67.27 | 1.87 | Fine |
| | 8 | Channel Banks | 6.01 | 80.06 | 13.93 | Medium |
| | | Channel Plains | 4.72 | 62.73 | 32.55 | Coarse |
| | | Thalweg | 32.99 | 62.61 | 4.39 | Fine |

| | Station | Location | Total Silt and Clay % (0 to 0.0625 mm) | Sand % (0.0625 mm to 2 mm) | Gravel % (>2 mm) | Median Grain Size |
|---|---|---|---|---|---|---|
| March 2017 | 1 | Channel Banks | 1.51 | 98.49 | 0.00 | Fine |
| | | Channel Plains | 0.70 | 89.73 | 9.57 | Medium |
| | | Thalweg | 45.25 | 54.76 | 0.00 | Fine |
| | 2 | Channel Banks | 7.89 | 87.05 | 5.06 | Fine |
| | | Channel Plains | 16.61 | 76.80 | 6.59 | Medium |
| | | Thalweg | 50.85 | 49.14 | 0.00 | Fine |
| | 3 | Channel Banks | 16.34 | 82.85 | 0.81 | Fine |
| | | Channel Plains | 10.18 | 66.07 | 23.75 | Coarse |
| | | Thalweg | 34.17 | 65.83 | 0.00 | Fine |
| | 4 | Channel Banks | 30.25 | 69.75 | 0.00 | Fine |
| | | Channel Plains | 19.37 | 70.92 | 9.71 | Fine |
| | | Thalweg | 39.25 | 60.75 | 0.00 | Fine |
| | 5 | Channel Banks | 6.67 | 75.69 | 17.64 | Medium |
| | | Channel Plains | 3.47 | 79.61 | 16.92 | Medium |
| | | Thalweg | 28.78 | 71.22 | 0.00 | Fine |
| | 6 | Channel Banks | 15.66 | 83.32 | 1.01 | Medium |
| | | Channel Plains | 23.28 | 63.63 | 13.08 | Medium |
| | | Thalweg | 12.48 | 85.03 | 2.48 | Medium |
| | 7 | Channel Banks | 8.33 | 70.73 | 20.94 | Medium |
| | | Channel Plains | 7.38 | 91.05 | 1.57 | Medium |
| | | Thalweg | 11.41 | 88.59 | 0.00 | Medium |
| | 8 | Channel Banks | 34.83 | 43.28 | 21.89 | Medium |
| | | Channel Plains | 8.56 | 68.44 | 23.00 | Medium |
| | | Thalweg | 47.23 | 52.77 | 0.00 | Fine |

### Sediment Nutrients

Table 11 displays sediment nutrient values from all Stations for pre-restoration surveys; Table 12 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, January 2016, May 2016, and March 2017 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 several spikes in May 2015, which subsequently dropped. Examples include Station 3 bank (1,500 mg/kg, dropped to 270 mg/kg January 2016 survey and 340 mg/kg in May 2016) and Station 6 plain (2,200 mg/kg, dropped to 520 mg/kg January 2016 survey and was found to be 750 mg/kg in the most recent March 2017 survey). Other spike examples showed similar trends. Additionally, those spikes were several times smaller than thalweg spikes at several of the pre-restoration Stations (Table 11, e.g., Station B plain at 3,450 mg/kg for TN and TKN). Station 1 had consistently low values for all sediment nutrients for both the most recent surveys (i.e. May 2016 and March 2017).

Table 11. 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 |

| | Station | Location | Nitrate (mg/kg) | TN (mg/kg) | TKN (mg/kg) | TP (mg/kg) |
|---|---|---|---|---|---|---|
| | 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 |
| 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 | ND | 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 12. 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 |

| | Station | Location | Nitrate + Nitrite, as N (mg/kg) | TN (mg/kg) | TKN (mg/kg) | TP (mg/kg) |
|---|---|---|---|---|---|---|
| | | Thalweg | 1.41 | 533.00 | 532.00 | 501.00 |
| | 5 | Channel Bank | 1.39 | 385.00 | 384.00 | 625.00 |
| | | 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 |

| | Station | Location | Nitrate + Nitrite, as N (mg/kg) | TN (mg/kg) | TKN (mg/kg) | TP (mg/kg) |
|---|---|---|---|---|---|---|
| | | 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 |
| | | Channel Plain | ND | 2200.00 | 2200.00 | 31.00 |
| | | Thalweg | ND | ND | ND | 57.00 |
| | 7 | Channel Bank | 1.10 | 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 |
| | | | | | | |

| | Station | Location | Nitrate + Nitrite, as N (mg/kg) | TN (mg/kg) | TKN (mg/kg) | TP (mg/kg) |
|---|---|---|---|---|---|---|
| May 2016 | 1 | Channel Bank | ND | ND | ND | 180.00 |
| | | Channel Plain | ND | 200.00 | 200.00 | 350.00 |
| | | Thalweg | ND | 280.00 | 280.00 | 390.00 |
| | 2 | Channel Bank | ND | 430.00 | 430.00 | 540.00 |
| | | Channel Plain | ND | 660.00 | 660.00 | 440.00 |
| | | Thalweg | ND | 600.00 | 600.00 | 380.00 |
| | 3 | Channel Bank | ND | 340.00 | 340.00 | 540.00 |
| | | Channel Plain | ND | 400.00 | 400.00 | 330.00 |
| | | Thalweg | ND | 590.00 | 590.00 | 310.00 |
| | 4 | Channel Bank | ND | 1300.00 | 1300.00 | 460.00 |
| | | Channel Plain | ND | 710.00 | 710.00 | 340.00 |
| | | Thalweg | ND | 700.00 | 700.00 | 290.00 |
| | 5 | Channel Bank | ND | 530.00 | 530.00 | 420.00 |
| | | Channel Plain | ND | 760.00 | 760.00 | 380.00 |
| | | Thalweg | ND | 710.00 | 710.00 | 310.00 |
| | 6 | Channel Bank | ND | 330.00 | 330.00 | 500.00 |
| | | Channel Plain | ND | 1300.00 | 1300.00 | 490.00 |
| | | Thalweg | ND | 650.00 | 650.00 | 370.00 |
| | 7 | Channel Bank | ND | 470.00 | 470.00 | 370.00 |
| | | Channel Plain | ND | 1200.00 | 1200.00 | 370.00 |
| | | Thalweg | ND | 320.00 | 320.00 | 310.00 |
| | 8 | Channel Bank | ND | 310.00 | 310.00 | 430.00 |
| | | Channel Plain | ND | 270.00 | 270.00 | 320.00 |
| | | Thalweg | ND | 1100.00 | 1100.00 | 420.00 |
| | | | | | | |
| March 2017 | 1 | Channel Bank | ND | ND | ND | 270.00 |
| | | Channel Plain | ND | ND | ND | 230.00 |
| | | Thalweg | ND | 750.00 | 750.00 | 320.00 |
| | 2 | Channel Bank | 1.60 | 380.00 | 380.00 | 330.00 |
| | | Channel Plain | 3.90 | 470.00 | 470.00 | 480.00 |
| | | Thalweg | ND | 460.00 | 460.00 | 260.00 |
| | 3 | Channel Bank | ND | 730.00 | 730.00 | 260.00 |
| | | Channel Plain | 2.00 | 300.00 | 300.00 | 390.00 |
| | | Thalweg | ND | 900.00 | 900.00 | 210.00 |
| | 4 | Channel Bank | ND | 430.00 | 430.00 | 620.00 |
| | | Channel Plain | 3.10 | 460.00 | 460.00 | 510.00 |
| | | Thalweg | ND | 500.00 | 500.00 | 300.00 |

| | Station | Location | Nitrate + Nitrite, as N (mg/kg) | TN (mg/kg) | TKN (mg/kg) | TP (mg/kg) |
|---|---|---|---|---|---|---|
| | 5 | Channel Bank | ND | 190.00 | 190.00 | 280.00 |
| | | Channel Plain | 4.50 | 600.00 | 600.00 | 270.00 |
| | | Thalweg | ND | 500.00 | 500.00 | 220.00 |
| | 6 | Channel Bank | ND | 460.00 | 460.00 | 390.00 |
| | | Channel Plain | 9.60 | 750.00 | 750.00 | 420.00 |
| | | Thalweg | ND | 450.00 | 450.00 | 180.00 |
| | 7 | Channel Bank | ND | 290.00 | 290.00 | 300.00 |
| | | Channel Plain | 2.20 | 330.00 | 330.00 | 330.00 |
| | | Thalweg | ND | 430.00 | 430.00 | 200.00 |
| | 8 | Channel Bank | ND | 460.00 | 460.00 | 330.00 |
| | | Channel Plain | 1.90 | 690.00 | 690.00 | 350.00 |
| | | Thalweg | ND | 550.00 | 550.00 | 290.00 |

### *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 and another decrease in May 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 an expected trend. Since channel cross-section data (Figures 8-13) did not demonstrate any large scale increases in elevation, sediment grain size distributions are likely still regularly fluctuating with variations in the 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. Data show that fine-grained sediments are flushing out of the system, preventing the buildup of sedimentation and anoxic materials.

Sediment nutrients remained fairly consistent between pre- and post-restoration surveys. Multiple large spikes for all nutrients were present in the pre-restoration September 2006 and April 2007 data which doubled the highest concentrations identified in post-restoration surveys. Post-restoration sediment nutrient data also displayed more uniform distributions and smaller total ranges. 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. Additionally, nutrients may have been sequestered into SAV, rather than being deposited in the sediments as SAV in the form of seagrasses were present as higher overall percent cover for Year 4 across several stations. Lastly, nutrient values should decrease in the future when Las Virgenes Municipal Water District eliminates discharges to Malibu Creek and when the City of Malibu Treatment Plant comes online.

# Biological Monitoring

An important component of the biological assessments of the Malibu Lagoon Restoration Project is observable improvements in the establishment and persistence of species diversity and native organisms. Biological monitoring components are being 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 includes 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. This report details biological monitoring results through Year 4 of the monitoring program and will continue for one additional year.

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) over time and to evaluate against pre-restoration data.

### *Methods*

Post-restoration benthic invertebrate community sampling was conducted at eight stations (Figure 14) on 5 May 2014, 30 December 2014, 21 January 2016, and 8 March 2017 using two different methods: 1) bank net sweeps, and 2) benthic cores, as described in the Monitoring Plan. The 2017 date was later in the year due to a higher number of rain events, which delayed surveying. Post-restoration data are compared to pre-restoration data from 13 September 2006 and 26 September 2007. 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 35 taxa across 11 classes represented in the post-restoration surveys, including the small benthic cores (26 taxa) and the net sweep (16 taxa) invertebrate data (Table 13). Figures 27 and 28 display data from the 2006 and 2007 pre-restoration surveys, and all of the post-restoration surveys, including 2017 (Year 4). 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" abundances, or pollution-intolerant species, in the post-restoration years (e.g. from 8.9% in 2007 to 99.9% in December of 2014, and 74.5% in March 2017 for benthic core invertebrates) (Figures 27a and 28a), and a decrease in the percent abundance of the pollution-tolerant taxa (e.g. from 93.6% and 91.7% pre-restoration to 10.7% post-restoration in the most recent March 2017 surveys for the net sweep data). All post-restoration years (1-4) show a reduction in pollution-tolerant abundances of invertebrate taxa as compared to pre-restoration survey abundances.

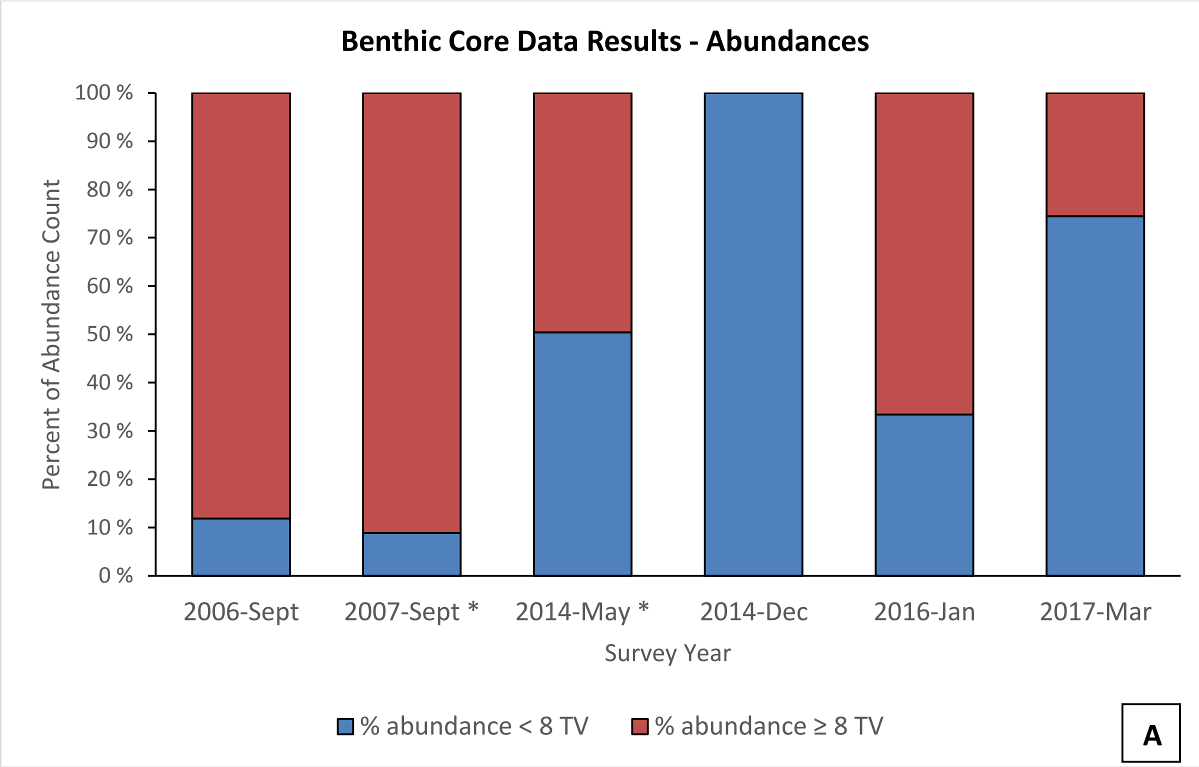
A similar trend, albeit less dramatic, was expressed by the percentages of the numbers of taxa, which showed a slight increase in sensitive (pollution-intolerant) species use of the site as a trend through March 2017 for both survey types (e.g. from 40.0 and 55.5% pre-restoration to 75.0% in both of the most recent post-restoration surveys, and a slight decrease in the percent of number of pollution tolerant taxa (e.g. from 60.0 and 44.4% to 25%; Figures 27b and 28b). Both survey types for the most recent data in March 2017 exhibited a more sensitive invertebrate community than pre-restoration conditions.

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

Table 13. Taxa presence list for all post-restoration surveys combined. Asterisks indicate a closed berm condition.

| | | | | | Benthic Cores | | | | Net Sweeps | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Phylum** | **Class** | **Order** | **Family** | **Lowest Possible Taxon** | *** May 2014** | **Dec 2014** | **Jan 2016** | **Mar 2017** | *** May 2014** | **Dec 2014** | **Jan 2016** | **Mar 2017** |
| Annelida | Oligochaeta | | | Oligochaeta | | | | | X | X | X | X |
| Annelida | Oligochaeta | Haplotaxida | Tubicidae | Tubicidae | X | | | | | | | |
| Annelida | Oligochaeta | Haplotaxida | Tubificidae | Tubificidae | | X | X | X | | | | |
| Annelida | Polychaeta | Sedentaria | Capitellidae | *Capitella capitata* complex | | 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 | | | 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 | Ceratopogon | | | | | | | | X |
| Arthropoda | Insecta | Diptera | Ceratopogonidae | Dasyhelea | | | | | X | | | |
| Arthropoda | Insecta | Diptera | Chironomidae | Chronomini | X | X | X | | X | X | X | X |
| Arthropoda | Insecta | Diptera | Chironomidae | Orthocladiinae | | | | X | | | | |
| Arthropoda | Insecta | Diptera | Chironomidae | Tanytarsini | | | | | | | | X |
| Arthropoda | Insecta | Diptera | Diptera | *Dasyhelea sp.* | | X | | | | | | |
| Arthropoda | Insecta | Diptera | Dolichopodidae | Dolichopodidae | X | X | | X | X | | | X |
| Arthropoda | Insecta | Diptera | Ephydridae | Ephydridae | | | | | | | | X |
| Arthropoda | Insecta | Diptera | Psychodidae | Psychodidae | | | | | | | | X |
| Arthropoda | Insecta | Hemiptera | Corixidae | Corixidae | X | | | | X | | X | |
| Arthropoda | Insecta | Hemiptera | Corixidae | *Trichocorixa sp.* | X | | | | X | | | |
| Arthropoda | Malacostraca | Amphipoda | Corophiidae | *Americorophium sp.* | | | | | | | | X |
| Arthropoda | Malacostraca | Amphipoda | Corophiidae | *Monocorophium insidiosum* | | | | X | | | | |
| Arthropoda | Malacostraca | Amphipoda | Gammaridae | *Gammarus sp.* | | X | | | | | | |
| Arthropoda | Malacostraca | Amphipoda | Hyalellidae | Hyalella | | | | | | | | X |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Arthropoda | Malacostraca | Amphipoda | Talitridae | *Traskorchestia sp.* | | | | X | | | | |
| Arthropoda | Maxillopoda | Calanoida | | Calanoida | X | | X | | | | | |
| Arthropoda | Maxillopoda | Harpactacoida | | Harpactacoida | | | X | | | | | |
| Arthropoda | Ostracoda | | | Ostracoda | | | | | | X | X | X |
| Arthropoda | Ostracoda | Podocopida | | Podocopida | X | 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 | | | | | | | |



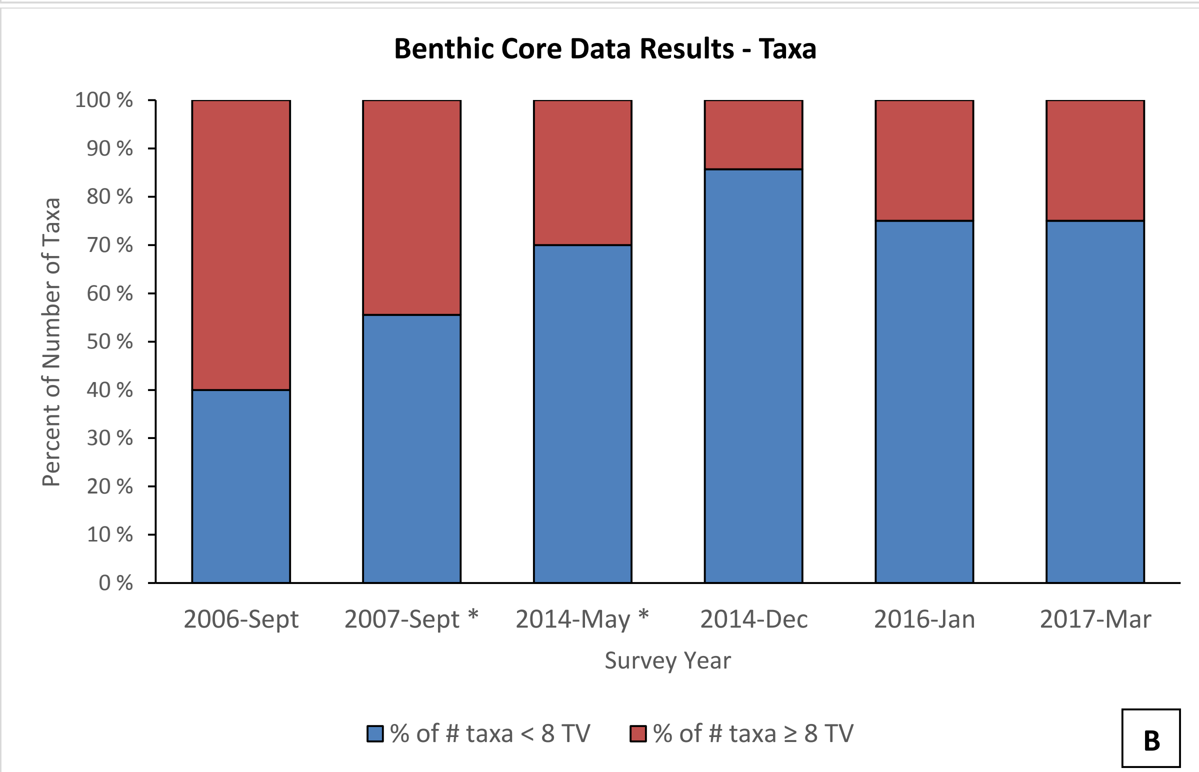




Figure 27. Benthic invertebrate core data results organized by (A) percent of abundance count data with pollution tolerance values (TV) below 8, and (B) percent of number of taxa with TV below 8. Asterisks indicate a closed berm condition.

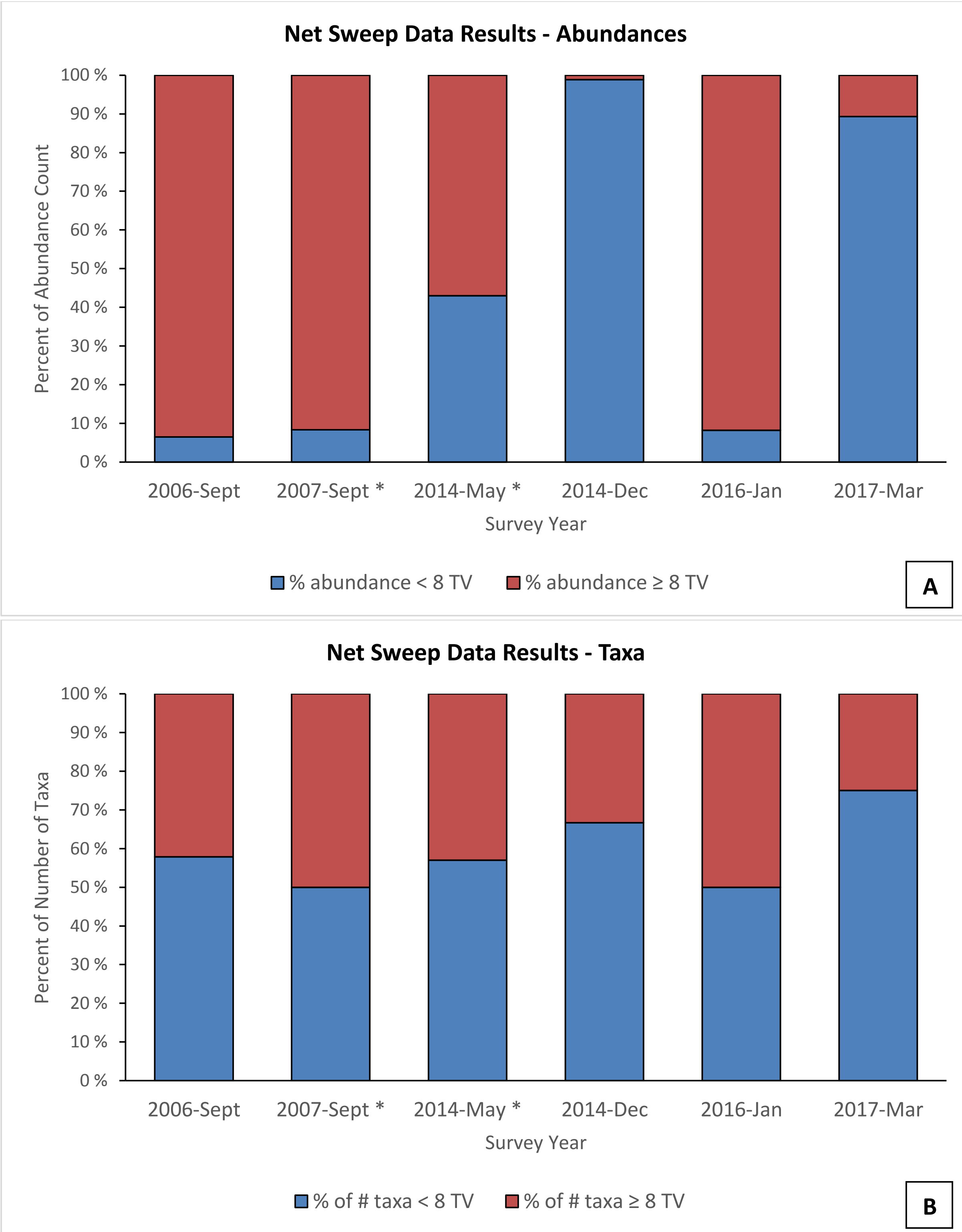



Figure 28. Net sweep invertebrate data results organized by (A) percent of abundance count data with pollution tolerance values (TV) below 8, and (B) percent of number of taxa with TV below 8. Asterisks indicate a closed berm condition.

### *Performance Evaluation*

The invertebrate survey data results have established a trend from a depauperate, pollution-tolerant invertebrate community (pre-restoration), to a healthier, diverse invertebrate community that included a higher percentage abundance of sensitive species and numbers of taxa (post-restoration). This trend reversed slightly in the January 2016 survey data results, indicating a decrease in sensitive taxa between December 2014 and January 2016. However, the overall community exhibited a trend back towards pollution-sensitive taxa in the 2017 data results. The data are likely to continue to fluctuate slightly over time. The current abundances and numbers of sensitive taxa are much higher than pre-restoration conditions and did not exhibit decreases across multiple years; thus, the benthic community is meeting the project success criteria.

It will be important to continue to evaluate these data in the subsequent monitoring report (Year 5) across all five monitoring years to have a full evaluation of trends over time. Invertebrate populations are also likely to have been affected by El Nino (warmer oceanic water conditions – e.g. 2016 results) and winter seasons with higher rain events (e.g. 2017). Similarly, abundances of marine invertebrates were reduced in the 2017 survey likely due to the larger than usual freshwater influx from rainfall. Seven new taxa were identified in 2017.

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 an example in the 2017 results for the benthic invertebrate data, three taxa making up 37% of the sample did not have a pollution tolerance value assigned and are thus only represented in the taxa presence list.

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 (June 2016 and March 2017).

### *Methods*

Post-construction fish surveys of Malibu Lagoon were conducted on 8 January 2013, 15 May 2014, 11 December 2014, 27 May 2015, 12 January 2016, 1 June 2016, and 3 March 2017 by a team led by the Resource Conservation District of the Santa Monica Mountains with assistance from CDPR, TBF, and additional volunteers. 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 29 and 30) 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. On 3 March 2017, due to the shallow nature of the lagoon at the time, blocking nets spanned the entire channel, instead of the triangle form. Additionally, on 3 March 2017, an additional spot seine was surveyed adjacent to the tree snag at Site 3, but the beach spot seines were not conducted due to time constraints.

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 4 was inaccessible; therefore, Site 2a was surveyed again (similarly to previous surveys) to comply with monitoring plan requirements. The lagoon (berm) was closed to the ocean for the June 2016 survey, but it was open for the March 2017 survey.


Figure 29. Map of the six permanent fish monitoring Sites.

Figure 30. Representative photograph of fish surveys being conducted at Site 1 on 1 June 2016 (photo: RCDSMM).

### *Results*

For detailed water quality parameter measurements, fish species counts, and incidental invertebrate capture counts for each survey, see Appendices 1 and 2 and the previous post-restoration baseline reports (Abramson et al. 2013, 2015, 2016). Table 14 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 14. 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 | Jun 2016 * | Mar 2017 |
|---|---|---|---|---|---|---|---|---|---|
| Arrow goby | *Cleavlandia ios* | | | X | | | | | |
| Bay goby | *Lepidogobius lepidus* | | | X | | | | | |
| California killifish | *Fundulus parvipinnis* | X | | X | | | | X | X |
| California halibut | *Paralichthys californicus* | | | | | | | X | |
| Diamond turbot | *Hypsopsetta guttulata* | | X | X | | | | X | |
| Long-jawed mudsucker | *Gillichthys mirabilis* | X | | X | | X | | X | X |
| Northern anchovy | *Engraulis mordax* | | X | | X | | X | X | |
| Opaleye | *Girella nigricans* | X | | | | | | | |
| Staghorn sculpin | *Leptocottus armatus* | | X | X | | | X | X | X |
| Striped mullet | *Mugil cephalus* | | | X | X | X | X | X | X |
| Tidewater goby | *Eucyclogobius newberryi* | X | X | X | | X | | X | X |
| Topsmelt | *Atherinops sp.* | X | X | X | X | X | X | X | X |
| Topsmelt larva (< 5 cm) | *Atherinops sp.* | | | X | | X | X | X | X |
| Unidentified fish larva (< 5 cm) | ---- | | | X | | X | | X | |
| Unidentified smelt larva (< 5 cm) | *Atherinops sp.* | | | X | | X | X | | |
| **Non-Native Fish** | | | | | | | | | |
| Mississippi silversides | *Menidia berylina* | | X | | X | X | X | X | |
| Mosquitofish | *Gambusia affinis* | X | X | X | X | X | X | X | X |
| Carp | *Cyprinus carpio* | X | | X | | | | | |

### January 2013 Survey

The five native fish species documented in the first post-construction survey (January 2013, Table 14) 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 (*Gambusia affinis*) were observed in both the pre and post-construction surveys. Seining in the main body of the lagoon also documented juvenile staghorn sculpin (*Leptocottus armatus*) and topsmelt (*Atherinops affinis*), but additionally supported very small diamond turbot (*Hypsopsetta guttalata*), northern anchovy (*Engraulis mondax*) and tidewater goby.

### May 2014 Survey

Ten native fish species and one non-native species were captured in the May 2014 survey (Table 14). 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 14). 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 14 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 (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.

**June 2016 Survey**

A total of 17 tidewater gobies were captured and concentrated primarily along the lagoon/beach face. Striped mullet were observed jumping throughout the lagoon. The dominant species surveyed and identified was topsmelt (adult n=133, larvae n= 1289), although quite a few longjaw mudsuckers of all age classes (n=63) and a few other species were observed. Additionally, both adult and juvenile staghorn sculpin were found, as well as juvenile diamond turbot and California halibut.

**March 2017 Survey**

A total of 12 tidewater gobies were captured in several sites (Figure 31). Due to time constraints, we did not conduct spot surveys along the beach, where they have also been identified in past surveys. Striped mullet were observed jumping throughout the lagoon. The dominant species surveyed and identified was staghorn sculpin (juveniles =132), followed by topsmelt (adult n=49, juvenile n= 35). Notably, only one non-native mosquitofish was captured across all sites.

Figure 31. Photograph of two tidewater gobies from the March 2017 survey (credit: R. Dagit, RCDSMM).

### *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 of many species. Both the native fish species richness' and the overall native fish abundances are higher in all three of the post-restoration summer surveys than in the pre-restoration summer survey. Up to 12 native fish species have been documented in the lagoon, as compared to a pre-restoration species richness of five. Non-native fish abundances are lower, post-restoration, and the non-native species richness is the same. Tidewater gobies were observed in both the pre- and post-restoration surveys.

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 being exposed to tidal conditions. Interestingly, due to the high rainfall in the most recent winter season (2016/17), the fish surveys had to be postponed to March to avoid sampling within several days of a rain event. The March 2017 survey found eight native fish species and only one individual mosquitofish, even though LA County Vector Control regularly releases them into Malibu Creek. It is possible that the heavy rainfall influenced the March 2017 identified fish community.

## 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.

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, 26-27 October 2015, 11-12 January 2016, 26-27 April 2016, 25-26 July 2016, and 25-26 October 2016. Surveys were conducted throughout 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 number of species and abundances 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.

Additionally, a separate analysis of birds identified within the western channels only was completed for this report. This allows for a separate evaluation of the actual restoration area, rather than the entire lagoon system, though neither summary should be considered statistically significant or indicative of definitive long-term trends.

### *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; in the third post-restoration year, 11,299 individual birds were identified. Year 4 surveys identified the highest total number of birds yet, at 11,736 individuals, representing an approximately 46% increase for Year 4 over the pre-restoration average. Species richness, which dropped in the first two years post-restoration, rebounded somewhat by 2015 [i.e. 119 in 2005-06, then 88 (2013), 87 (2014), 100 (2015)], and returned to 88 in 2016. The cumulative number of species and identifiable subspecies detected across all four post-restoration years was 151, with five new species identified in 2016.

Analyses from the western channels only (restoration area) show an overall increase in both post-restoration counts (abundances) and species richness when compared to pre-restoration counts from 2005-06. However, comparison of sheer numbers and species richness totals are 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.

The presence of all landbird and waterbird guild species recorded on all pre- and post-restoration site-wide avifauna surveys are presented in Tables 15 and 16. Quantities and additional details for each identified species can be found in Appendix 3.

#### 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. However, counts of these species in 2016 were the lowest yet, more comparable to the first year after restoration was complete. Counts of scrub / woodland species continued to increase since 2013, with cumulative numbers of these species just over half those recorded in 2005-06 prior to restoration (152 individuals in 2016, vs. 276 in 2005-06) (Table 15). However, species richness within this guild continued at a higher level than the first year post-restoration (8 species in 2013 vs. 16 species in 2015 and 11 species in 2016). For urban species, after two straight years of declines, numbers began to increase in 2015, and this trend continued in 2016, with counts of individual urban species in 2016 roughly triple those in 2015.

These observations may be supplemented with a much larger database of citizen observational data from birders' reports to the eBird database (www.ebird.org). One representative scrub-dwelling species, the Song Sparrow, shows ever-increasing counts through the spring/summer nesting season in recent years. This suggests that the species has been able to adapt well to the scrub plantings on the site year after year.

### Waterbird results

Birds associated with freshwater marsh habitat surged in numbers in 2015 (17 to 74 individuals) and continued to rise in 2016 (96 individuals), with yet another species found that had not been recorded on the survey since the pre-restoration years (i.e. Sora) (Table 16). Fish-eating waterbirds (e.g. Ruddy Duck) initially 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. However, analyses of the longer-term trends for fish-eating waterbirds shows no clear trend in overall direction and remain similar in counts and species richness as pre-restoration numbers.

Higher numbers of marine birds have been identified in recent years (4,404 and 3,879 in 2015 and 2016, respectively) compared to pre-restoration (2,311), although they fluctuate heavily. Shorebird numbers in 2016 increased significantly from 2015, but were still recorded at roughly a third the level prior to restoration (approximately 300/year, versus approximately 900/year in 2005-06). Large waders (herons and egrets; Figure 32 continued to remain slightly lower than pre-restoration numbers, with counts of individuals in 2016 slightly less than those of prior years. Waterfowl numbers remain lower than pre-restoration numbers, with a bump occurring in 2013, likely caused by a surge in numbers of American Coot attracted to the open mud habitat exposed by the restoration construction. Waterbird species richness fluctuates by year (e.g. 15 in 2015, 13 in 2016), but remains similar to pre-restoration numbers (i.e. 15).

### Western Channels Analysis (restoration area only)

In the four years since the site was restored, certain bird species have been able to use more of the site, particularly waterbirds using the aquatic habitats in the western portion of the lagoon, which had been shallow and narrow prior to the restoration. A comparison of 22 common waterbirds in the western channels (Table 17 and Figure 33) show a steady increase in species richness on surveys since 2005 (from 16 to 21 species). Similarly, the total number of individuals has increased post-restoration from 174 pre-restoration to 1,802 (over 900% increase) and 533 (over 200% increase) in 2015 and 2016, respectively. It should be noted that the 2015 total count was heavily weighted by a high concentration of Brown Pelicans (approximately 1,000) roosting on the islands in the western channels on 21 April 2015.

Table 15. 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)** | **2016 (Year 4)** |
| Open country | American Pipit | X | X | | X | |
| | Killdeer | X | X | X | X | X |
| | Savannah Sparrow | X | X | X | X | X |
| | Say's Phoebe | X | X | X | X | X |
| | Western Kingbird | X | | | X | |
| | Western Meadowlark | | X | X | X | X |
| Scrub/Woodland | Allen's Hummingbird | X | X | X | X | X |
| | American Robin | | X | | | |
| | Anna's Hummingbird | X | | X | X | |
| | Bewick's Wren | X | X | X | X | X |
| | Bushtit | X | X | X | X | X |
| | California Scrub-Jay | | | | | X |
| | California Towhee | X | X | X | X | X |
| | Cedar Waxwing | X | | | | |
| | Hermit Thrush | | | X | X | X |
| | House Wren | X | X | X | X | X |
| | Lincoln's Sparrow | X | | X | X | |
| | Oak Titmouse | X | | | X | X |
| | Orange-crowned Warbler | X | | X | X | X |
| | Ruby-crowned Kinglet | X | X | X | X | X |
| | Song Sparrow | X | X | X | X | X |
| | Spotted Towhee | X | | X | X | |
| | Townsend's Warbler | | | | X | |
| | Wilson's Warbler | X | | | X | |
| | Yellow Warbler | X | | | X | |
| Urban | American Crow | X | X | X | X | X |
| | Black Phoebe | X | X | X | X | X |
| | Brewer's Blackbird | X | | | | |
| | Brown-headed Cowbird | X | X | X | X | X |
| | European Starling | X | X | X | X | X |
| | Hooded Oriole | X | X | | | |
| | House Finch | X | X | X | X | X |
| | Rock Pigeon | | | | | X |
| | Northern Mockingbird | X | X | X | X | X |

Table 16. Presence of waterbird species recorded during all pre- and post-construction surveys by guild (see footnotes in Appendix 3 regarding species omissions). Note the overlap of several species between multiple guilds (e.g. several species present in both 'waders' and 'fish-eaters').

| | | Pre-restoration | Post-restoration | | | |
|---|---|---|---|---|---|---|
| **Guild** | **Species** | **2005-06** | **2013 (Year 1)** | **2014 (Year 2)** | **2015 (Year 3)** | **2016 (Year 4)** |
| Freshwater Marsh | Common Yellowthroat | X | X | X | X | X |
| | Great-tailed Grackle | X | X | X | X | X |
| | Marsh Wren | X | | | X | X |
| | Red-winged Blackbird | X | | | X | X |
| | Sora | X | | | | X |
| | Virginia Rail | X | | | | |
| Marine/Beach | Black Oystercatcher | X | X | | | |
| | Bonaparte's Gull | X | X | X | X | X |
| | Brant | X | X | | X | X |
| | Brown Pelican | X | X | X | X | X |
| | Caspian Tern | X | X | X | X | X |
| | Double-crested Cormorant | X | X | X | X | X |
| | Elegant Tern | X | X | X | X | X |
| | Forster's Tern | X | X | | X | |
| | Glaucous-winged Gull | X | X | X | X | X |
| | Heermann's Gull | X | X | X | X | X |
| | Herring Gull | X | X | X | X | X |
| | Horned Grebe | X | | | X | |
| | Least Tern | X | | | X | |
| | Mew Gull | X | | X | | |
| | Red-breasted Merganser | X | X | X | X | X |
| | Red-throated Loon | | X | X | | |
| | Royal Tern | | X | X | X | X |
| | Ruddy Turnstone | X | X | X | X | X |
| | Sanderling | X | X | X | X | X |
| | Snowy Plover | X | X | X | X | X |
| | Surfbird | | | X | | |
| | Western Grebe | | X | X | X | X |
| | Western Gull | X | X | X | X | X |
| Shorebirds | American Avocet | X | X | | | |
| | Black-bellied Plover | X | X | X | X | X |
| | Black-necked Stilt | | | | X | |
| | Dunlin | X | X | X | | |
| | Greater Yellowlegs | X | X | | | X |

| | | Pre-restoration | Post-restoration | | | |
|---|---|---|---|---|---|---|
| **Guild** | **Species** | **2005-06** | **2013 (Year 1)** | **2014 (Year 2)** | **2015 (Year 3)** | **2016 (Year 4)** |
| | Least Sandpiper | X | X | X | X | X |
| | Long-billed Curlew | X | | | | |
| | Long-billed Dowitcher | X | | | X | X |
| | Marbled Godwit | X | X | X | X | X |
| | Semipalmated Plover | X | X | X | X | X |
| | Spotted Sandpiper | X | X | X | X | X |
| | Western Sandpiper | X | X | X | X | X |
| | Whimbrel | X | X | X | X | X |
| | Willet | X | X | X | X | X |
| | Wilson's Phalarope | | | | X | |
| Waders | Black-crowned Night Heron | X | X | X | X | |
| | Great Blue Heron | X | X | X | X | X |
| | Great Egret | X | X | X | X | X |
| | Green Heron | X | | X | X | |
| | Snowy Egret | X | X | X | X | X |
| Waterfowl | American Coot | X | X | X | X | X |
| | American Wigeon | X | X | X | X | X |
| | Blue-winged Teal | X | | | X | X |
| | Bufflehead | X | X | X | X | X |
| | Cinnamon Teal | X | | | X | X |
| | Eared Grebe | X | X | X | X | X |
| | Gadwall | X | X | X | X | X |
| | Green-winged Teal | X | X | X | X | X |
| | Hooded Merganser | | | | X | |
| | Lesser Scaup | X | X | X | | |
| | Mallard | X | X | X | X | X |
| | Northern Pintail | X | | X | X | X |
| | Northern Shoveler | X | X | X | X | X |
| | Pied-billed Grebe | X | X | X | X | X |
| | Ruddy Duck | X | X | X | X | X |
| | Snow Goose | X | | | X | |
| Fish-eaters | Belted Kingfisher | | X | X | X | X |
| | Black-crowned Night Heron | X | X | X | X | |
| | California Brown Pelican | X | X | X | X | X |
| | Caspian Tern | X | X | X | X | X |
| | Double-crested Cormorant | X | X | X | X | X |
| | Forster's Tern | X | X | | X | |
| | Great Blue Heron | X | X | X | X | X |

| | | Pre-restoration | Post-restoration | | | |
|---|---|---|---|---|---|---|
| **Guild** | **Species** | **2005-06** | **2013 (Year 1)** | **2014 (Year 2)** | **2015 (Year 3)** | **2016 (Year 4)** |
| | Great Egret | X | X | X | X | X |
| | Green Heron | X | | X | | |
| | Hooded Merganser | | | | X | |
| | Least Tern | X | | | X | |
| | Osprey | X | | | | X |
| | Pied-billed Grebe | X | X | X | X | X |
| | Red-breasted Merganser | X | X | X | X | X |
| | Red-throated Loon | | X | X | | |
| | Royal Tern | | X | X | X | X |
| | Snowy Egret | X | X | X | X | X |

Figure 32. Photograph of egret adjacent to tidal channel at Malibu Lagoon (credit: TBF, 27 December 2016).

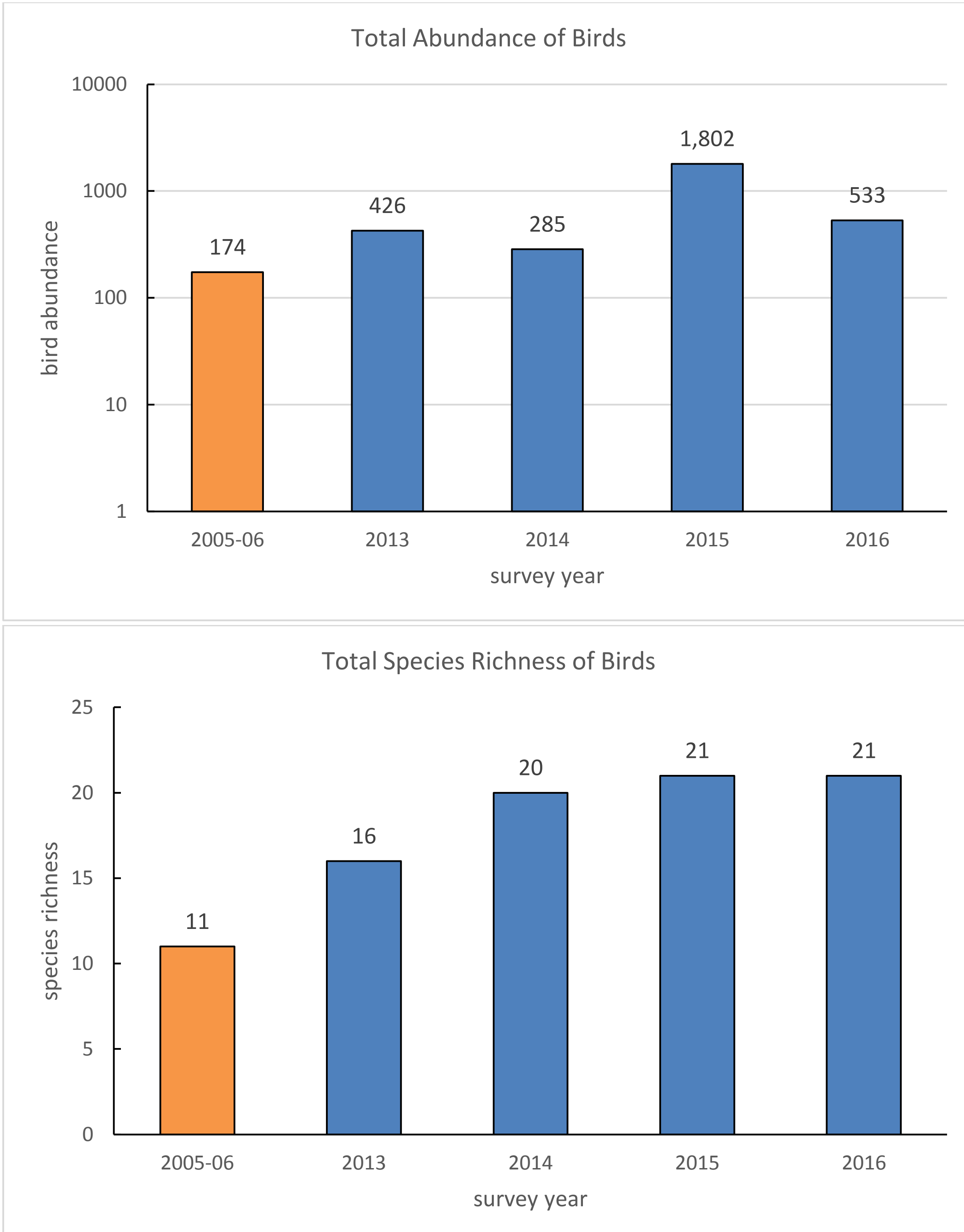



Figure 33. Comparison of total bird numbers (top) and species richness (bottom) in restoration area only (western channels) of Malibu Lagoon during surveys (2005-2016).

Table 17. Selected waterbird use of the restoration area only (western channels) of Malibu Lagoon, 2005-2016, during surveys.

| | Pre-restoration | Post-restoration | | | |
|---|---|---|---|---|---|
| **Species** | **2005-06** | **2013** | **2014** | **2015** | **2016** |
| American Wigeon | | 30 | 2 | 1 | 7 |
| Black-bellied Plover | | | 6 | 60 | 22 |
| Brown Pelican | | | 3 | 1106 | 1 |
| Caspian Tern | 3 | 1 | 2 | 8 | 8 |
| Double-cr. Cormorant | | 15 | 5 | 45 | 40 |
| Eared Grebe | | 24 | 25 | 15 | 3 |
| Elegant Tern | | | | 5 | 250 |
| Gadwall | 27 | 104 | 59 | 114 | 27 |
| Great Blue Heron | 9 | 14 | 5 | 11 | 9 |
| Great Egret | 5 | 9 | 2 | 5 | 4 |
| Green-winged Teal | 70 | 28 | 15 | 61 | 20 |
| Killdeer | 6 | 28 | 9 | 34 | 18 |
| Least Sandpiper | 26 | 6 | 3 | | |
| Marbled Godwit | | | 37 | 6 | 17 |
| Northern Shoveler | 5 | 82 | 13 | 9 | 26 |
| Pied-billed Grebe | 2 | 16 | 3 | 4 | 12 |
| Red-breasted Merganser | | 4 | 1 | 5 | 9 |
| Ruddy Duck | | 24 | 47 | 226 | 3 |
| Snowy Egret | 19 | 38 | 36 | 53 | 44 |
| Western Grebe | | 3 | | 7 | 8 |
| Whimbrel | 2 | | 6 | 17 | |
| Willet | | | 6 | 10 | 5 |
| Total # of Individuals | 174 | 426 | 285 | 1,802 | 533 |
| Species Richness | 11 | 16 | 20 | 21 | 20 |

### *Performance Evaluation*

Several patterns have emerged after four years of post-restoration bird monitoring, and while none may be statistically significant, they may provide an indication of how the site's avifauna are responding to the restoration. Special-status species in Year 4 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 2016 included 11,736 individual birds identified, representing the highest count of birds recorded in any pre- or post-restoration years.

No specific success criteria were identified for avifaunal community surveys regarding abundances and species richness, rather the restoration was targeted at overall habitat improvement. Similarly, since 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 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 necessarily indicative of project success.

As noted in prior reports, many additional analyses could be conducted using the bird data from Malibu Lagoon, including seasonality. Intra-site usage provides another avenue of analysis. Since data were collected by region of the site (e.g., beach, western channels, main lagoon), a separate analysis of waterbirds was conducted showing increases in abundances and species richness, post-restoration. This analysis and future, more in-depth analyses, could help clarify the role of the actual restoration across the site on a particular species or species group. However, it should be noted that 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.

## 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, 19 January 2016, and 15 December 2016 (Year 4). Floating, mat, and attached submerged aquatic vegetation and macroalgae were monitored at eight stations (Figure 14). Three, 50-meter (or the total maximum length of the SAV zone) 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 13% or less, and several stations had less than 5% average cover for the most recent survey on 15 December 2016 (i.e. Stations 4 and 6), which is consistent with results from previous years (Tables 18 and 19). The grand mean total algal and SAV cover (± SE) for all surveys on 15 December 2016 was 8.00 % ± 2.44. 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. The wrack percent of total cover averaged for all stations was approximately 17%, with a range of 0 (Station 9) to 100 % (Station 6).

At several stations, the most recent survey also identified *Ruppia sp.*, or ditchgrass, which is an attached submerged aquatic vegetation (SAV) species (Table 18, Figure 34. Percent of total cover averaged for all stations for *Ruppia* equaled approximately 55% of the total cover, with a range from 0-100% of the total cover; it varied by station, but was found to be 0% at Station 6 and 100% at Station 8. SAV in the form of seagrasses sequester nutrients and carbon and provide oxygen to the water column. They also provide important estuarine habitat for invertebrates and fish.

Figure 34. Photograph of *Ruppia sp.* at the Malibu Lagoon on 26 August 2016.

Table 18. Algae data as station total percent cover ± standard error for the four post-restoration surveys. Note that the total cover includes both algae (e.g. wrack, *Cladophora*) and SAV (e.g. *Ruppia*).

| | 14 Feb 2013 | 23 Dec 2014 | 19 Jan 2016 | 15 Dec 2016 |
|---|---|---|---|---|
| Station 1 | 2.98 ± 0.57 | 10.17 ± 3.80 | 6.63 ± 1.27 | 8.84 ± 2.00 |
| Station 2 | 0.45 ± 0.27 | 7.68 ± 2.21 | 11.51 ± 2.18 | 11.13 ± 5.67 |
| Station 3 | 0.87 ± 0.87 | 0.95 ± 0.53 | 2.74 ± 1.20 | 9.69 ± 4.59 |
| Station 4 | 2.10 ± 0.10 | 1.28 ± 0.27 | 0.82 ± 0.35 | 3.26 ± 1.76 |
| Station 5 | 0 ± 0 | 3.84 ± 1.50 | 3.64 ± 1.58 | 6.53 ± 1.30 |
| Station 6 | 0 ± 0 | 0.23 ± 0.10 | 0.40 ± 0.13 | 0.26 ± 0.02 |
| Station 7 | 0.46 ± 0.06 | 0.29 ± 0.11 | 2.19 ± 0.37 | 13.14 ± 2.16 |
| Station 8 | 5.08 ± 2.01 | 0.25 ± 0.11 | 2.56 ± 1.73 | 11.14 ± 2.02 |
| **Grand Mean** | **1.49 ± 0.49** | **3.09 ± 1.08** | **3.81 ± 1.10** | **8.00 ± 2.44** |

Table 19. Algae data as station average wrack and *Cladophora* percent cover ± standard error for the four post-restoration surveys. Note that the 19 January and 15 December 2016 surveys had *Ruppia* as a separate column.

| | 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 ± 3.70 | 0.31 ± 0.21 | 4.06 ± 1.40 | 2.55 ± 0.28 | 0.02 ± 0.02 |
| Station 2 | 0.44 ± 0.28 | 0.01 ± 0.01 | 7.58 ± 2.12 | 0.10 ± 0.10 | 7.44 ± 0.98 | 4.07 ± 2.04 | 0 ± 0 |
| Station 3 | 0.20 ± 0.20 | 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 ± 0.40 | 0.10 ± 0.10 | 0 ± 0 |
| Station 5 | 0 ± 0 | 0 ± 0 | 3.84 ± 1.50 | 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 | 4.40 ± 2.42 | 0.25 ± 0.11 | 0 ± 0 | 2.44 ± 1.80 | 0 ± 0 | 0.12 ± 0.08 |

| | 15 Dec 2016 | | |
|---|---|---|---|
| | wrack | *Cladophora* | *Ruppia* |
| Station 1 | 2.59 ± 0.2 | 1.56 ± 0.38 | 4.69 ± 1.45 |
| Station 2 | 0.38 ± 0.27 | 6.73 ± 4.16 | 4.02 ± 1.25 |
| Station 3 | 0.13 ± 0.13 | 7.07 ± 5.72 | 2.49 ± 2.09 |
| Station 4 | 0.1 ± 0.1 | 1.22 ± 0.85 | 1.94 ± 0.98 |
| Station 5 | 0.02 ± 0.02 | 0.96 ± 0.45 | 5.54 ± 1.69 |
| Station 6 | 0.26 ± 0.02 | 0 ± 0 | 0 ± 0 |
| Station 7 | 0.01 ± 0.01 | 2.96 ± 0.51 | 10.17 ± 2.32 |
| Station 8 | 0 ± 0 | 0 ± 0 | 11.14 ± 2.02 |

### *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 four 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. Algal bloom occurrences have decreased, post-restoration.

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. While a small amount of live *Phyllospadix sp.* and *Ruppia sp.* cover was present during the 19 January 2016 survey, the most recent survey on 15 December 2016 showed a substantial increase in *Ruppia* cover. *Ruppia* beds positively contribute to community ecology, providing habitat and nursery areas for fish. Additionally, *Ruppia* has been recognized as an important food source for migrating and wintering waterfowl, wading birds, and shorebirds (Kantrud 1991).

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. These criteria were exceeded for post-restoration conditions as well as the other SAV metrics.

## 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*

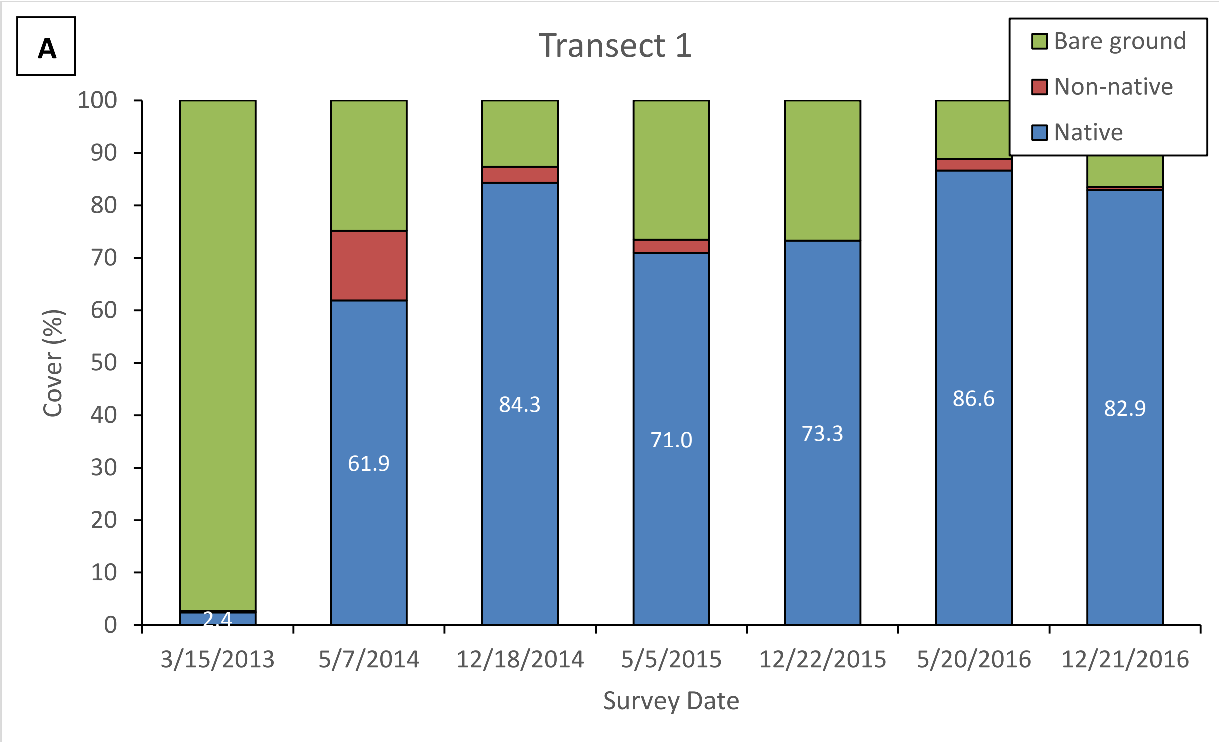
Data for absolute percent cover of native/nonnative vegetation species were collected along three, 50-meter transects (Figure 35) using the line-intercept method on 15 March 2013, 7 May 2014, 18 December 2014, 5 May 2015, 22 December 2015, 20 May 2016, and 21 December 2016. These data were combined to provide a comprehensive set of post-restoration vegetation surveys to evaluate native and non-native relative vegetation cover over time.

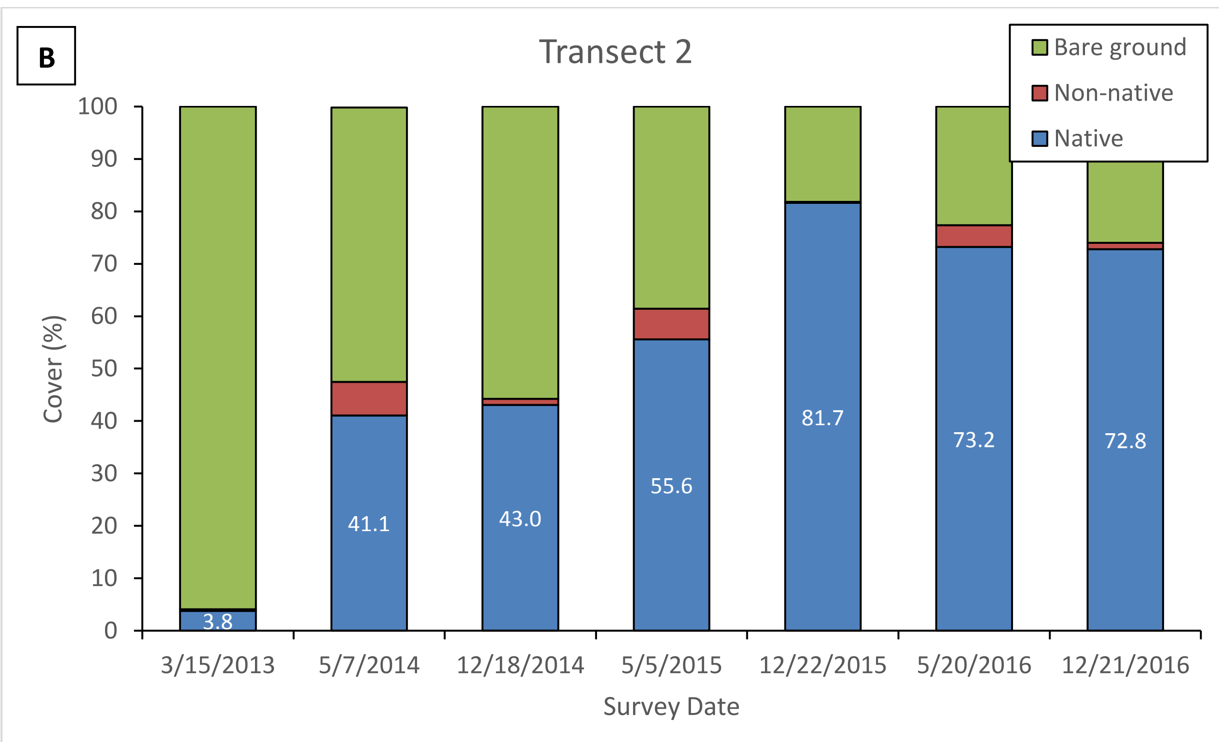
Each transect location was recorded with a submeter global positioning system (GPS) unit and photographed at each end. Absolute cover data were calculated based on the total distance for each species within each transect. Species data were collected to an accuracy of 0.01 m along each 50-meter transect.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


Figure 35. 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 1, at 82.9% and lowest on Transect 3 at 51.8% (Figure 36). Native cover was slightly higher in the May 2016 (first Year 4) survey at 86.6% on Transect 1 and 54.8% on Transect 3. All transects have shown a general trend over time of increasing native vegetation cover and decreasing bare ground over time, with slight fluctuations in the most recent survey year (Year 4). Additionally, the non-native cover for Transects 1, 2, and 3 was 0.6%, 1.25%, and 0.0%, respectively, remaining consistently low over time. The highest cover for non-native vegetation is usually seen in the spring surveys (still usually only a few percent) which capture annual non-natives, but which are then subsequently weeded out during restoration events.


A
Transect 1
Bare ground
Non-native
Native
100
90
80
70
60
50
40
30
20
10
0
Cover (%)
2.4
61.9
84.3
71.0
73.3
86.6
82.9
3/15/2013
5/7/2014
12/18/2014
5/5/2015
12/22/2015
5/20/2016
12/21/2016
Survey Date


B
Transect 2
Bare ground
Non-native
Native
100
90
80
70
60
50
40
30
20
10
0
Cover (%)
3.8
41.1
43.0
55.6
81.7
73.2
72.8
3/15/2013
5/7/2014
12/18/2014
5/5/2015
12/22/2015
5/20/2016
12/21/2016
Survey Date

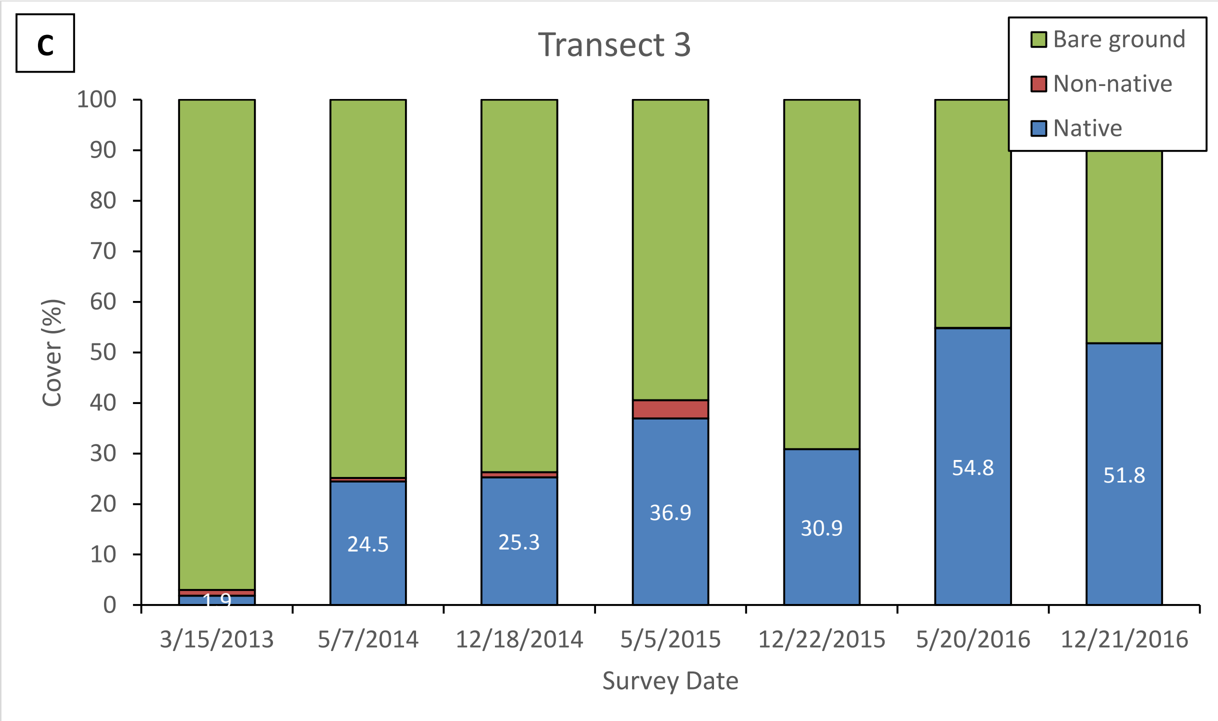



Figure 36. Graphs displaying absolute cover of vegetation across each Transect: (A) 1, (B) 2, and (C) 3.

### *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 1.25% cover in the most recent sampling period. Reductions or variability in non-native cover are likely the result of extensive weeding and non-native species removal efforts during monthly restoration events.

All transects have already met the non-native success criteria for Year 3 (i.e. < 10% cover) and all three are above the native vegetation cover success criteria (i.e. > 50%), with Transects 1 and 2 significantly over that criteria limit. One final monitoring year will be compared against the Year 5 success criteria for the vegetation cover requirements. Similarly, the CRAM biotic metric continued increasing in Year 3, supplementing the assessment that the vegetation cover continues to develop and become more complex over time. Continued observation and monitoring is recommended, and future supplemental plantings may be recommended in the area surrounding Transect 3 to increase the overall cover area.

The number and species richness of vegetation planted throughout the Lagoon is variable based on habitat, but over 67,000 individual plants of over 70 species were planted in total throughout the site, in addition to the areas that received hydroseeding treatments. Post-restoration surveys indicated a range of approximately 10 to 17 native plant species identified immediately adjacent to the transects (within about 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 37) 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, 22 December 2015, 16 May 2016, and 27 December 2016 (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 |

| | | | | |
|---|---|---|---|---|
| 16 May 2016 | Photo Point 1 | 155° | 7:20 AM | 1 |
| | Photo Point 2 | 300°, 75° | 7:34 AM | 2 |
| | Photo Point 3 | 220°, 100° | 7:47 AM | 2 |
| 27 December 2016 | Photo Point 1 | 155° | 8:37 AM | 1 |
| | Photo Point 2 | 300°, 75° | 8:41 AM | 2 |
| | Photo Point 3 | 220°, 100° | 8:45 AM | 2 |

Figure 37. 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 38 through 42 (A - G) 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 and fourth year surveys (May 2015, December 2015, May 2016, and December 2016) showed more subtle variations.

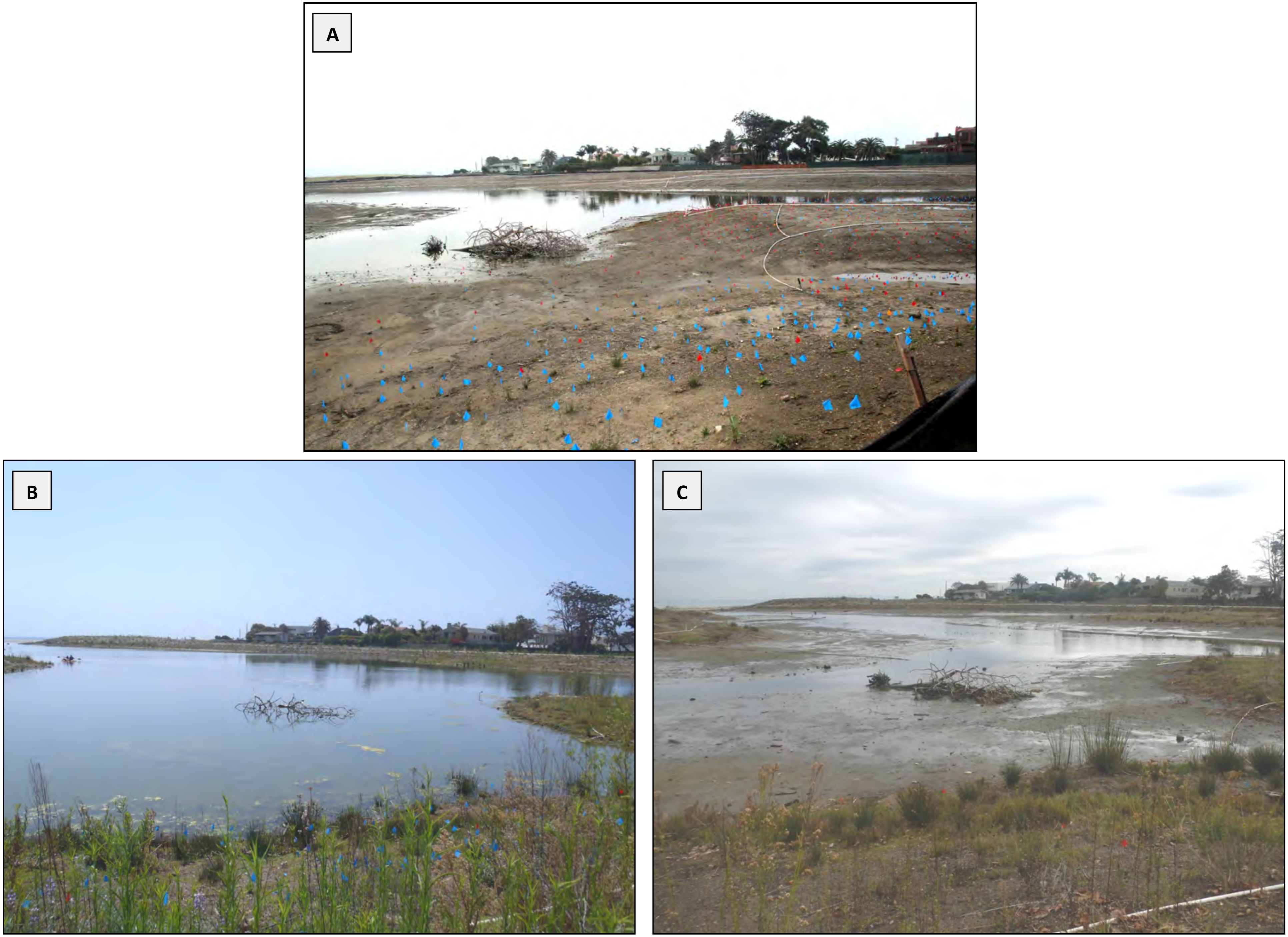


Figure 38. Photograph of Photo Point 1, bearing 155° on (A) 15 March 2013; (B) 7 May 2014; (C) 18 December 2014.

Figure 38 (*continued*). Photograph of Photo Point 1, bearing 155° on (D) 5 May 2015; (E) 22 December 2015; (F) 16 May 2016; (G) 27 December 2016.

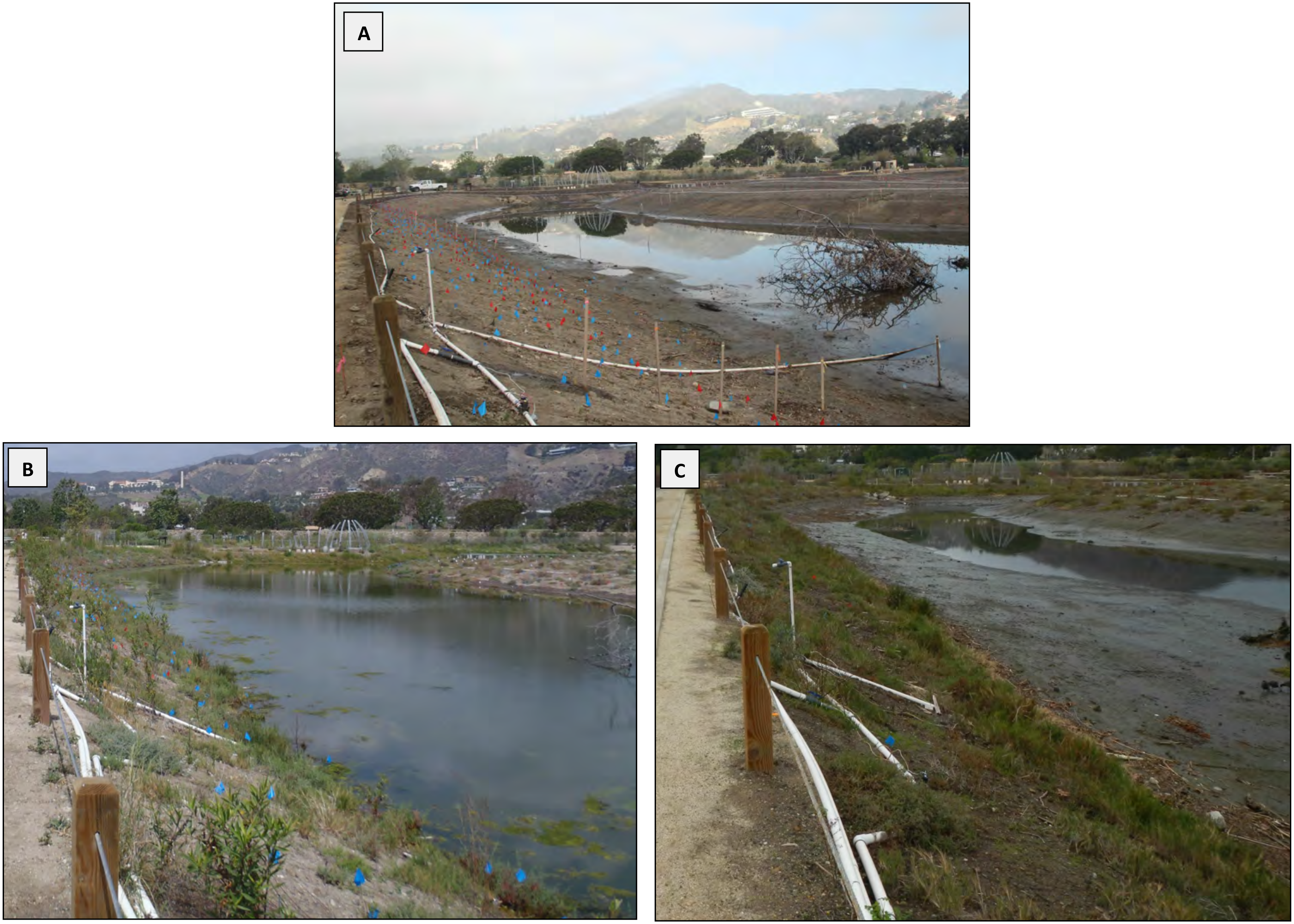



Figure 39. Photograph of Photo Point 2, bearing 300° on (A) 15 March 2013; (B) 7 May 2014; (C) 18 December 2014.

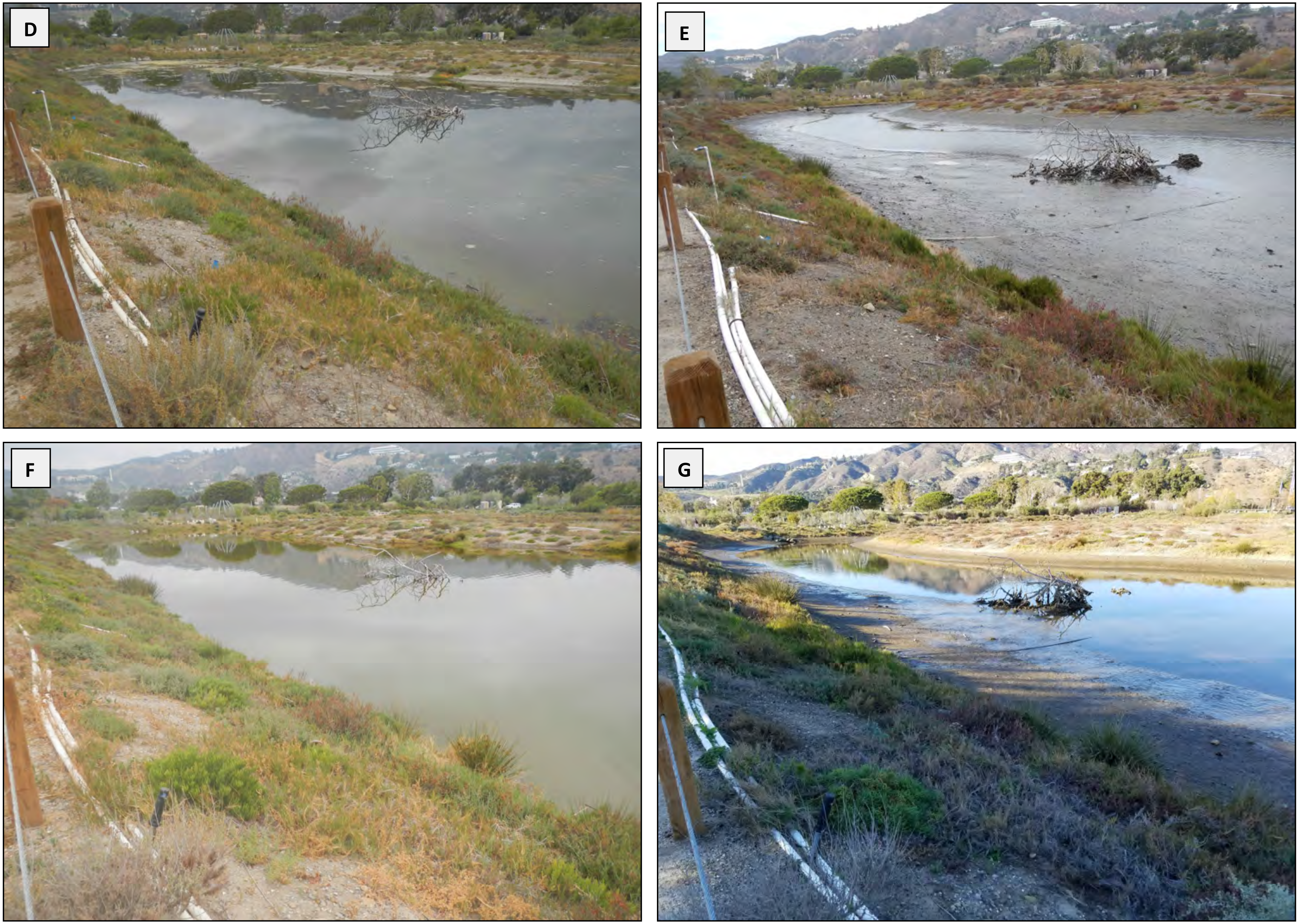



Figure 39 (*continued*). Photograph of Photo Point 2, bearing 300° on (D) 5 May 2015; (E) 22 December 2015; (F) 16 May 2016; (G) 27 December 2016.

Figure 40. Photograph of Photo Point 2, bearing 75° on (A) 15 March 2013; (B) 7 May 2014; (C) 18 December 2014.

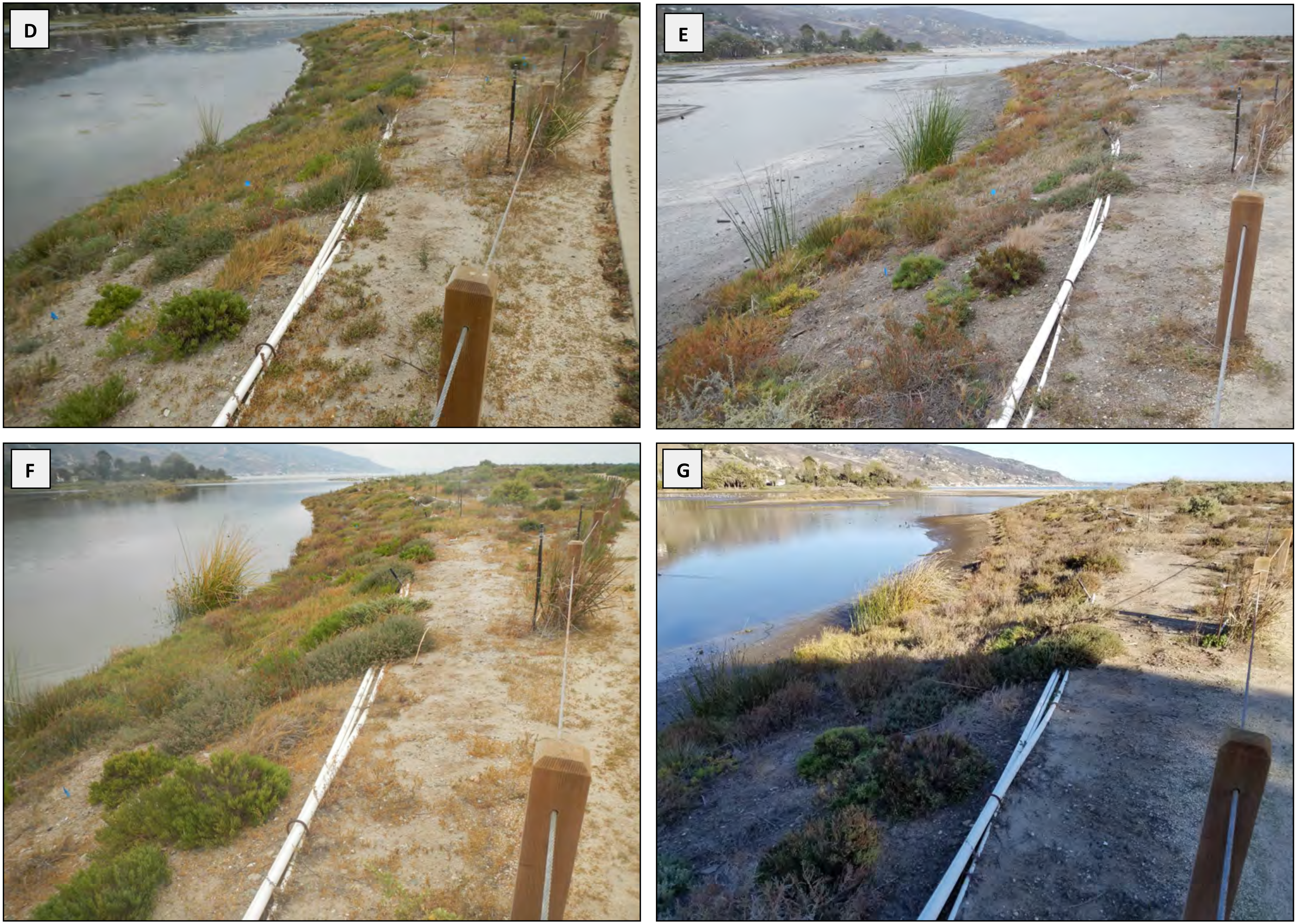


Figure 40 (*continued*). Photograph of Photo Point 2, bearing 75° on (D) 5 May 2015; (E) 22 December 2015; (F) 16 May 2016; (G) 27 December 2016.

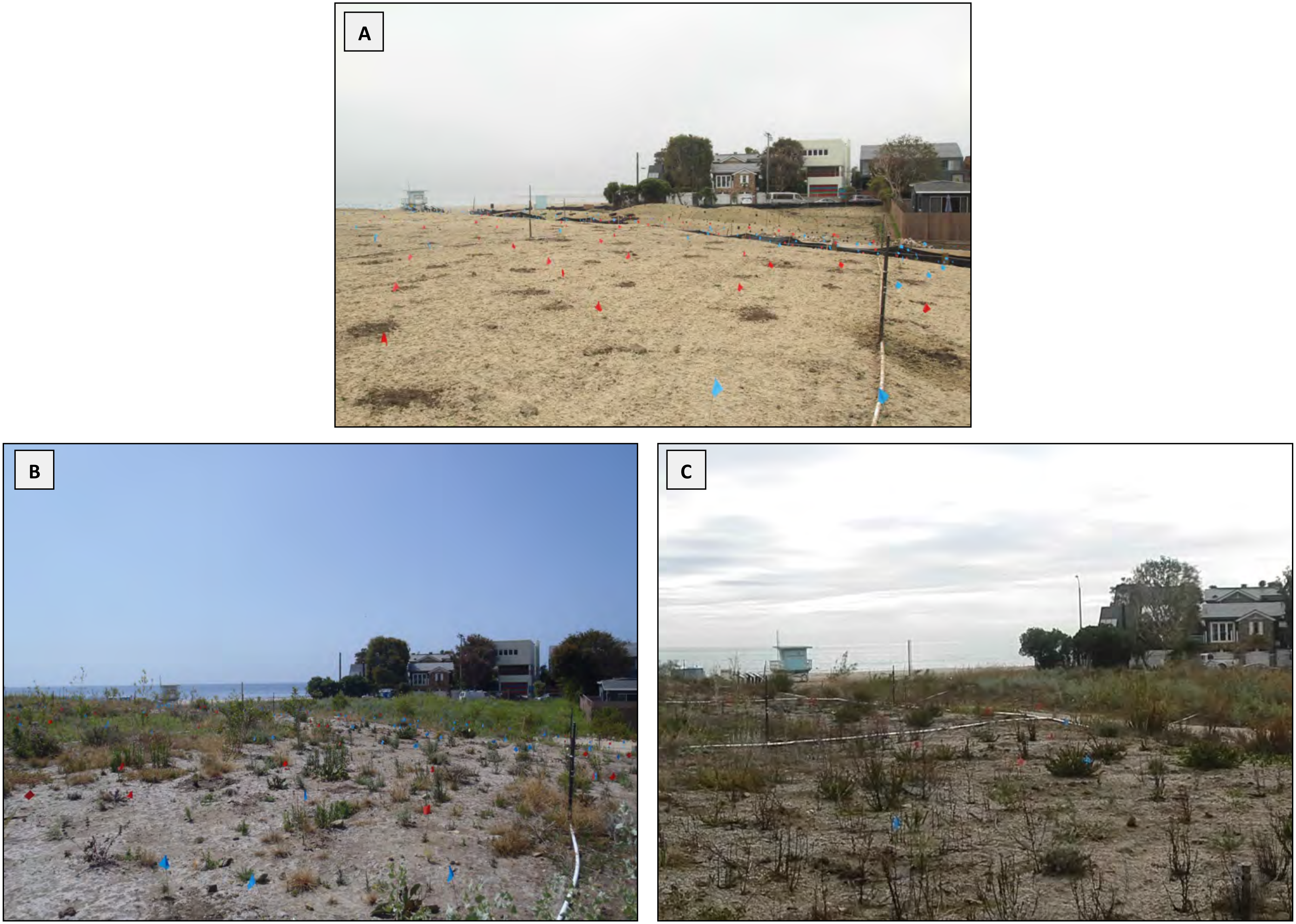



Figure 41. Photograph of Photo Point 3, bearing 220° on (A) 15 March 2013; (B) 7 May 2014; (C) 18 December 2014.

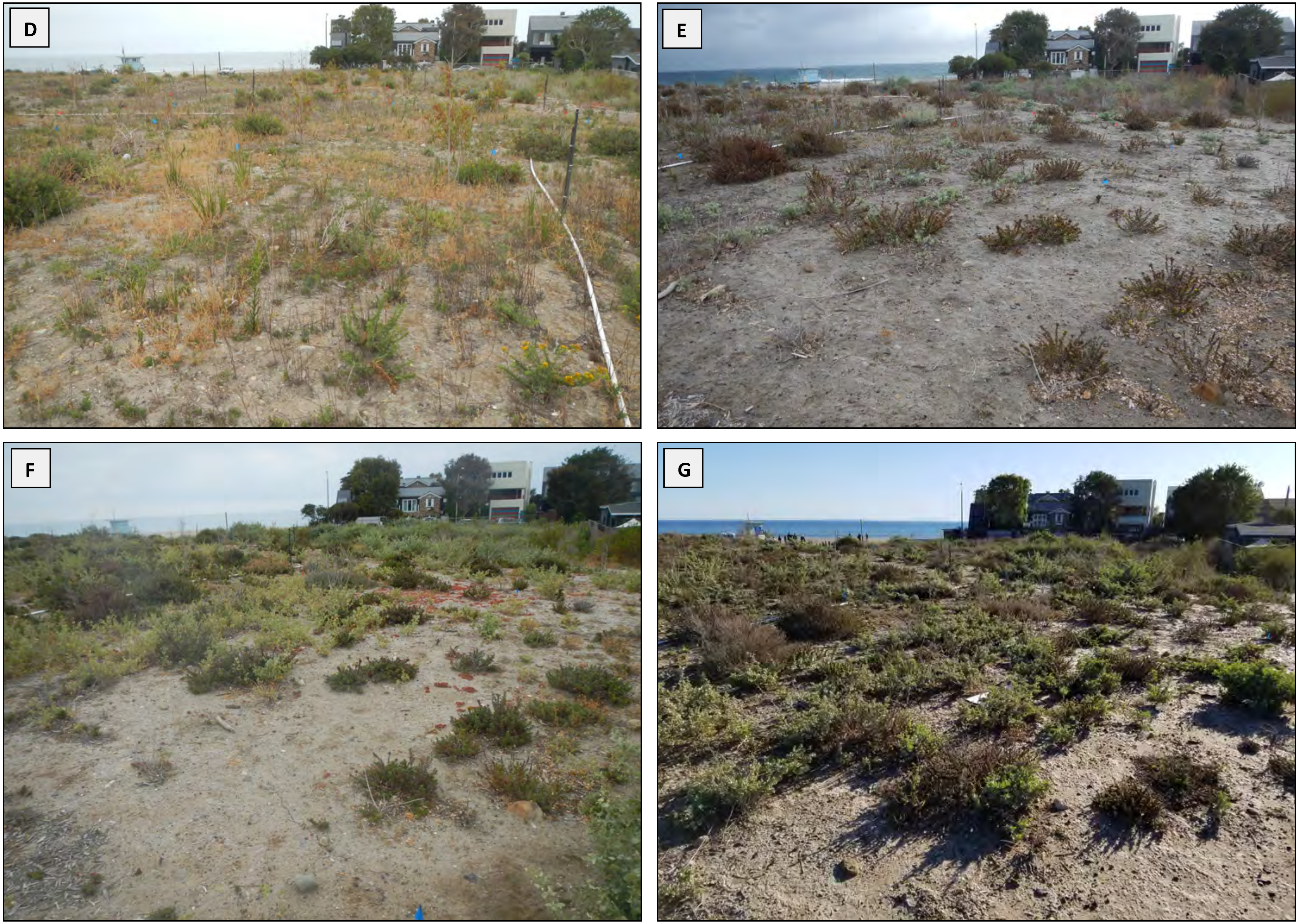



Figure 41 (*continued*). Photograph of Photo Point 2, bearing 220° on (D) 5 May 2015; (E) 22 December 2015; (F) 16 May 2016; (G) 27 December 2016.

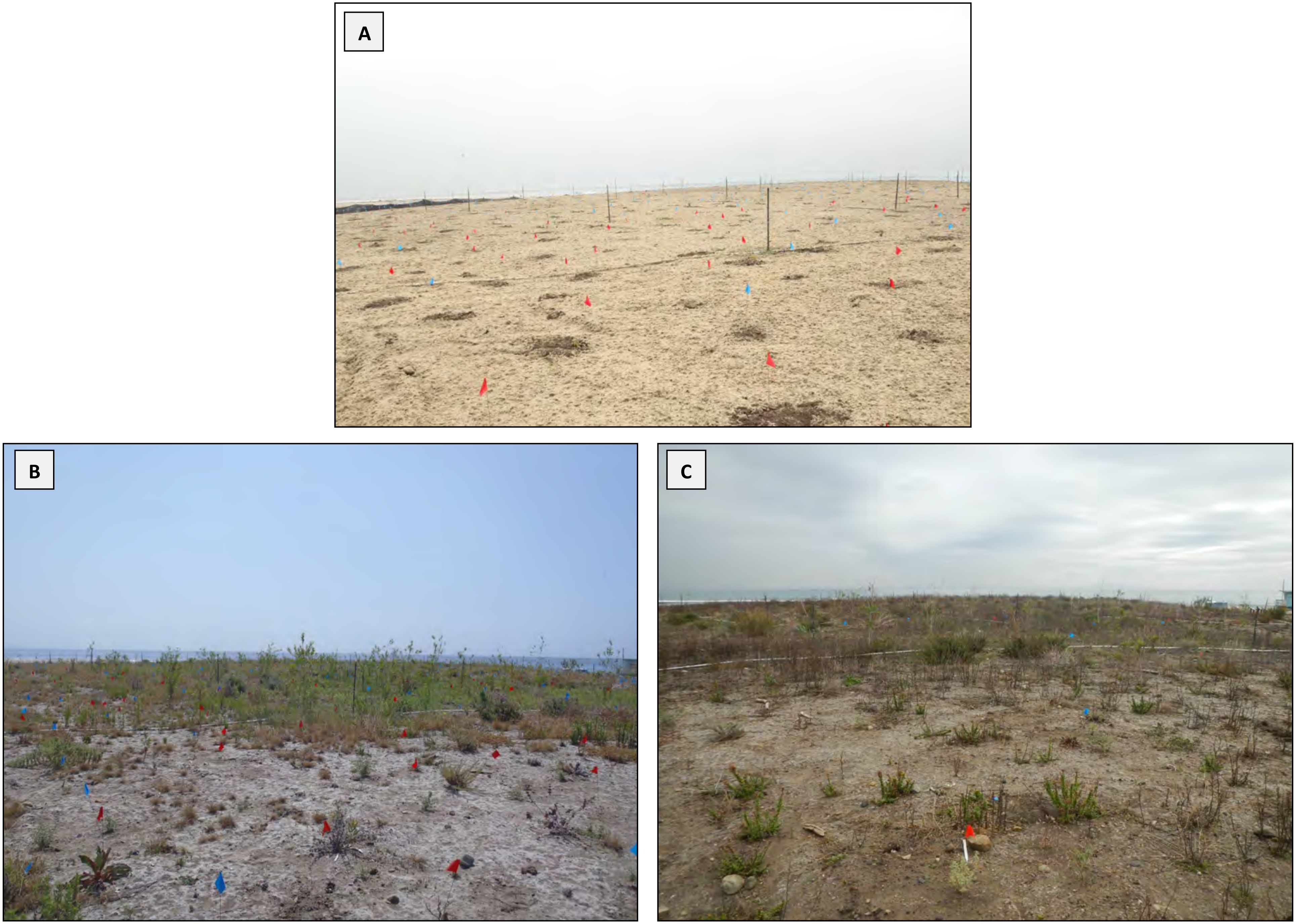



Figure 42. Photograph of Photo Point 3, bearing 100° on (A) 15 March 2013; (B) 7 May 2014; (C) 18 December 2014.

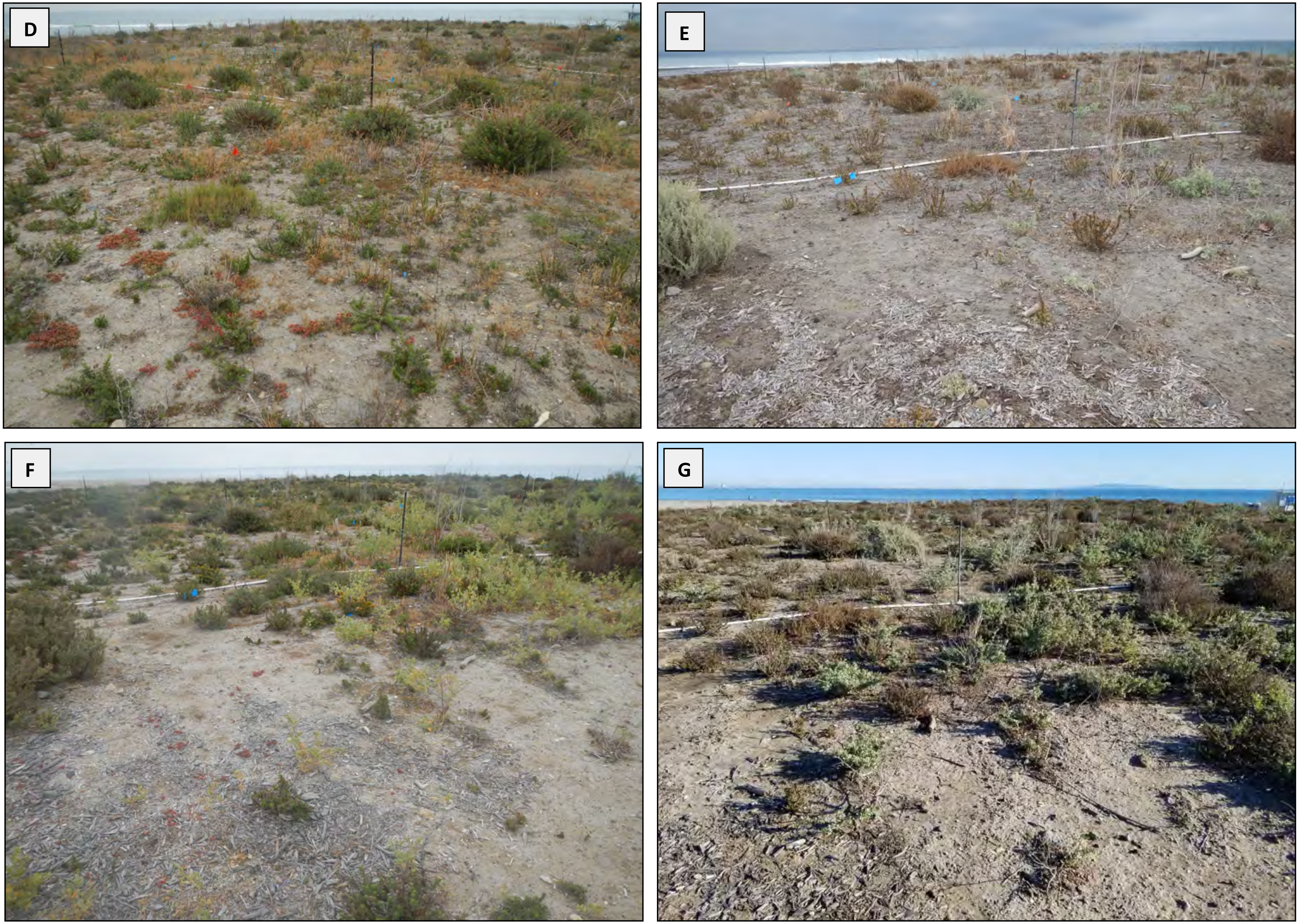



Figure 42 (*continued*). Photograph of Photo Point 2, bearing 100° on (D) 5 May 2015; (E) 22 December 2015; (F) 16 May 2016; (G) 27 December 2016.

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# Appendix 1. Malibu Lagoon Post-construction Fish Survey Results: June 2016 (Prepared by R. Dagit)

# Malibu Lagoon
# Post Construction Fish Survey June 2016

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

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

**June 2016**

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# EXECUTIVE SUMMARY

A post-construction fish survey of Malibu Lagoon was conducted on Tuesday, 1 June 2016 by a team from the RCD of the Santa Monica Mountains with assistance from CDPR and Santa Monica Bay Foundation staff.

Malibu Lagoon was open to the ocean between December 2015 and April 2016. The lagoon was closed and had overwashed on to the beach berm from the lagoon side during the 1 June survey.

A total of six permanent sites were seined to depletion. The lagoon water level registered just over seven feet elevation on the ramp. High tide was at 07:08 am. The moon was new and there was some evidence of potential tidal overflow to the lagoon. One site established for monitoring in 2013 (Site 4) continued to be inaccessible. We therefore continued to use site (2a) to comply with the monitoring plan requirements. In addition, we conducted spot surveys along the lagoon side of the beach berm. The east lagoon bank from just above the PCH bridge to the beach was not accessible due to high water levels. There was almost no algal cover but the bank vegetation is filling in nicely.

A total of 17 federally endangered tidewater gobies (*Eucyclogobius newberryi)* were captured and concentrated primarily along the lagoon/beach face. Striped mullet (*Mugil cephalus*) were observed jumping throughout the lagoon. The dominant species surveyed and identified was Topsmelt (*Atherinops affinis*, adult n=133, larvae n= 1289), although quite a few longjaw mudsuckers (*Gillichthys mirabilis*) of all age classes (n=63) and a few other species were observed. We were happy to also find both adult and juvenile staghorn sculpin (*Leptocottus armatus*), as well as juvenile flatfish (*Hypsopsetta guttulata* and *Paralichthys californicus*).

Species captured or observed during the January 2016 survey include:

**Native Fish Species**

| | |
|---|---|
| Tidewater goby | *Eucyclogobius newberryi* |
| Topsmelt | *Atherinops affinis* |
| Northern Anchovy | *Engraulis mondax* |
| Staghorn sculpin | *Leptocottus armatus* |
| Striped mullet | *Mugil cephalus* |
| CA Halibut | *Paralichthys californicus* |
| Diamond Turbot | *Hypsopsetta guttalata* |
| Longjawed mudsucker | *Gillithys mirabilis* |
| CA Killifish | *Fundulus parvipinnis* |
| Unidentified smelt 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, Jamie King, and Danielle LeFer, CDPR for their assistance. The contract for this work was provided by CDPR. State Park also provided Nick Chang, Dayana Doroteo, and Geovanni De Leon to help with the seining. Rod Abbot and Viktoria Kuehn from the Santa Monica Bay Foundation were also most helpful.

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
Jen Mongolo, Conservation 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. In 2016, the lagoon was surveyed closed in January and open in June.

### 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.

The 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.

This sixth survey occurred on 1 June 2016 with the lagoon closed and quite full (elevation registered over seven feet on the ramp), with overspill onto the beach berm, which has not been observed previously. The water reached a maximum depth of 20 cm on the beach berm, and it is also possible that high tides overwashed and connected as well. Weather was overcast with no wind.

# METHODS

A. Blocking Net Sampling Method for Permanent Stations
A meter tape was laid out along the shoreline at the water's 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 water's 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 (3)
- buckets (8)
- 30 m tape
- data sheets
- ice chest for voucher specimens
- hand sanitizer

-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 |

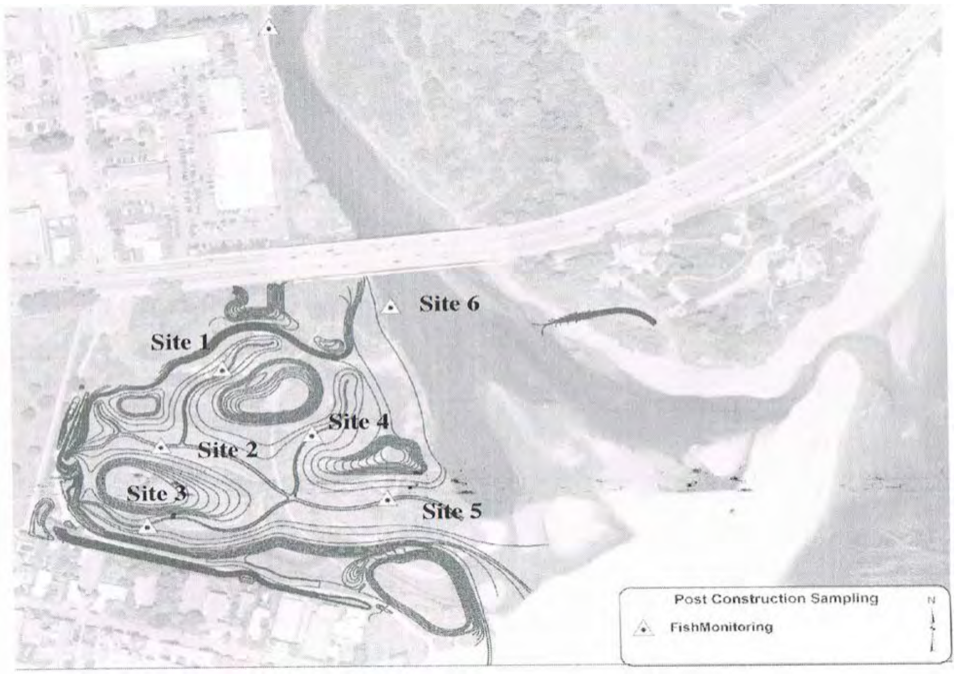



**Figure 1. Map of the Permanent Monitoring Sites, Malibu Lagoon Restoration (Established in January 2013 and revised in May 2014)**


**Figure 2. Locations of spot surveys 1 June 2016**

# RESULTS

Table 2 summarizes the water quality conditions documented during the seines.

Table 2. Water Quality and site conditions at the permanent monitoring sites 1 June 2016

| Variable | Site 1 | Site 2 | Site 2a | Site 3 | Site 5 | Site 6 |
|---|---|---|---|---|---|---|
| Avg depth (cm) | 45 | 70 | 20 | 80 | 50 | 20 |
| Water T ($^{o}$C) | 21.8 | 22.9 | 22.6 | 22.8 | 23.3 | 23.0 |
| Air T ($^{o}$C) | 18.0 | 21.5 | 18.0 | 23.0 | 26.5 | 19.0 |
| Salinity ppt | 10 | 11 | 10 | 11 | 12 | 11 |
| DO mg/l | 5.7 | 5.17 | 9.44 | 3.64 | 5.3 | 4.04 |
| pH | 9.0 | 9.03 | 9.07 | 9.0 | 9.0 | 9.0 |
| 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 | 60 | 0 | 100 | 100 | 100 |
| Emergent Vegetation type | Jaumea, Distichlis, Salicornia, Juncus | Jaumea, Distichlis, Salicornia | NA | Jaumea, Distichlis, Salicornia, Juncus | Jaumea, Distichlis. Salicornia, Juncus | Jaumea, Distichlis. Salicornia |
| Dominant Substrate | Sand and silt | Sand and silt | Sand and cobble | Sand and silt | Sand | Sand and cobble |
| Time start | 10:08 | 11:13 | 10:31 | 12:25 | 13:10 | 9:30 |

The dominant identifiable fish species captured in seine nets was larval smelt (n= 1289). The second dominant species was topsmelt (6-16 cm). Tidewater goby juveniles under 5 cm (n=17cm), five staghorn sculpin (5-10cm), Long-jaw mudsuckers (n=63), and one juvenile California Killifish were captured and released. We also captured two species of flatfish, Diamond Turbot (n=5) and California Halibut (n=1). Striped mullet were observed leaping throughout the lagoon. Although not numerous, non-natives mosquitofish (n=10) and Mississippi silversides (n=16) were also present.

Table 3. Summary of Fish and Invertebrates captured/observed 1 June 2016

| **Lagoon-ocean connection conditions** | **OPEN** | **Site 1** | **Site 2** | **Site 2a** | **Site 3** | **Site 5** | **Site 6** | **Spot "east beach by adamson house"** | **Spot "5 beach center"** | **Spot "6 beach center"** | **Spot 7** | **Spot 8** | **TOTALS** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Seine pull total to depletions** | | 9 | 34 | 42 | 32 | 26 | 22 | 9 | 3 | 6 | 6 | 2 | 191 |
| **Native Fish Species** | | | | | | | | | | | | | |
| Steelhead trout | *Onchorhynchus mykiss* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tidewater goby (<5 cm) | *Eucyclogobius newberryi* | 0 | 0 | 0 | 1 | 0 | 0 | 7 | 7 | 0 | 2 | 0 | 17 |
| Tidewater goby adult (6-8 cm) | *Eucyclogobius newberryi* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CA Halibut | *Paralichthys californicus* | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| CA killifish juvenile (<5cm) | *Fundulus parvipinnis* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Long-jaw mudsucker (<5 cm) | *Gillichthys mirabilis* | 2 | 0 | 0 | 6 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 11 |
| Long-jawed mudsucker (5-10 cm) | *Gillichthys mirabilis* | 4 | 2 | 1 | 3 | 1 | 8 | 27 | 4 | 2 | 0 | 0 | 52 |
| Topsmelt larva (<5 cm) | *Atherinops affinis* | 6 | 3 | 591 | 3 | 151 | 12 | 99 | 25 | 170 | 49 | 180 | 1289 |
| Topsmelt juvenile (6-15 cm) | *Atherinops affinis* | 8 | 69 | 6 | 19 | 7 | 3 | 6 | 8 | 1 | 3 | 3 | 133 |
| Staghorn sculpin (5-10 cm) | *Leptocottus armatus* | 0 | 1 | 0 | 1 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 5 |
| Diamond turbot | *Hypsopsetta guttulata* | 0 | 1 | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 5 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Northern anchovy ( <5 cm) | *Engraulis mordax* | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Unidentified larva (<1cm) | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 3 |
| **Non-Native Fish Species** | | | | | | | | | | | | | |
| Mosquitofish juveniles (<5cm) | *Gambusia affinis* | 0 | 0 | 0 | 8 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| Mississippi silversides | *Menida audens* | 1 | 1 | 0 | 0 | 4 | 10 | 0 | 0 | 0 | 0 | 0 | 16 |
| | | | | | | | | | | | | | |
| **Invertebrates** | | | | | | | | | | | | | |
| Oriental shrimp | *Shrimp sp.* | 0 | 0 | 0 | 17 | 9 | 31 | 0 | 0 | 0 | 1 | 0 | 58 |
| Hemigraspus crabs | | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

**SUMMARY**

The June 2016 post-construction fish survey was completed in one day with a team of 12 people.

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

Overall fish diversity and abundance in June 2016 was quite high and representatives of both common and uncommon species were captured, including Tidewater gobies. 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. The presence of both CA Halibut and diamond turbot indicated that spawning and rearing of these commercially important species is occurring.

Table 4. Summary of Fish and Invertebrates captured/observed 2005 – 2016

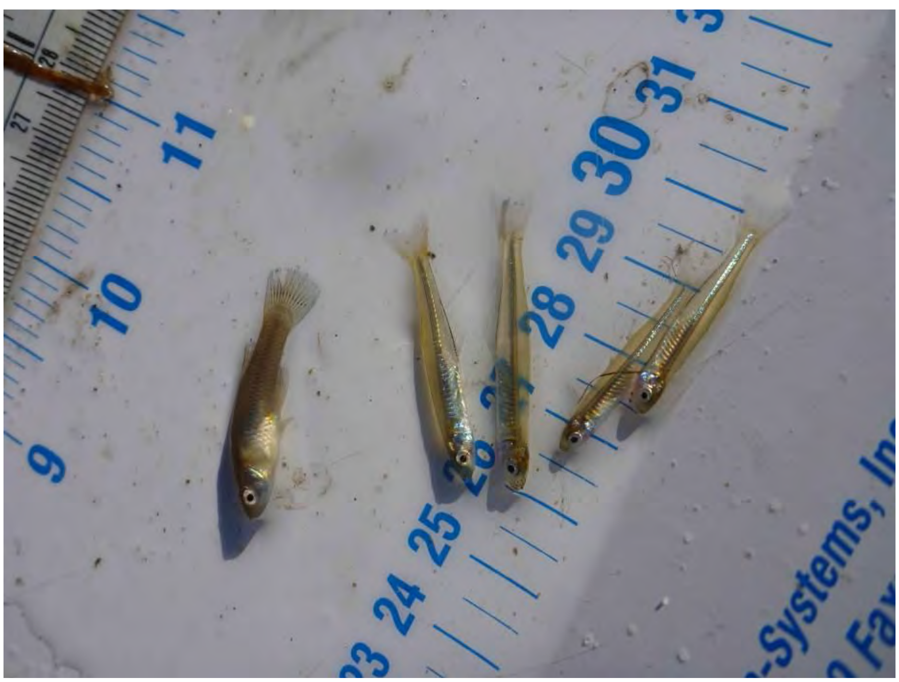
| | | **Survey** | **Relocation** | **Survey** | **Survey** | **Survey** | **Survey** | **Survey** | **Survey** |
|---|---|---|---|---|---|---|---|---|---|
| | | **6/1/05** | **June 2012** | **1/8/13** | **5/15/14** | **12/11/14** | **5/27/15** | **1/12/16** | **6/1/16** |
| | | **open** | **open** | **open** | **closed** | **open** | **closed** | **open** | **closed** |
| **Native Fish Species** | | | | | | | | | |
| Steelhead trout | *O.mykiss* | | | | 1 observed | | | | |
| Unidentified goby larva (<5 cm) | | | 2 | | 500~ | | | | 0 |
| Tidewater goby juveniles (<5cm) | *Eucyclogobius newberryi* | | | | 13 | | | | 17 |
| Tidewater goby adult (6-8 cm) | *Eucyclogobius newberryi* | 473 | 8 | | 0 | | 41 | | 0 |
| Arrow goby (<5 cm) | *Cleavlandia ios* | | | | 5 | | | | 0 |
| Bay goby? | *Lepidogobius lepidus* | | | | 2 | | | | 0 |
| CA Halibut | *Paralichthys californicus* | | | | | | | | 2 |
| CA killifish juveniles (<5cm) | *Fundulus parvipinnis* | | 306 | | 0 | | | | 1 |
| CA killifish (5-10 cm) | *Fundulus parvipinnis* | 46 | 16 | | 5 | | | | 0 |

| | | Survey | Relocation | Survey | Survey | Survey | Survey | Survey | Survey |
|---|---|---|---|---|---|---|---|---|---|
| | | **6/1/05** | **June 2012** | **1/8/13** | **5/15/14** | **12/11/14** | **5/27/15** | **1/12/16** | **6/1/16** |
| | | **open** | **open** | **open** | **closed** | **open** | **closed** | **open** | **closed** |
| Long-jawed mudsucker (<5 cm) | *Gillichthys mirabilis* | 1 | 8 | | 5 | | 3 | | 11 |
| Long-jawed mudsucker (5-10 cm) | *Gillichthys mirabilis* | | 11 | | | | 22 | 5 | 52 |
| Topsmelt larva (<5 cm) | *Atherinops sp* | | 1 | 3 | | | 176 | 6 | 1289 |
| Topsmelt juvenile (6-10 cm) | *Atherinops sp* | 244 | 0 | | 24 | | 60 | | 133 |
| Topsmelt adult (>16 cm) | *Atherinops sp* | | 0 | | | | 6 | | 0 |
| Unidentified smelt larva (<5 cm) | *Atherinops sp* | | 101 | | 15,293 | | 2244 | 64 | |
| Staghorn sculpin (<5 cm) | *L. armatus* | | | 17 | 11 | | | 1 | |
| Staghorn sculpin (5-10 cm) | *L.armatus* | | 3 | | | | | | 5 |
| Opaleye perch | *Girella nigricans* | | | | | | | | |
| Diamond turbot | *Hypsopsetta guttulata* | | | 7 | 1 | | | | 5 |
| Garabaldi (28 cm FL) dead dropped by birds | *Hypsypops rubicundus* | | | | | | | | |
| Northern anchovy (<5 cm) | *Engraulis mordax* | | 5 | | | | | 180 | 1 |
| Striped mullet | *Mugil cephalus* | observed | | observed | observed | 7 | 1 | | observed |
| Unidentified fish larva | | | | | | | 991 | | 3 |
| **Non-Native Fish Species** | | | | | | | | | |
| Mosquitofish Juveniles (<5cm) | *Gambusia affinis* | | | | | | 13 | 6 | 10 |
| Mosquitofish Adults (5-10cm) | *Gambusia affinis* | 65 | 4072 | | | 2 | 3 | | |
| Carp | *Cyprinus carpio* | 1 | | | observed | | | | |
| Mississippi silversides | *Menida audens* | | | 1 | 0 | 970 | 9 | 15 | 16 |

| | | Survey | Relocation | Survey | Survey | Survey | Survey | Survey | Survey |
|---|---|---|---|---|---|---|---|---|---|
| | | **6/1/05** | **June 2012** | **1/8/13** | **5/15/14** | **12/11/14** | **5/27/15** | **1/12/16** | **6/1/16** |
| | | **open** | **open** | **open** | **closed** | **open** | **closed** | **open** | **closed** |
| **Invertebrates** | | | | | | | | | |
| Oriental shrimp | *Palaemonetes sp.* | | | 37 | 209 | 43 | 10 | 5 | 58 |
| Hemigraspus crabs | | | | | 8 | 1 | 20 | 1 | 1 |
| Water boatman juveniles | | | 6000+ | | 2504 | | | | |
| Amphipods | | | 2500+ | | | | | | |
| Isopods | | | 2500+ | | | | | | |
| Ctenophore sp. (<2 cm) | | | | 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

Longjaw mudsucker (top) and Tidewater goby (bottom)

CA Halibut

Diamond turbot


Staghorn sculpin

# Appendix B. Site Photos


**Site 1**

**Site 2**

**Site 2a**

**Site 3**

**Photo missing**
**Site 5**

**Site 6**

**View east showing beach overwashed by lagoon**

**View east showing overwash by lagoon.**

**List of coordinates for spot seines**

| Spot | Coordinates |
|---|---|
| 1-4 | 118°40'44.22"W, 34°2'2.58"N |
| 5 | 118°40'44.34"W, 34°2'1.38"N |
| 6 | 118°40'45.42"W, 34°1'59.4"N |
| 7 | 118°40'47.34"W, 34°1'58.5"N |
| 8 | 118°40'48.94"W, 34°1'56.68"N |

# Appendix 2. Malibu Lagoon Post-construction Fish Survey Results: March 2017 (Prepared by R. Dagit)

# Malibu Lagoon
# Post Construction Fish Survey March 2017

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

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

**March 2017**

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# EXECUTIVE SUMMARY

A post-construction fish survey of Malibu Lagoon was conducted on Friday 3 March 2017 by a team from the RCD of the Santa Monica Mountains with assistance from CDPR, Santa Monica Bay Foundation staff, USFWS staff, Dr. Sabrina Drill and volunteers Andrew Burgess and Steve Howard.

Malibu Lagoon was open to the ocean since 28 November 2016. A series of strong storm events between January and February have maintained a wide breach connection, allowing the entire lagoon to ebb and flow with the tides. It was difficult to find a suitable time to conduct the survey as the almost weekly rain events forced postponement since January, and in fact there was a small rain event just four days prior to the survey.

A total of six permanent sites were seined to depletion. Due to the shallow, reduced condition of the lagoon even during high tide, it was not possible to utilize the normal method at site 1, and instead of a triangle, the blocking nets spanned the entire channel. The lagoon water level was below the level that could register on the ramp, even at high tide. High tide was at 12:52 pm (3.5' elevation) and the moon was new. Site 4, established for monitoring in 2013, continued to be inaccessible. We therefore continued to use site (2a) to comply with the monitoring plan requirements. In addition, we conducted a spot survey near the tree snag by site 3. There was almost no algal cover but the bank vegetation is filling in nicely.

A total of 12 federally endangered tidewater gobies (*Eucyclogobius newberryi)* were captured in several sites. Due to time constraints, we did not conduct spot surveys along the beach. Striped mullet (*Mugil cephalus*) were observed jumping throughout the lagoon. The dominant species surveyed and identified was staghorn sculpin (*Leptocottus armatus, juveniles =132*), followed by topsmelt (*Atherinops affinis,* adult n=49, juvenile n= 35). Only two juvenile longjaw mudsuckers (*Gillichthys mirabilis*) were observed and a single juvenile CA Killifish (*Fundulus parvipinnis*).

Species captured or observed during the March 2017 survey include:

| | |
|---|---|
| **Native Fish Species** | |
| Tidewater goby | *Eucyclogobius newberryi* |
| Topsmelt | *Atherinops affinis* |
| Staghorn sculpin | *Leptocottus armatus* |
| Striped mullet | *Mugil cephalus* |
| Longjawed mudsucker | *Gillithys mirabilis* |
| CA Killifish | *Fundulus parvipinnis* |
| **Non-Native Fish Species** | |
| Mosquitofish | *Gambusia affinis* |
| **Invertebrates** | |
| Oriental shrimp | *Palaemonetes sp.* |
| Hemigraspus crab | *Hemigraspus sp.* |
| Red Swamp Crayfish | *Procambarus clarkii* |

## ACKNOWLEDGEMENTS

We wish to thank Suzanne Goode, Jamie King, and Danielle LeFer, CDPR for their assistance. The contract for this work was provided by CDPR. Kendra Chan, biologist with US Fish and Wildlife Service, Rod Abbot and Melodie Grubbs from the Santa Monica Bay Foundation, Dr. Sabrina Drill and Andrew Burgess, and Steve Howard of R2 Resource Consultants were also most helpful.

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:

Danielle Alvarez, Stream Team
Garrett Nichols, Stream Team
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## 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. Thus far in 2017, the lagoon was surveyed open in March.

### 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.

The 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.

The sixth survey occurred on 1 June 2016 with the lagoon closed and quite full (elevation registered over seven feet on the ramp), with overspill onto the beach berm, which has not been observed previously. The water reached a maximum depth of 20 cm on the beach berm, and it is also possible that high tides overwashed and connected as well. Weather was overcast with no wind.

The seventh survey took place on 3 March 2017, after two months of efforts to fit in a survey between multiple storm events. The lagoon was open, and fully drained. Even with the incoming tide rising during the sampling event, water levels remained below the level on the ramp and the high tide at 12:52 pm was only 3.5'. The weather was sunny, with high upper level clouds increasing along with the westerly wind during the day. Air temperatures were in the 60's F.

## METHODS

A. Blocking Net Sampling Method for Permanent Stations

A meter tape was laid out along the shoreline at the water's 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 water's 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.

Due to low water levels, for site 1 we blocked the channel from bank to bank 10 m apart instead of making a triangle, and fished inside that area.

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 (3)
- buckets (8)
- 30 m tape
- data sheets
- ice chest for voucher specimens
- hand sanitizer

-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 |

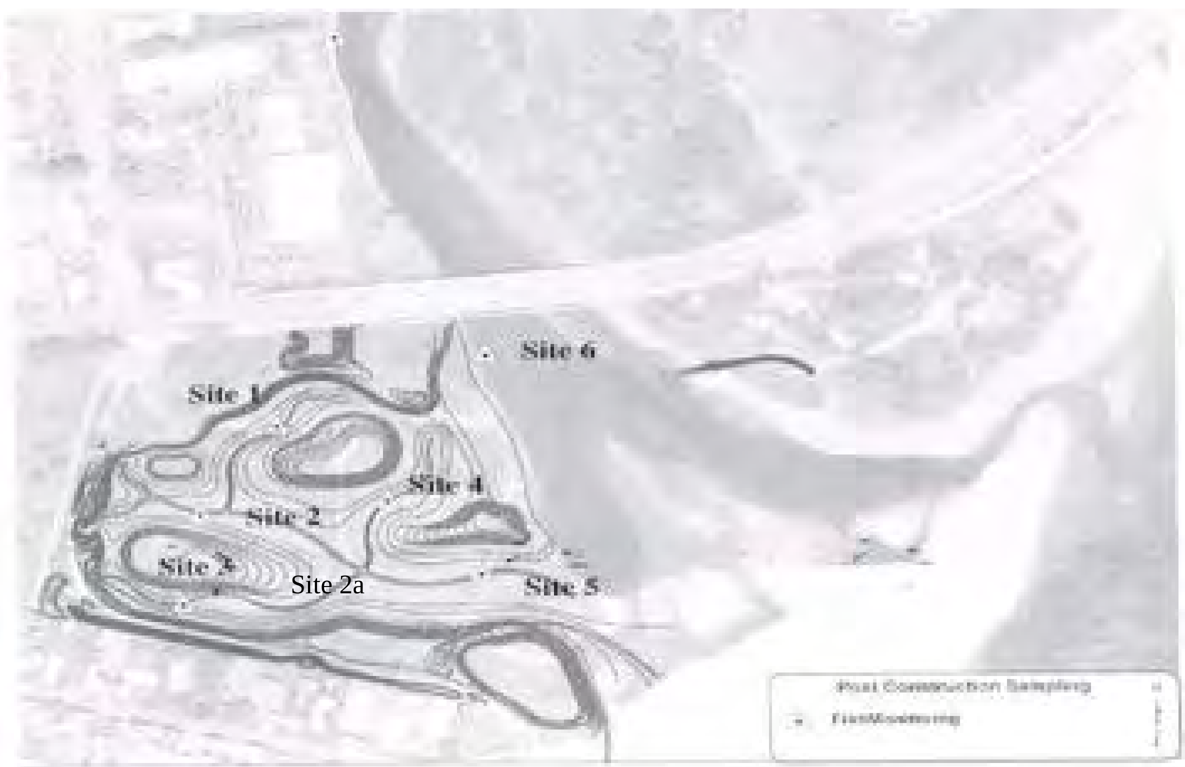



**Figure 1. Map of the Permanent Monitoring Sites, Malibu Lagoon Restoration (Established in January 2013 and revised in May 2014)**

# RESULTS

Table 2 summarizes the water quality conditions documented during the seines.

Table 2. Water Quality and site conditions at the permanent monitoring sites 3 March 2017

| Variable | Site 1 | Site 2 | Site 2a | Site 3 | Site 5 | Site 6 |
|---|---|---|---|---|---|---|
| Avg depth (cm) | 60 | 50 | 30 | 45 | 45 | 60 |
| Water T ($^o$C) | 23.6 | 19.2 | 20.3 | 20.4 | 14.1 | 16.4 |
| Air T ($^o$C) | 20.0 | 20.0 | 20.0 | 21.0 | 20.0 | 20.0 |
| Salinity ppt | 2 | 5 | 4 | 2 | 4 | 1 |
| DO mg/l | 8.05 | 15.44 | 17.25 | 10.53 | 9.5 | 7.55 |
| pH | 7.88 | 9.03 | 9.28 | 8.95 | 9.0 | 9.08 |
| Conductivity | 3 | 7.9 | 6.8 | 8.3 | 7.1 | 3.3 |
| % Floating Algae cover | 0 | 0 | 0 | 0 | 0 | 0 |
| % Submerged/ Attached Algae cover | 0 | 0 | 0 | 0 | 0 | 0 |
| % emergent vegetation bank cover | 0 | 0 | 0 | 0 | 0 | 0 |
| Emergent Vegetation type | NA | NA | NA | NA | NA | NA |
| Dominant Substrate | Sand and silt, muck | Sand and silt, muck | Sand and cobble | Sand and silt, muck | Sand and silt, muck | Sand and cobble |
| Time start | 14:40 | 13:00 | 13:55 | 11:15 | 09:40 | 15:05 |

All sites had variable layers of organic muck decomposing that made movement through the blocked area challenging and in the case of site 1, the amount of muck in the net resulted in anoxic conditions for the fish. The dominant identifiable fish species captured in seine nets was staghorn sculpin (<5 cm).The second dominant species was topsmelt (6-16 cm). Tidewater goby juveniles under 5 cm (n=12), two Long-jaw mudsuckers and one juvenile California Killifish were captured and released. Striped mullet were observed leaping throughout the lagoon. Only a single non-native mosquitofish and a single adult male crayfish were also present.  Cadis fly tubes were observed at all sites but were extremely numerous in site 2.

Table 3. Summary of Fish and Invertebrates captured/observed 3 March 2017

| Lagoon-ocean connection conditions | OPEN | Site 1 | Site 2 | Site 2a | Site 3 | Site 5 | Site 6 | Spot 1-tree snag by site 3 | TOTALS |
|---|---|---|---|---|---|---|---|---|---|
| **Seine pull total to depletions** | | 2 | 11 | 10 | 12 | 15 | 14 | 1 | |
| **Native Fish Species** | | | | | | | | | |
| Steelhead trout | *Onchorhynchus mykiss* | | | | | | | | 0 |
| Unidentified goby larva (<5 cm) | | | | | | | | | 0 |
| Tidewater goby (<5 cm) | *Eucyclogobius newberryi* | 3 | 3 | | | | | 6 | 12 |
| Tidewater goby adult (6-8 cm) | *Eucyclogobius newberryi* | | | | | | | | 0 |
| Arrow goby (<5 cm) | *Cleavlandia ios* | | | | | | | | 0 |
| Bay goby? | *Lepidogobius lepidus* | | | | | | | | 0 |
| CA Halibut | *Paralichthys californicus* | | | | | | | | 0 |
| CA killifish juveniles (<5cm) | *Fundulus parvipinnis* | 1 | | | | | | | 1 |
| CA killifish juveniles (5-10 cm) | *Fundulus parvipinnis* | | | | | | | | 0 |
| Long-jawed mudsucker (<5 cm) | *Gillichthys mirabilis* | | 2 | | | | | | 2 |
| Long-jawed mudsucker (5-10 cm) | *Gillichthys mirabilis* | | | | | | | | 0 |
| Topsmelt larva (<5 cm) | *Atherinops affinis* | 35 | | | | | | | 35 |
| Topsmelt juvenile (6-15 cm) | *Atherinops affinis* | 48 | | | | | | | 48 |
| Topsmelt adult (>15 cm) | *Atherinops affinis* | | | | | | | | 0 |
| Unidentified smelt larva (<5 cm) | *Atherinops sp* | | | | | | | | 0 |
| Staghorn sculpin (<5 cm) | *Leptocottus armatus* | 7 | 49 | 36 | 9 | 17 | 10 | 2 | 130 |
| Staghorn sculpin (5-10 cm) | *Leptocottus armatus* | | 3 | 1 | | | | | 4 |
| Opaleye | *Girella nigricans* | | | | | | | | 0 |
| Diamond turbot | *Hypsopsetta guttulata* | | | | | | | | 0 |
| Northern anchovy <5 cm | *Engraulis mordax* | | | | | | | | 0 |
| striped mullet | *Mugil cephalus* | | | | | | | | 0 |
| Unidentified larva (<1cm) | | | | | | | | | 0 |
| **Non-Native Fish Species** | | | | | | | | | 0 |
| Mosquitofish juveniles (<5cm) | *Gambusia affinis* | | | | 1 | | | | 1 |
| Mosquitofish adults (5-10 cm) | *Gambusia affinis* | | | | | | | | 0 |
| Carp | *Cyprinus carpio* | | | | | | | | 0 |
| Mississippi silversides | *Menida audens* | | | | | | | | 0 |
| | | | | | | | | | 0 |
| **Invertebrates** | | | | | | | | | 0 |
| Oriental shrimp | *Shrimp sp.* | 6 | 12 | 51 | 10 | 1 | 8 | 1 | 89 |
| Hemigraspus crabs | | | | 2 | | | | | 2 |
| Water boatman juveniles | | | | | | | | | 0 |
| Amphipods | | | | | | | | | 0 |
| Isopods | | | | | | | | | 0 |
| Ctenophore sp (<2 cm) | | | | | | | | | 0 |
| Salp sp (<2 cm) | | | | | | | | | 0 |
| Sea hare (5-10 cm) | *Aplysia californica* | | | | | | | | 0 |
| Segmented worm <2 cm) | | | | | | | | | 0 |
| Barnacles | | | | | | | | | 0 |
| Gastropoda | | | | | | | | | 0 |
| Crayfish | | | | 1 | | | | | 1 |
| | | | | | | | | | |
| Notes: | | | Lots of caddis fly tubes | | | | | | |

**SUMMARY**

The March 2017 post-construction fish survey was completed in one day with a team of 12 people.

Table 4 provides a summary comparing abundance of species documented in Malibu Lagoon prior to restoration (2005), species relocated during restoration (2012), and seven post-construction surveys (2013-2017).

A total of six native fish species were observed in March 2017, and given the extremely low water levels in the lagoon and the intense pulses of recent storm surges, including a flash flood event in January, it was good to identify which species were able to remain and reproduce. Almost all the fish captured were juveniles under 5 cm fork length and indicative of recent successful reproduction. This was especially true for the staghorn sculpins, topsmelt, and tidewater gobies, all of whom were primarily very small and in several size classes from 1-4 cm fork length.

Most importantly, there were few non-native fish species observed. During the drought conditions of summer and fall 2016, Vector Control released mosquitofish into the lagoon and their population exploded. It appears that the strong storm flows have washed most of them out to sea and the return of tidal conditions now favors the native fish again.

Table 4. Summary of Fish and Invertebrates captured/observed 2005 – 2017

| | | Survey 6/1/2005 open | Relocation June 2012 open | Survey 1/8/2013 open | Survey 5/15/2014 closed | Survey 12/11/2014 open | Survey 5/27/2015 closed | Survey 1/12/2016 open | Survey 6/1/2016 closed | Survey 3/3/2017 open |
|---|---|---|---|---|---|---|---|---|---|---|
| **Native Fish Species** | | | | | | | | | | |
| Steelhead trout | *O.mykiss* | | | | 1 observed | | | | | 0 |
| Unidentified goby larva (<5 cm) | | | 2 | | 500~ | | | | 0 | 0 |
| Tidewater goby larva (<5cm) | *Eucyclogobius newberryi* | | | | 13 | | | | 17 | 12 |
| Tidewater goby adult (6-8cm) | *Eucyclogobius newberryi* | 473 | 8 | | 0 | | 41 | | 0 | 0 |
| Arrow goby (<5 cm) | *Cleavlandia ios* | | | | 5 | | | | 0 | 0 |
| Bay goby? | *Lepidogobius lepidus* | | | | 2 | | | | 0 | 0 |
| CA Halibut | *Paralichthys californicus* | | | | | | | | 2 | 0 |
| CA killifish juveniles (<5cm) | *Fundulus parvipinnis* | | 306 | | 0 | | | | 1 | 1 |
| CA killifish (5-10 cm) | *Fundulus parvipinnis* | 46 | 16 | | 5 | | | | 0 | 0 |
| Long-jawed mudsucker (<5 cm) | *Gillichthys mirabilis* | 1 | 8 | | 5 | | 3 | | 11 | 2 |
| Long-jawed mudsucker (5-10 cm) | *Gillichthys mirabilis* | | 11 | | | | 22 | 5 | 52 | 0 |
| Topsmelt larva (<5 cm) | *Atherinops sp* | | 1 | 3 | | | 176 | 6 | 1289 | 35 |
| Topsmelt juvenile (6 cm) | *Atherinops sp* | 244 | 0 | | 24 | | 60 | | 133 | 48 |
| Topsmelt adult (16 cm) | *Atherinops sp* | | 0 | | | | 6 | | 0 | 0 |
| Unidentified smelt larva (<5 cm) | *Atherinops sp* | | 101 | | 15,293 | | 2244 | 64 | | 0 |
| Staghorn sculpin (<5 cm) | *L. armatus* | | | 17 | 11 | | | 1 | | 130 |
| Staghorn sculpin (5-10 cm) | *L.armatus* | | 3 | | | | | | 5 | 4 |
| Opaleye | *Girella nigricans* | | | | | | | | | 0 |
| Diamond turbot | *Hypsopsetta guttulata* | | | 7 | 1 | | | | 5 | 0 |
| Garabaldi (28 cm FL) dead droppe | *Hypsypops rubicundus* | | | | | | | | | 0 |
| Northern anchovy <5 cm | *Engraulis mordax* | | 5 | | | | | 180 | 1 | 0 |
| Striped mullet | *Mugil cephalus* | observed | | observed | observed | 7 | 1 | | observed | observed |
| Unidentified fish larva | | | | | | | 991 | | 3 | 0 |
| **Non-Native Fish Species** | | | | | | | | | | |
| Mosquitofish Juveniles (<5cm) | *Gambusia affinis* | | | | | | 13 | 6 | 10 | 1 |
| Mosquitofish Adults (5-10cm) | *Gambusia affinis* | 65 | 4072 | | | 2 | 3 | | | 0 |
| Carp | *Cyprinus carpio* | 1 | | | observed | | | | | 0 |
| Mississippi silversides | *Menida audens* | | | 1 | 0 | 970 | 9 | 15 | 16 | 0 |
| | | | | | | | | | | |
| **Invertebrates** | | | | | | | | | | 0 |
| Oriental shrimp | *Palaemonetes sp.* | | | 37 | 209 | 43 | 10 | 5 | 58 | 89 |
| Hemigraspus crabs | | | 6 | | 8 | 1 | 20 | 1 | 1 | 2 |
| Water boatman juveniles | | | 6,000+ | | 2504 | | | | | 0 |
| Amphipods | | | 2500+ | | | | | | | 0 |
| Isopods | | | 2500+ | | | | | | | 0 |
| Ctenophore sp (<2 cm) | | | | 3 | | | | | | 0 |
| Salp sp (<2 cm) | | | | 3 | | | | | | 0 |
| Sea hare (5-10 cm) | *Aplysia californica* | | | 2 | | | | | | 0 |
| Segmented worm <2 cm) | | | | 3 | | | | | | 0 |
| Gastropoda | | | | | | | 4 | | | 0 |
| Water scavenger larva | Hydrophilidae | | | | | | 1 | | | 0 |
| Crayfish | *Procambarus clarkii* | | | | | | | | | 1 |

# Appendix A. Photographs of fish species


Staghorn sculpin

Topsmelt juvenile and CA Killifish

Tidewater goby

Fishing in the muck!

# Appendix B. Site Photos

**Site 1**

**Site 2**

**Site 2a**

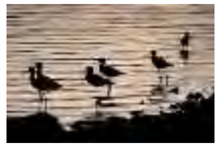
**Site 3**

**Site 5**

**Site 6**

**Spot Seine by tree snag Site 3**

# Appendix 3. Avian Usage of Post-restoration Malibu Lagoon: Year 4 (2016) (Prepared by D. Cooper)



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# Avian Usage of Post-restoration Malibu Lagoon Year 4 (2016)

## Malibu Lagoon State Beach

## Malibu, California

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January 3, 2017

## Summary

Several patterns have emerged after four 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. These patterns differ for various species guilds, making generalizations difficult. The Year 4 (2016) survey recorded 11,736 individuals, the highest total yet. The cumulative number of species and identifiable subspecies detected in all four years is 151, with five species new for 2016. Analyses from the western channels only (restoration area) show an overall increase in post-restoration counts and species richness when compared to pre-restoration counts from 2005-06.

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 marsh vegetation was removed and replaced with low coastal scrub and riparian plantings. However, counts of species like Marsh Wren and Red-winged Blackbird in 2015 suggested freshwater marsh birds may be returning to the site, and 2016 saw numbers of Marsh Wren increase and one of the few observations of Sora since the start of restoration in 2012, both freshwater marsh obligates that were frequent in winter prior to restoration. Urban birds declined in years 1 and 2 post-restoration, and while their numbers have remained below pre-restoration levels, they have been increasing steadily in years 3 and 4, presumably as more shrub and woodland habitat fills-in. Birds of scrub and woodland appear to be continuing to increase in year 4 after an initial decline in year 1, 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.

In year 4, fish-eating waterbirds and marine species have shown mixed or possibly stable trends at the lagoon overall, presumably due to predictable and robust fish fauna, ample foraging habitat, and little change to the coastal strand habitat at the site (i.e., the beach) following restoration. However, waterbird usage of the "Western Channels" area of the lagoon, which were greatly widened and deepened during the restoration, is seeing higher usage by waterbirds both for foraging and, especially, for roosting. Counts of large waders (herons/egrets) and waterfowl continued to exhibit a drop in numbers lagoon-wide each year following restoration, despite a diverse set of species continuing to use the site. Counts of shorebirds (# of individual birds) overall are still lower than pre-restoration into year 4, presumably due to loss of very shallow ("mucky") foraging habitat, though species richness of this group remains similar to pre-restoration levels. However, several additional years of monitoring will probably be necessary to confirm these trends, and none should be considered statistically significant. Special-status species continue to make heavy use of the site, in particular the beach and lower lagoon area (e.g., Brown Pelican and Snowy Plover)[1].

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

## 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 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 five years of data, each with quarterly surveys: pre-restoration (2005-06) and post-restoration (2013-2016), 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
- 11-12 January 2016
- 26-27 April 2016
- 25-26 July 2016
- 25-26 October 2016

[2] Cooper, D.S. 2013. Avian usage of post-restoration Malibu Lagoon. Report to Santa Monica Bay Restoration Foundation. February 13, 2013.
[3] No comprehensive bird surveys were conducted at Malibu Lagoon between November 2006 and January 2013; however, nesting bird surveys were conducted on a single day in 2011, and on multiple dates through the spring-summer breeding season in 2012.

During each survey period, I would walk the entire site in the morning or afternoon on 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 began 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. In each survey, I split the site into three main areas (Main Lagoon, Western Channels/Parking Lot, and Beach), and recorded how many birds of each species were seen using each site. For birds that moved between one area and another, I tried to record all areas where they were seen during each visit, but for the analysis, I used only where they were seen *initially*.

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 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 the first year or so after restoration, 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, I only considered species that were recorded as more than one individual (excluding obviously the same individual bird present for more than one day, such as a Mute Swan on 28-29 October 2014), and I omitted both aerial foragers as well as species that could not be reliably identified to species (e.g., California and/or Ring-billed Gulls that were recorded as simply "gull sp."). I also omitted two very common species with no specific habitat affinity, Yellow-rumped Warbler and White-crowned Sparrow. And, we omitted most raptors from the analysis, which are typically seen flying over the site and rarely lingering, with the exception of Osprey[4].

I must urge caution 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 in all three). These numbers should be taken merely as indices, rather than absolute abundances; in the analysis, I pooled the counts by year (simply adding up all counts on each day), rather than trying to derive an average or high count by quarter or by visit. Thus, some of these totals could be divided (by eight) to get something closer to an accurate daily estimate[5].

## Results

The Year 4 (2016) survey recorded 11,736 individuals, the highest total yet, though remarkably close to the 2015 count of 11,299. Prior to 2015, the total number of individual birds recorded during each year of quarterly surveys pre- and post-restoration was similar (7563-8489 individuals), suggesting that some change in 2015 has led to many more individual birds using the site (a nearly 30% increase over the prior years' average[6]). This phenomenon is discussed below.

The cumulative number of species and identifiable subspecies detected in all four years is 151, with five species new for 2016[7]. Species richness, which dropped in the first two years post-restoration, rebounded somewhat by 2015 (119 in 2005-06, then 88 (2013), 87 (2014), 100 (2015), and back to 88 in 2016. 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[8]. Tables 1 and 2

[4] Other 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.
[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 California Scrub-Jay (fka Western Scrub-Jay), House Sparrow, Lesser Yellowlegs, Ring-necked Duck, and Rock Pigeon. All had been recorded multiple times at the lagoon, just not on the quarterly surveys reported on here.
[8] Because several pre-restoration surveys (2005-06) were conducted by another surveyor and not Cooper, it is possible that these early counts included species flying over the site, which were omitted in post-restoration surveys (e.g., American Pipit).

summarize counts of selected groupings by ecological guilds of species from 2005 (pre-restoration) to 2015 (post-restoration).

Landbirds

For landbird analyses, 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. Whereas in prior years I the percentage 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), with five years of data, it is easier to detect actual trends, so these are listed in the tables (for each guild). This hopefully provides a clearer picture of actual changes taking place in the avifauna of the site post-restoration.

Addressing each ecological guild separately, counts of open country species surged in 2015, with levels nearly double those during the pre-restoration years. However, counts of these species in 2016 were the lowest yet, more comparable to the first year after restoration was complete.

Counts of scrub/woodland species have continued to increase from 2013 (the first year post-restoration), with cumulative numbers of these species just over half those recorded in 2005-06 prior to restoration (152 individuals in 2016, vs. 276 in 2005-06). Species richness within this guild was being maintained at a higher level than the first year post-restoration (8 spp. in 2013 vs. 16 spp. in 2015 and 11 spp. in 2016).

For urban species, after two straight years of declines, numbers began to increase in 2015, and this trend continued in 2016, with counts of individual urban species in 2016 roughly triple those in 2015 (but still less than half pre-restoration levels), which is encouraging.

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 2012 (pre-restoration), which shows ever-increasing counts through the spring/summer nesting season in recent years. This suggests that the species has been able to adapt well to the scrub plantings on the site year after year.

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 in 2015 (17 to 74 individuals) and continued to rise in 2016 (96 indiv.), with yet another species found that had not been recorded on the survey since the pre-restoration years (Sora).

By contrast, marine birds (those often found on the barrier beach or outer shoreline of the lagoon) and fish-eaters show a murkier trend with no clear direction.

Shorebird numbers in 2016 increased significantly from 2015, but were still recorded at roughly a third the level prior to restoration (c. 300/year, vs. 900+/year in 2005-06). Figure 2 shows higher numbers the first three years of analysis (2012-14) than in more recent years.

Large waders (herons and egrets) and waterfowl numbers continued to drop at the lagoon, with counts of individuals in 2016 less than those of all prior years (waterfowl numbers bumped up slightly in 2013, likely caused by a surge in numbers of American Coot attracted to the open mud habitat exposed by the restoration construction). Figure 3 shows average counts for a representative large wader species (Snowy Egret), and Figure 4 shows counts for a typical waterfowl species, the Northern Shoveler, at the site, where numbers in the years before and just after restoration (2012-13) were higher than those in recent years.

<u>Intra-site Changes in Avian Usage</u>

In the four years since the site was restored, certain bird species have been able to use more of the site, particularly waterbirds using the aquatic habitats in the western portion of the lagoon, which had been shallow and narrow prior to the restoration. A comparison of 22 common waterbirds in the Western Channels (Table 3) shows a steady increase in species richness on our surveys since 2005 (from 16 to 21 species). Numbers of individuals also appear to be increasing here, even without the exceptional concentration of 1,000+ Brown Pelicans observed roosting on the islands in the Western Channels (on 21 April 2015).

## Discussion

The c. 30% increase in individual birds detected in the 2015 and 2016 quarterly surveys were likely due to very large numbers of the three most common (numerically) species at the site, Brown Pelican, California Gull, and Elegant Tern, which were observed roosting throughout the lagoon in very large numbers. The 2016 count of Elegant Tern at the lagoon was the highest yet, a four-fold increase over the prior year, and included 1,400 birds roosting at the lagoon on 26 April (this was a pre-breeding aggregation; post-breeding counts in July and October were in the low double-digits). Elegant Terns were observed using the Western Channels in large numbers for the first time in 2016 (250 roosting here on 26 April 2016), and small numbers of these and other fish-eaters (including Caspian Tern and Brown Pelican) have begun foraging in the wider channels which now support large fish. Shorebirds such as Black-bellied Plover and Willet appear to be using the Western Channels area of the lagoon in higher numbers than in years pre-restoration, though mainly for roosting (see Table 3).

Landbirds

The surge in open country birds in 2015 was apparently temporary, likely due to a combination of extreme drought conditions in the region, and the still-recent removal of high, brushy vegetation as part of the restoration in 2012-13; by 2016, however, species like Savannah Sparrow and Western Meadowlark were not found to be maintaining large numbers at the site, and the total individuals counted this year (43) was the lowest total to date. Future surveys are needed to determine whether this is a permanent condition or not. These species have been particularly hard-hit in the region in recent decades 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 continuing increase in birds of scrub and woodland also over prior years (to just over 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 coast 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 hummingbirds, towhees, Bewick's Wren and Orange-crowned Warbler, none of which have come close to pre-restoration numbers. 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 riparianobligate 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 nearly doubled in 2016, but was still roughly half pre-restoration numbers. As trees and shrubs grow back, numbers of urban species will likely increase somewhat, but as of 2016, the site's avifauna has become markedly less urban, which is notable.

Waterbirds

The dramatic increase in freshwater marsh species in 2015, due to the emergence (in early 2015; Cooper, pers. obs.) of small stands of reeds at the edges of the former "western channels" portion of the lagoon. Numbers of Marsh Wren, Common Yellowthroat, and Red-winged Blackbird continue to build toward pre-restoration levels, and 2016 recorded another marsh species, Sora, feared "lost" by the restoration. As these reeds expand and fill in, continued and increased usage by this guild will surely occur; Virginia Rail is now the only regularly-occurring freshwater marsh species unrecorded by the post-restoration surveys, and it will almost certainly be found in future years

Shorebird usage at the site is complex, as these birds occur in several roles, and numbers have fluctuated from year to year post-restoration. The 2016 tally of individuals (334) was the highest since 2013, but still well short of the 917 recorded pre-restoration, which suggests that the site is still not attractive to shorebirds as it once was. This applies to obviously brackish-water/mudflat species like Long-billed Dowitcher, but also to strongly marine species like Willet which would be expected to be making heavier use of the lagoon and adjacent beach for foraging (yet both have unequivocally declined).

The smaller sandpipers (Least and Western sandpipers, Dunlin and Greater Yellowlegs) have been fairly stable (as a group), but are also appearing in much lower numbers than in years prior to restoration. Yet, many shorebird species continue to use the site (i.e., the species richness has not changed dramatically), so it may be that the loss of very shallow water (<1" deep) and the removal of "roosting rocks" 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. The very shallow, "silted-in" channels that were dredged and widened as part of the restoration likely removed habitat for smaller species of shorebirds; these had been regularly seen feeding in small flocks from the footbridges at the site prior to 2012 (Cooper, 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 habitat, 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 that is not constantly disturbed by human usage (rope fencing for Snowy Plover and Least Tern has helped somewhat, but signage is very unclear, and large gaps in the fence almost encourage people to explore the shoreline of the lagoon. 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.

Waterfowl also continue to decline from pre-restoration counts, particularly for two diving ducks (Bufflehead and Ruddy Duck) that presumably forage on marine worms and small fish, but also several "dabbling ducks" that graze on submerged vegetation, including Gadwall and Green-winged Teal. However, I am reluctant to speculate on the causes of these declines without concomitant information on diet and food availability at the site.

For fish-eating birds, abundance patterns do not conform to any recognizable trend, and cumulative annual counts of individuals have fluctuated between 300 and 500 birds since before the restoration.

As noted in prior reports, 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.

<u>Sensitive species</u>

Only a handful of special-status species regularly occur at Malibu, which is not surprising given the small size of the site. These include the Brant (California Species of Special Concern), California Brown Pelican (California Fully Protected), Western Snowy Plover (Federally Threatened), and the California Least Tern (Federally Endangered/State Endangered). Brant continue to occur in very 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 2016, occurring almost exclusively on the sand spit separating the main lagoon from the beach (which was not affected by the restoration). No individual State Threatened Belding's Savannah Sparrows were reported from Malibu Lagoon in 2016 (ebird; D.S. Cooper, unpubl. data).

The California Least Tern again attempted to breed in early summer [aside from an apparently anomalous nesting attempt in 2013[9], it has not successfully bred at the lagoon at any point in recorded history.] In 2016, 10-20 birds were present into early June (including at least one pair observed copulating and another exchanging fish within the fenced-off beach exclosure on 2 June 2016; K. Garrett, ebird). However, these birds did not successfully breed, presumably due to American Crows and other predators (*fide* T.P. Ryan), and an adult with a juvenile on 6 August (K. Garrett/ebird) likely originated at a nearby colony (Ventura Co.?) and was using the site for a post-breeding stopover.

[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).

## Figures and Tables


Figure 1. Counts of Song Sparrow at Malibu Lagoon, Jan. 2012 - Nov. 2016 (from eBird data).

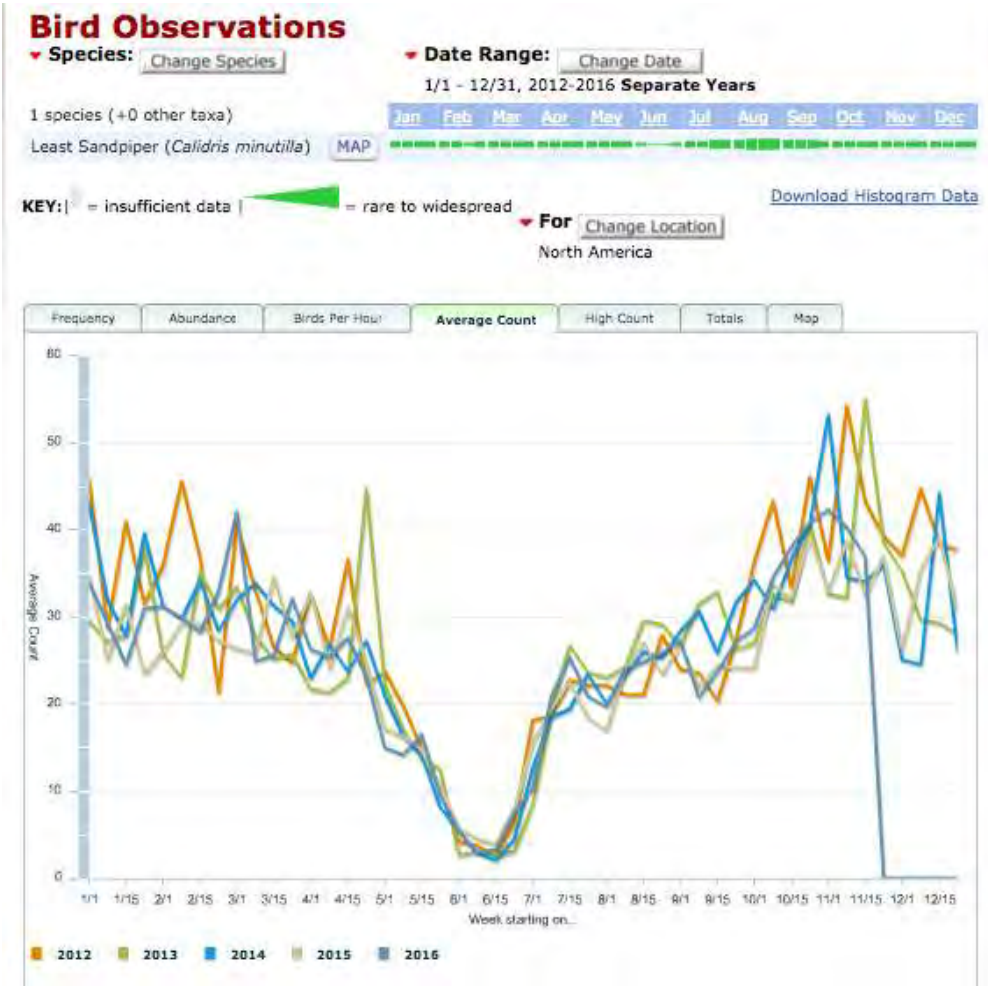


Figure 2. Counts of Least Sandpiper at Malibu Lagoon, Jan. 2012 – Nov. 2016 (from eBird data).


Figure 3. Counts of Snowy Egret at Malibu Lagoon, Jan. 2012 – Nov. 2016 (from eBird data).

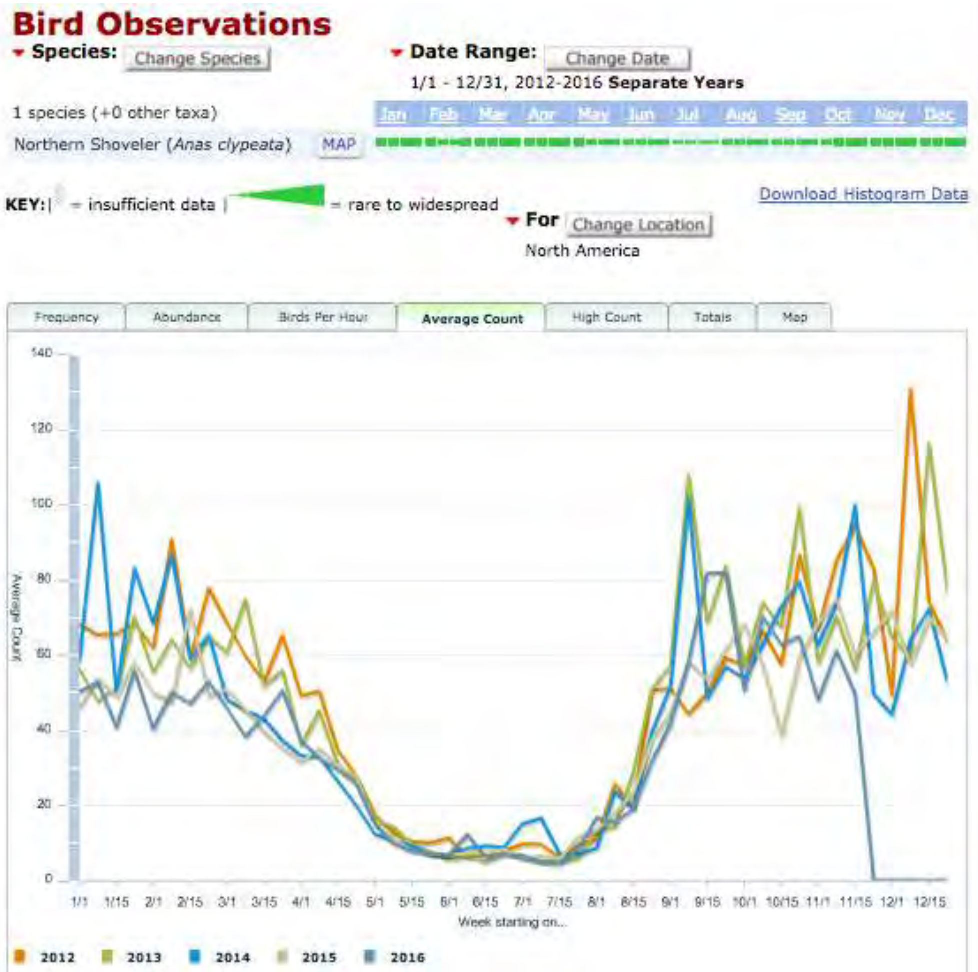


Figure 4. Counts of Northern Shoveler at Malibu Lagoon, Jan. 2012 – Nov. 2016 (from eBird data).

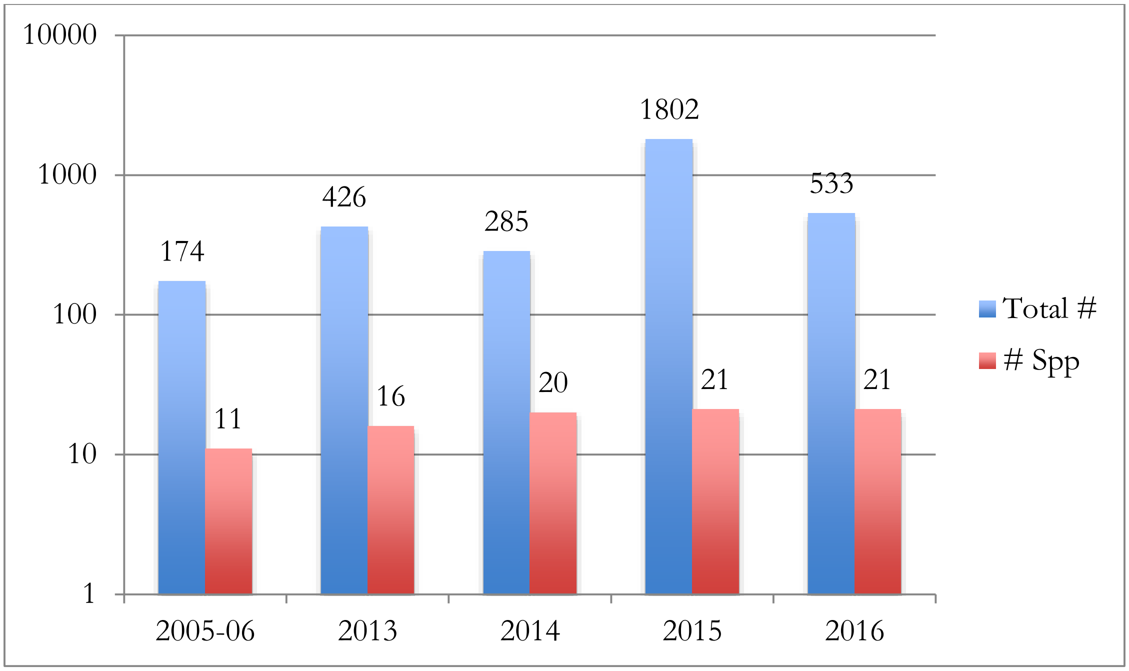


Figure 5. Comparison of Total Bird Numbers and Species Richness in Western Channels area of Malibu Lagoon From Surveys in 2005-Present.

Table 1. Landbird guilds (excludes aerial foragers[10]).

| Guild | Species | 2005-06 | 2013 | 2014 | 2015 | 2016 | Trend |
|---|---|---|---|---|---|---|---|
| OPEN COUNTRY[11] | | | | | | | |
| | American Pipit | 10[12] | 3 | 0 | 5 | 0 | |
| | Killdeer | 48 | 31 | 14 | 36 | 30 | |
| | Savannah Sparrow | 2 | 3 | 5 | 8 | 3 | |
| | Say's Phoebe | 1 | 6 | 4 | 1 | 4 | |
| | Western Kingbird | 6 | 0 | 0 | 1 | 0 | |
| | Western Meadowlark | 0 | 5 | 27 | 55 | 6 | |
| Total open country (# species) | | 67 (5) | 48 (5) | 50 (5) | 106 (6) | 43 (5) | Mixed |
| SCRUB/WOODLAND[13] | | | | | | | |
| | Allen's Hummingbird | 38 | 10 | 10 | 13 | 15 | |
| | American Robin | 0 | 3 | 0 | 0 | 0 | |
| | Anna's Hummingbird | 21 | 0 | 3 | 2 | 0 | |
| | Bewick's Wren | 15 | 1 | 1 | 1 | 2 | |
| | Bushtit | 70 | 22 | 35 | 24 | 65 | |
| | California Scrub-Jay | 0 | 0 | 0 | 0 | 4 | |
| | California Towhee | 18 | 9 | 7 | 6 | 7 | |
| | Cedar Waxwing | 14 | 0 | 0 | 0 | 0 | |
| | Hermit Thrush | 0 | 0 | 2 | 8 | 2 | |
| | House Wren | 5 | 2 | 3 | 4 | 12 | |
| | Lincoln's Sparrow | 5 | 0 | 2 | 2 | 0 | |
| | Oak Titmouse | 1 | 0 | 0 | 5 | 5 | |
| | Orange-crowned Warbler | 11 | 0 | 3 | 4 | 4 | |
| | Ruby-crowned Kinglet | 5 | 3 | 8 | 12 | 3 | |
| | Song Sparrow | 51 | 47 | 40 | 38 | 37 | |
| | Spotted Towhee | 15 | 0 | 2 | 1 | 0 | |
| | Townsend's Warbler | 0 | 0 | 0 | 4 | 0 | |
| | Wilson's Warbler | 3 | 0 | 0 | 2 | 0 | |
| | Yellow Warbler | 4 | 0 | 0 | 3 | 0 | |
| Total scrub/woodland (# species) | | 276 (15) | 97 (8) | 116 (12) | 129 (16) | 156 (11) | Decline/some recovery |
| URBAN | | | | | | | |
| | American Crow | 49 | 16 | 6 | 8 | 18 | |
| | Black Phoebe | 28 | 17 | 11 | 7 | 20 | |
| | Brewer's Blackbird | 27 | 0 | 0 | 0 | 0 | |
| | Brown-headed Cowbird | 14 | 5 | 1 | 1 | 3 | |
| | European Starling | 123 | 1 | 2 | 28 | 4 | |
| | Hooded Oriole | 7 | 1 | 0 | 0 | 0 | |
| | House Finch | 65 | 11 | 17 | 19 | 96 | |
| | Rock Pigeon | 0 | 0 | 0 | 0 | 7 | |
| | Northern Mockingbird | 7 | 3 | 5 | 4 | 6 | |
| Total urban (# species) | | 320 (8) | 54 (7) | 42 (6) | 67 (6) | 153 (7) | Decline/some recovery |

[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] Might have included fly-over birds, discarded from totals in subsequent years

[13] 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 | 2016 | Trend |
|---|---|---|---|---|---|---|---|
| FRESHWATER MARSH | | | | | | | |
| | Common Yellowthroat | 63 | 16 | 12 | 22 | 41 | |
| | Great-tailed Grackle | 20 | 41 | 5 | 43 | 25 | |
| | Marsh Wren | 3 | 0 | 0 | 6 | 8 | |
| | Red-winged Blackbird | 84 | 0 | 0 | 5 | 21 | |
| | Sora | 5 | 0 | 0 | 0 | 1 | |
| | Virginia Rail | 6 | 0 | 0 | 0 | 0 | |
| Total freshwater marsh (# species) | | 181 (6) | 57 (2) | 17 (2) | 76 (4) | 96 (5) | Decline/some recovery |
| MARINE/BEACH | | | | | | | |
| | Black Oystercatcher | 3 | 1 | 0 | 0 | 0 | |
| | Bonaparte's Gull | 1 | 2 | 11 | 9 | 2 | |
| | Brant | 4 | 6 | 0 | 6 | 6 | |
| | Brown Pelican | 862 | 167 | 4142 | 2821 | 374 | |
| | Caspian Tern | 83 | 13 | 26 | 19 | 20 | |
| | Double-cr. Cormorant | 109 | 310 | 142 | 193 | 107 | |
| | Elegant Tern | 258 | 219 | 310 | 781 | 2880 | |
| | Forster's Tern | 2 | 6 | 0 | 4 | 0 | |
| | Glaucous-winged Gull | 1 | 2 | 4 | 10 | 1 | |
| | Heermann's Gull | 216 | 30 | 466 | 176 | 43 | |
| | Herring Gull | 1 | 4 | 2 | 18 | 2 | |
| | Horned Grebe | 3 | 0 | 0 | 2 | 0 | |
| | Least Tern | 30 | 0 | 0 | 2 | 0 | |
| | Mew Gull | 2 | 0 | 1 | 0 | 0 | |
| | Red-breasted Merganser | 7 | 8 | 4 | 12 | 9 | |
| | Red-throated Loon | 0 | 2 | 1 | 0 | 0 | |
| | Royal Tern | 0 | 7 | 12 | 26 | 51 | |
| | Ruddy Turnstone | 10 | 34 | 21 | 8 | 24 | |
| | Sanderling | 58 | 460 | 48 | 8 | 115 | |
| | Snowy Plover | 52 | 202 | 137 | 16 | 76 | |
| | Surfbird | 0 | 0 | 4 | 0 | 0 | |
| | Western Grebe | 0 | 3 | 16 | 9 | 9 | |
| | Western Gull | 608 | 576 | 325 | 284 | 160 | |
| Total marine/beach (# species) | | 2311 (19) | 2054 (21) | 5672 (18) | 4404 (19) | 3879 (16) | Mixed/increase |

Table 2. (continued)

| Guild | Species | 2005-06 | 2013 | 2014 | 2015 | 2016 | Trend |
|---|---|---|---|---|---|---|---|
| SHOREBIRDS[14] | | | | | | | |
| | American Avocet | 9 | 6 | 0 | 0 | 0 | |
| | Black-bellied Plover | 287 | 224 | 169 | 73 | 202 | |
| | Black-necked Stilt | 0 | 0 | 0 | 4 | 0 | |
| | Dunlin | 5 | 2 | 1 | 0 | 0 | |
| | Greater Yellowlegs | 8 | 1 | 0 | 0 | 1 | |
| | Least Sandpiper | 71 | 33 | 4 | 1 | 18 | |
| | Long-billed Curlew | 2 | 0 | 0 | 0 | 0 | |
| | Long-b. Dowitcher | 14 | 0 | 0 | 1 | 1 | |
| | Marbled Godwit | 54 | 15 | 63 | 19 | 38 | |
| | Semipalmated Plover | 27 | 16 | 3 | 10 | 13 | |
| | Spotted Sandpiper | 11 | 6 | 7 | 8 | 2 | |
| | Western Sandpiper | 197 | 21 | 11 | 6 | 26 | |
| | Whimbrel | 20 | 27 | 9 | 21 | 13 | |
| | Willet | 212 | 47 | 15 | 38 | 20 | |
| | Wilson's Phalarope | 0 | 0 | 0 | 2 | 0 | |
| Total shorebirds (# species) | | 917 (13) | 398 (11) | 282 (9) | 183 (11) | 334 (10) | Mixed/ decline |
| WADERS | | | | | | | |
| | Black-cr. Night-heron | 31 | 5 | 3 | 5 | 0 | |
| | Great Blue Heron | 24 | 26 | 9 | 17 | 13 | |
| | Great Egret | 13 | 13 | 5 | 8 | 10 | |
| | Green Heron | 1 | 0 | 1 | 1 | 0 | |
| | Snowy Egret | 55 | 77 | 87 | 66 | 71 | |
| Total waders (# species) | | 124 (5) | 121 (4) | 105 (5) | 97 (5) | 94 (3) | Decline |
| WATERFOWL | | | | | | | |
| | American Coot | 628 | 1096 | 562 | 239 | 461 | |
| | American Wigeon | 16 | 49 | 17 | 10 | 13 | |
| | Blue-winged Teal | 6 | 0 | 0 | 4 | 3 | |
| | Bufflehead | 46 | 26 | 10 | 4 | 1 | |
| | Cinnamon Teal | 16 | 0 | 0 | 3 | 1 | |
| | Eared Grebe | 10 | 27 | 74 | 29 | 5 | |
| | Gadwall | 94 | 164 | 107 | 143 | 54 | |
| | Green-winged Teal | 147 | 48 | 42 | 66 | 33 | |
| | Hooded Merganser | 0 | 0 | 0 | 2 | 0 | |
| | Lesser Scaup | 2 | 1 | 1 | 0 | 0 | |
| | Mallard | 170 | 98 | 28 | 99 | 97 | |
| | Northern Pintail | 8 | 0 | 2 | 2 | 6 | |
| | Northern Shoveler | 47 | 163 | 31 | 18 | 40 | |
| | Pied-billed Grebe | 14 | 28 | 12 | 13 | 14 | |
| | Ruddy Duck | 55 | 90 | 76 | 276 | 7 | |
| | Snow Goose | 8 | 0 | 0 | 1 | 0 | |
| Total waterfowl (# species) | | 1267 (15) | 1790 (11) | 962 (12) | 909 (15) | 735 (13) | Decline |
| FISH-EATERS[15] | | | | | | | |
| | Belted Kingfisher | 0 | 3 | 1 | 2 | 2 | |
| | Black-cr. Night-heron | 31 | 5 | 3 | 5 | 0 | |
| | Caspian Tern | 83 | 13 | 26 | 19 | 20 | |
| | Double-cr. Cormorant | 109 | 310 | 142 | 193 | 107 | |
| | Forster's Tern | 2 | 6 | 0 | 4 | 0 | |

[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).

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Great Blue Heron | 24 | 26 | 9 | 17 | 13 | |
| | Great Egret | 13 | 13 | 5 | 8 | 10 | |
| | Green Heron | 1 | 0 | 1 | 0 | 0 | |
| | Hooded Merganser | 0 | 0 | 0 | 2 | 0 | |
| | Least Tern | 30 | 0 | 0 | 2 | 0 | |
| | Osprey | 2 | 0 | 0 | 0 | 4 | |
| | Pied-billed Grebe | 14 | 28 | 12 | 13 | 14 | |
| | Red-br. Merganser | 7 | 8 | 4 | 12 | 9 | |
| | Red-throated Loon | 0 | 2 | 1 | 0 | 0 | |
| | Royal Tern | 0 | 7 | 12 | 26 | 51 | |
| | Snowy Egret | 55 | 77 | 87 | 66 | 71 | |
| Total fish-eaters (# species) | | 371 (12) | 498 (12) | 303 (12) | 369 (13) | 301 (10) | Stable |

Table 3. Selected Waterbird Usage of "Western Channels" Portion of Malibu Lagoon, 2005-Present.

| Species | 2005-06 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|
| American Wigeon | 0 | 30 | 2 | 1 | 7 |
| Black-bellied Plover | 0 | 0 | 6 | 60 | 22 |
| Brown Pelican | 0 | 0 | 3 | 1106 | 1 |
| Caspian Tern | 3 | 1 | 2 | 8 | 8 |
| Double-cr. Cormorant | 0 | 15 | 5 | 45 | 40 |
| Eared Grebe | 0 | 24 | 25 | 15 | 3 |
| Elegant Tern | 0 | 0 | 0 | 5 | 250 |
| Gadwall | 27 | 104 | 59 | 114 | 27 |
| Great Blue Heron | 9 | 14 | 5 | 11 | 9 |
| Great Egret | 5 | 9 | 2 | 5 | 4 |
| Green-winged Teal | 70 | 28 | 15 | 61 | 20 |
| Killdeer | 6 | 28 | 9 | 34 | 18 |
| Least Sandpiper | 26 | 6 | 3 | 0 | 0 |
| Marbled Godwit | 0 | 0 | 37 | 6 | 17 |
| Northern Shoveler | 5 | 82 | 13 | 9 | 26 |
| Pied-billed Grebe | 2 | 16 | 3 | 4 | 12 |
| Red-breasted Merganser | 0 | 4 | 1 | 5 | 9 |
| Ruddy Duck | 0 | 24 | 47 | 226 | 3 |
| Snowy Egret | 19 | 38 | 36 | 53 | 44 |
| Western Grebe | 0 | 3 | 0 | 7 | 8 |
| Whimbrel | 2 | 0 | 6 | 17 | 0 |
| Willet | 0 | 0 | 6 | 10 | 5 |
| **Total #** | **174** | **426** | **285** | **1802** | **533** |
| **# Spp** | **11** | **16** | **20** | **21** | **21** |